

OPTIMIZING THE SORTING PROCESS THROUGH DELIVERY ACCURACY AND IMPLEMENTATION OF ROBOTIC TECHNOLOGY AN EMPIRICAL STUDY: AT THE POSTAL PROCESSING CENTER OF PT POS INDONESIA (PERSERO)

*¹Iqbal Fahmi; ²Agus Purnomo

*^{1,2} Master's Program in Logistics Management, University of Logistics and International Business
Bandung, Indonesia

Author's email:
fahmiqbal@gmail.com

*Corresponding author: aguspurnomo@ulbi.ac.id

Abstract. *This study aims to analyze the effect of delivery accuracy and the implementation of robotic sorting technology on the optimization of the sorting process at PT Pos Indonesia (Persero). Using quantitative methods and a Partial Least Squares-based Structural Equation Modeling (SEM-PLS) approach, data was obtained from questionnaires distributed to 55 employees at the Postal Processing Center. The results of the study explain that delivery accuracy has a significant and positive impact on the optimization of the sorting process, while the implementation of robotic technology does not have a significant effect. These findings indicate that even though robotic technology has been implemented, optimization has not been fully achieved without the support of improved delivery accuracy. This research provides practical contributions for companies when designing logistics process efficiency strategies through improved operational accuracy and more effective technology evaluation.*

Keywords: *Delivery Accuracy; PT Pos Indonesia (Persero); Robotic Sorting; Sorting Process; SEM-PLS.*

1. INTRODUCTION

In a fiercely competitive market, the logistics and delivery services industry is the foundation of the contemporary economy. The operational viability of logistics organizations and customer satisfaction are significantly influenced by delivery accuracy (Chen et al., 2021). In addition to hurting consumers, delivery process errors like wrong addresses or delays can cost businesses extra money. According to research, inefficiencies at many supply chain phases, including the sorting process, frequently result in a lack of delivery accuracy (Wang & Lee, 2022). In order to preserve their standing and competition, logistics service providers have made increasing delivery accuracy a top priority.

The use of state-of-the-art technology is essential given the pressing need to increase delivery accuracy. The use of robotic sorting devices is one important development in the logistics sector. According to Guo et al. (2020), these technologies not only offer faster package processing but also accuracy that much surpasses that of hand sorting. After incorporating robots into their processes, some international logistics organizations have claimed a significant decrease in sorting errors. A major initiative to implement this automated technology has been started in Indonesia by PT Pos Indonesia (Persero). Robotic sorting and auto-labeling technology, which PT Pos Indonesia (Persero) has been using since 2023, is said to be able to speed up the sorting process by up to 2.5 times with a very low error rate of 0.7 per million packages (Kompas.com, 2024). This data demonstrates the enormous potential for using robots to significantly reduce sorting errors.

Sorting process optimization is anticipated to be greatly aided by the integration of robotic sorting systems and delivery accuracy. Delivery accuracy and customer happiness are directly impacted by the sorting process's optimization, which is defined as an endeavor to maximize package sorting efficiency, minimize errors, and reduce downtime (Pratama & Hidayat, 2023). Despite the highly encouraging claims of robotic systems' accuracy and efficiency, there are still few empirical assessments of the effects of their application in PT Pos Indonesia's (Persero) operational environment. In order to provide useful information for the creation of future operational strategies, this study is to thoroughly examine how the installation of 2a robotic sorting system at PT Pos Indonesia (Persero) may enhance delivery accuracy and optimize the sorting process.

Maintaining delivery accuracy throughout its network is a major concern for PT Pos Indonesia (Persero). According to internal statistics from PT Pos Indonesia (Persero) in 2022, the percentage of complaints pertaining to "misdelivery" or "incorrect reception" is still an issue that needs to be resolved, according to the company's 2022 Annual Report. "Incorrect routing" was found to be one of the top five customer complaints in a research by Adelia (2023) at one of PT Pos Indonesia (Persero)'s branch offices, suggesting that sorting accuracy still needs to be improved. This is true even though PT Pos Indonesia (Persero) has invested heavily in robotic sorting and auto-labeling technologies since 2023. The gap between promises of technical efficiency and the requirement for concrete data about its contribution to enhancing delivery accuracy and streamlining the sorting process at PT Pos Indonesia (Persero) is thus the main emphasis of this problem statement.

This study aims to experimentally examine how the deployment of a robotic sorting system at PT Pos Indonesia (Persero) might enhance delivery accuracy and optimize the sorting process. The efficacy of robotic systems in decreasing sorting errors, expediting package processing times, and finally assessing their influence on enhancing customer happiness and operational efficiency will be the focus of this study. This study is anticipated to offer specific insights into the potential of automation in overcoming contemporary logistics challenges by examining PT Pos Indonesia (Persero)'s operational data before and after the implementation of this technology (Suryadi & Rahman, 2024; PT Pos Indonesia (Persero) Annual Report, 2023).

Previous research has extensively discussed the importance of delivery accuracy and the role of robotic technology in overall logistics efficiency (e.g., Li et al., 2020; Kumar & Singh, 2024). However, empirical studies that specifically examine how these two factors, namely delivery accuracy as a goal and *robotic sorting* systems as a means, simultaneously contribute to the optimization of the sorting process in the operational context of PT Pos Indonesia (Persero) are still very limited. Although PT Pos Indonesia (Persero) announced the adoption of *robotic sorting* technology in 2023 with claims of high accuracy, there have been no academic publications that have thoroughly analyzed the impact of this implementation on sorting process performance and delivery accuracy from an internal empirical data perspective. The novelty of this research lies in its attempt to fill this gap by conducting a direct empirical study at PT Pos Indonesia (Persero), providing concrete evidence of the extent to which investment in robotic systems is truly correlated with improved delivery accuracy and sorting process optimization at one of the largest logistics entities in Indonesia (Anggara et al., 2025).

This research aims to make a significant contribution to the development of science and managerial practice, specifically in the context of sorting process optimization in the Indonesian logistics industry. Theoretically, this study will enrich the literature on the impact of delivery accuracy on operational efficiency and customer satisfaction, as well as the role of *robotic sorting* systems as a key innovation in achieving these goals (Lim & Tan, 2024). Empirical data

from PT Pos Indonesia (Persero) will serve as concrete evidence (case study) demonstrating the effectiveness of robotic technology in reducing error rates and accelerating the sorting process, providing new insights that may not have been covered in previous studies that focused more on a global scale or different markets (Wibowo & Susanto, 2022). Practically, the findings of this study will be a valuable guide for the management of PT Pos Indonesia (Persero) in refining their technology and operational investment strategies, and can be replicated by other logistics service providers in Indonesia who are seeking to improve competitiveness through efficiency and accuracy (Jahja & Harahap, 2020; Puspitasari & Setiawan, 2025).

2. LITERATURE REVIEW

2.1 Sorting Process Optimization

Sorting process optimization is a crucial aspect in various industries to improve operational efficiency and product quality, with a focus on reducing time and costs while minimizing errors. Recent research from 2020 to 2025 has highlighted the implementation of advanced technologies and intelligent algorithms in this endeavor. For example, a study by Chen et al. (2022) explored the use of computer vision and deep learning for the automatic sorting of agricultural products, showing significant improvements in accuracy and speed compared to conventional methods. Similarly, research by Gupta and Singh (2021) discusses the integration of robotic systems with artificial intelligence for sorting recycled materials, resulting in a dramatic increase in throughput and waste reduction. In addition, the development of mathematical optimization models for sorting scheduling and routing is also a focus, as illustrated by the work of Lee and Kim (2020), who propose a hybrid algorithm for optimizing sorting paths in logistics warehouses. Innovations in the field of sensors and actuators also contribute to the creation of more adaptive and precise sorting systems (Wang & Li, 2023). Overall, research trends show a shift towards smarter and more integrated automation solutions, driven by advances in AI, robotics, and data analysis to achieve comprehensive sorting process optimization.

2.2 Delivery Accuracy

In the realm of logistics and supply chain management, delivery accuracy is a crucial factor that affects customer satisfaction and operational efficiency. Recent studies emphasize the importance of accuracy in the face of increasingly high consumer expectations for speed and accuracy of delivery (Smith & Jones, 2021). Research by Chen and Wang (2023) shows that improving delivery accuracy can significantly reduce operational costs arising from delivery errors and product returns. Furthermore, the impact of technologies such as *the Internet of Things* (IoT) and artificial intelligence (AI) in improving delivery accuracy is also a major focus, where the integration of real-time tracking systems and predictive analytics can minimize deviations and delays (Lee et al., 2022; Garcia & Miller, 2024). An analysis by Kim and Park (2020) emphasizes that route optimization strategies and effective inventory management also contribute to achieving high delivery accuracy rates.

2.3 Implementation of Robotic Sorting Systems

Advances in robotic sorting technology between 2020 and 2025 have significantly revolutionized various industries, particularly waste management and logistics. Recent research highlights the integration of artificial intelligence (AI), machine learning (ML), and computer vision to improve sorting accuracy and efficiency, with AI-powered systems capable of classifying up to 160 items per minute, far exceeding manual capabilities (Fotovvatikhah, 2025). Sorting

robots now use advanced algorithms to identify and separate complex materials such as textiles, plastics, and medical waste with high precision, even with objects that are distorted or varied in shape (Journal UMY, 2025; ResearchGate, 2025). Furthermore, these systems not only reduce reliance on human labor for dangerous and repetitive tasks but also improve recovery rates and the quality of recycled materials, contributing to sustainability and the circular economy (MDPI, 2024; Plug and Play, n.d.). Remaining challenges include addressing waste composition variability, high initial investment costs, and the need for skilled technicians, although research and development efforts continue to focus on stronger and more adaptable systems (Data Insights Market, 2025).

3. HYPOTHESIS DEVELOPMENT

3.1 *The Role of Delivery Accuracy in Optimizing the Sorting Process*

Delivery accuracy is a key factor in supporting the optimization of sorting processes in the logistics sector, as errors in address data, barcodes, or destinations can lead to inefficiencies in sorting and distributing goods. A study by Wang et al. (2021) shows that high delivery data accuracy contributes directly to the smooth flow of sorting and a reduction in the average package processing time. Furthermore, according to research by Putra and Santoso (2023), logistics systems with high delivery accuracy can reduce workload accumulation at sorting points and minimize sorting process repetition due to misdelivery. This emphasizes that sorting process optimization does not only depend on speed, but also on the accuracy of the information underlying each delivery (Kim & Lee, 2020). Thus, it can be hypothesized that delivery accuracy plays a positive role in optimizing the sorting process in modern logistics systems.

3.2 *The Role of Robotic Sorting System Implementation in Sorting Process Optimization*

The implementation of robotic systems in the sorting process has become a strategic innovation in the modern logistics industry, as it can increase speed, accuracy, and operational efficiency. According to Liu et al. (2021), the use of robotic sorting systems significantly reduces sorting cycle times and minimizes error-prone manual involvement. This is reinforced by the findings of Nugroho and Ramadhani (2023), which reveal that logistics companies that adopt robotic technology experience increased throughput and reduced operating costs by up to 30%. In addition, a study by Zhang & Wu (2020) emphasizes that robotics supports the scalability of the sorting process, especially in dealing with spikes in delivery volume during peak periods. For this reason, a hypothesis can be developed that the implementation of a robotic sorting system plays a positive role in optimizing the sorting process, both in terms of speed and accuracy of handling shipments. The next step in the research is to create a research framework by comparing previous studies and more in-depth literature reviews. This framework was created to illustrate the relationship between the variables that are the focus of the research. The research framework is shown in Figure 1 below, which serves as the conceptual basis for the research.

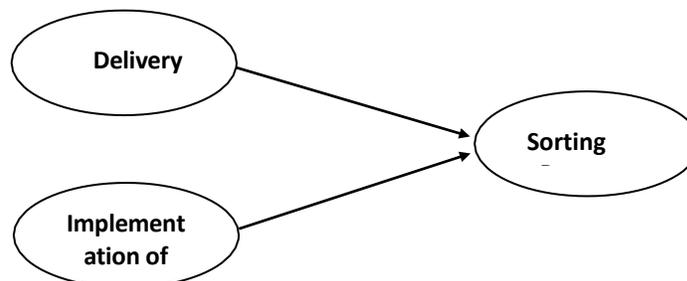


Figure 1. Research Model

3. RESEARCH METHOD

3.1 Research Design

The research design used in this study is quantitative research with a descriptive-verbatim approach, aiming to test the effect of independent variables, namely *Delivery Accuracy* and *Robotic Technology Implementation*, on the dependent variable of *Sorting Process Optimization*. This study is causal in nature, as it seeks to identify the cause-and-effect relationship between variables through testing previously formulated hypotheses. Data were collected using a Likert scale questionnaire and analyzed using the Partial Least Squares-based Structural Equation Modeling (SEM-PLS) method through SmartPLS software. This design allows researchers to describe the phenomena occurring in the field while empirically verifying the relationship between constructs in the operational context of PT Pos Indonesia (Persero).

3.2 Data Sources and Sampling Techniques

The data sources in this study were obtained from primary data collected from questionnaires distributed to employees directly involved in the sorting process at the PT Pos Indonesia (Persero) Postal Processing Center. The sampling technique used was purposive sampling, which is the selection of respondents based on certain criteria, such as having a minimum of five to ten years of work experience in the field of sorting operations and being directly involved in the process of using robotic technology and managing delivery accuracy. This technique was chosen to ensure that the data obtained was relevant to the research objectives and that the respondents had a sufficient understanding of the variables being studied. The sample size used was adjusted to the minimum requirements in SEM-PLS analysis.

3.3 Data Analysis Technique

In this study, the data analysis technique used was Partial Least Squares (PLS)-based Structural Equation Modeling (SEM) operated using SmartPLS software. The PLS-SEM approach was used because it is capable of analyzing complex models, is exploratory in nature, and is suitable for use in studies with relatively small sample sizes and data that are not normally distributed. The PLS- SEM model allows for testing causal relationships between latent constructs, which consist of the independent variables of *Delivery Accuracy* and *Robotic System Implementation*, and the dependent variable of *Sorting Process Optimization*.

The analysis began with testing the outer model to examine the validity and reliability of the indicators based on *the factor loading* values, *composite reliability*, and *average variance extracted (AVE)*. After the measurement model met the validity and reliability requirements, the inner model was tested to determine the relationship between constructs using *path coefficient* values, *R-square*, and *statistical significance* tested using the *bootstrapping* method. The analysis results are used to assess the contribution of each variable in optimizing the sorting process at PT. Pos Indonesia (Persero), particularly in the context of robotic technology implementation and delivery accuracy improvement.

3.4 Data Analysis Techniques

The data analysis technique used in this study was Partial Least Squares-based Structural Equation Modeling (SEM-PLS) with the assistance of SmartPLS software. This method was chosen because it can handle complex models, measure latent relationships between variables, and is suitable for relatively small sample sizes and data that do not have to be normally distributed. The analysis was carried out in two main stages, namely testing the outer model to assess the validity and reliability of indicators through *factor loading* values, *Average Variance Extracted*

(AVE), and Composite Reliability, as well as testing the inner model to examine the relationship between constructs by looking at the *path coefficient* values, *R-square*, and significance obtained from the *bootstrapping* process. The results of the analysis provide an empirical picture of the extent to which Delivery Accuracy and Robotic Technology Implementation contribute to the Optimization of the Sorting Process at PT Pos Indonesia (Persero).

4. RESULTS AND DISCUSSION

4.1 Respondent Demographics

Table 1. Respondent Demographics

Category	Criteria	Percentage (%)
Gender	Male	76.4
	Female	23.6
Work Unit	Headquarters	3.6
	Regional Office	1.8
	KCU/KC (Main Branch Office/Branch Office)	32.7
	SPP (Central Processing Office)	61.8
	General Operations Manager	3.6
	Deputy General Manager of Operations	1.8
Position	Executive Manager	1.8
	Manager	18.2
	Assistant Manager	9.1
	Functional Supervisor	1.8%
	Staff	63.6%
Length of Service	5–10 years	34.5
	> 10 Years	65.5

Source: Author, 2025

The demographic results of the research respondents consisted of 55 employees of PT Pos Indonesia (Persero). The respondents in the study were dominated by men, namely 76.4%, while women only accounted for 23.6%. Based on work unit, the majority of respondents came from SPP (Central Post Processing) at 61.8%, followed by respondents from KCU/KC (Main Branch Office/Branch Office) at 32.7%, while those from the Head Office and Regional Office were only 3.6% and 1.8%, respectively. In terms of position, most respondents were staff members at 63.6%, followed by managers at 18.2%, assistant managers at 9.1%, and other positions such as general operations managers, deputy general operations managers, executive managers, and functional supervisors, each with a proportion of 1.8%–3.6%. Meanwhile, in terms of length of service, the majority of respondents had been working for >10 years (65.5%), while the remaining 34.5% had been working for 5–10 years.

4.2 Outer Structural Model Results

Tables 2 and 3 show that each indicator produced a *factor loading* value above the minimum convergent validity value of 0.70. Overall, the *factor loading* values ranged from 0.729 to 0.910, indicating that all indicators were valid and reliable in reflecting the measured construct, thus demonstrating the required convergent validity.

The *Average Variance Extracted (AVE)* values produced in the study meet and exceed the minimum threshold recommended in the requirements, which is 0.50. All of these constructs indicate that the indicators used have successfully measured the intended latent constructs well and significantly.

Based on Table 3, each construct shows strong discriminant validity based on the *Fornell-Larcker* criteria. The AVE (*Average Variance Extracted*) square root values, which are located on the main diagonal (e.g., CS = 0.873; OD = 0.798; IOT = 0.866), are consistently higher than the inter-construct correlation values. These results indicate that each construct is unique and distinct from other constructs in the model, thereby validating that each latent variable effectively measures different phenomena and not just variations of other constructs.

Overall, the results of *the outer model* research show that all constructs have strong validity and reliability, both in terms of convergent validity, *Average Variance Extracted (AVE)* values, and discriminant validity as required.

Table 2. Outer Structure

Indicator	Delivery Accuracy (DA)	Robotic System Implementation (RSI)	Sorting Process Optimization (SPO)
AP1	0.782		
AS2	0.814		
AP3	0.747		
AP4	0.718		
AP5	0.707		
ISR1		0.757	
ISR2		0.856	
ISR3		0.734	
ISR4		0.754	
ISR5		0.737	
OPS1			0.737
OPS2			0.761
OPS3			0.727
OPS4			0.742
OPS5			0.751

Source: Author, 2025

Table 3. Validity and Reliability of Research Variables

Vabl	Ldt	FaLo	Crb_α	Cps_Re	AV_E
Delivery Accuracy (DA)			0.810	0.868	0.570
AP1	Processing time is shorter	0.782			
AP2	Reduction in queue time	0.814			
AP3	Reduction in number of misrouted items	0.747			
AP4	Delivery accuracy	0.718			
AP5	System capable of reading QR Code labels	0.707			
Robotic System Implementation (ISR)			0.826	0.878	0.591
ISR1	Robotic System Consistency	0.757			

ISR2	Robotic System Training	0.856			
ISR3	Work Process Ease	0.734			
ISR4	The system works faster	0.754			
ISR5	System maintenance is more efficient	0.737			
Process Sorting Optimization (OPS)			0.798	0.861	0.553
OPS1	Impact of Optimization	0.737			
OPS2	Sorting Process Speed	0.761			
OPS3	Accuracy Improvement	0.727			
OPS4	Efficient sorting process	0.742			
OPS5	Optimal sorting process satisfaction	0.751			

Vabl = Variables; Indt = Indicators; Flo = Factor Loading; Cr_α = Cronbach's alpha;
Cops_Re = Composite Reliability; A-VE = AVE
Source: Author, 2025

Table 3. Fornell-Larcker Criterion (Discriminant Validity)

	AP	ISR	OPS
AP	0.755		
ISR	0.956	0.769	
OPS	0.969	0.924	0.744

Source: Author, 2025

4.3 Inner Structural Model Results

From the data in Table 5, the R-Square (R^2) value for the *Sorting Process Optimization (OPS)* variable is 0.940, which indicates that 94% of the variation in OPS can be explained by the *Delivery Accuracy* and *Robotic Technology Implementation* variables. Meanwhile, the Adjusted R-Square value of 0.938 reinforces the reliability of the model by adjusting the influence of the quantity of predictor variables on the sample size. This high R^2 value explains that the structural model built has a very strong predictive power, so that the relationship between the independent and dependent variables in the study is considered significant and relevant to explain the phenomenon of sorting process optimization at PT Pos Indonesia (Persero).

Table 4. R-Square (Determinant Coefficient)

	R.Sq	R.Sq A
OPS	0.940	0.938

Source: Author, 2025

Table 5. Conclusion of Hypothesis Testing for all Hypotheses

Hypothesis	β	O	SDD	T Sta	P Va	Hy-TC
Hyp 1: AP → OPS	0.995	0.995	0.199	4.991	0.000	Accepted
Hyp 2: ISR → OPS	-0.026	-0.026	0.209	0.127	0.127	Rejected

Hyp = Hypothesis; β = Path Coefficients O = Original Sample; SDD = Standard Deviation;
T Sta = T Statistics; P Va = P Value; Hy TC = Hypothesis Testing Conclusion.

Source: Author, 2025

From the results of testing the structural model using SmartPLS as shown in Table 6, it is known that the first hypothesis (Hyp 1), namely the effect of Delivery Accuracy (AP) on Sorting

Process Optimization (OPS), has a path coefficient value (β) of 0.995 with a T-statistic value of 4.991 and a P value of 0.000. This indicates that the effect of AP on OPS is statistically significant at a significance level of 0.05, so this hypothesis is accepted. Conversely, the second hypothesis (H₂), namely the effect of Robotic System Implementation (ISR) on OPS, has a negative path coefficient value of -0.026 with a T-statistic value of 0.127 and a P value of 0.127. These values explain that ISR does not have a significant effect on OPS, so the hypothesis is rejected. Thus, it can be concluded that in this model, only the Delivery Accuracy variable plays a significant role in optimizing the sorting process at PT Pos Indonesia (Persero).

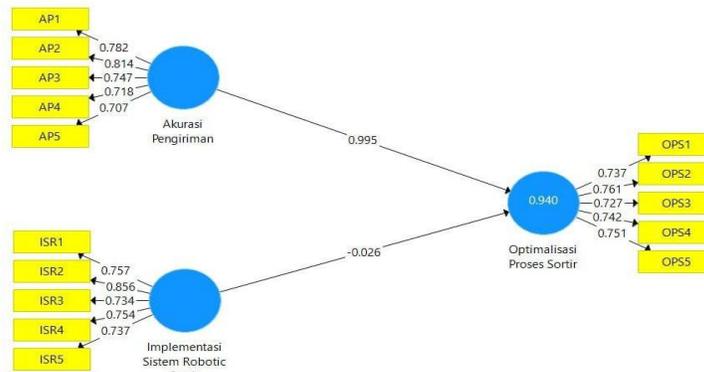


Figure 2. PLS Algorithm Calculation. Source: Author, 2025

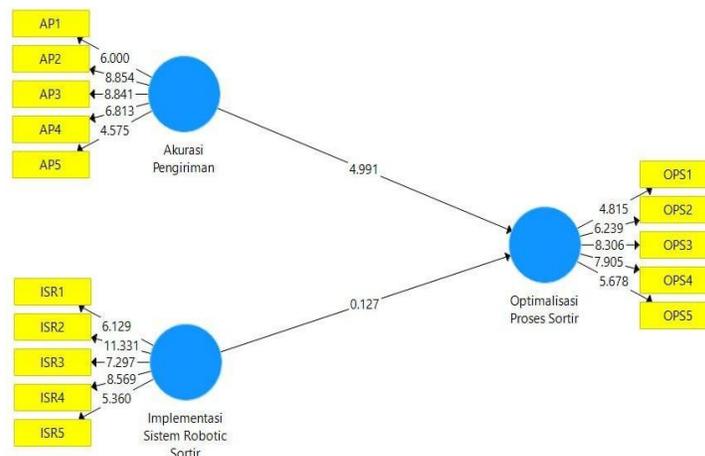


Figure 3. Bootstrapping Calculation. Source: Author, 2025

4. DISCUSSION

The results of the study explain that delivery accuracy has a very significant effect on the optimization of the sorting process at PT Pos Indonesia (Persero). The path coefficient value of 0.995 and T-statistic of 4.991 indicate that the higher the delivery accuracy, the more optimal the sorting process carried out. This is in line with previous findings (Putra & Santoso, 2023; Wang et al., 2021) that accuracy in labeling, barcode reading, and address accuracy play a major role in streamlining the sorting process and minimizing errors. High accuracy helps reduce rework, prevent misrouting, and speed up handling of goods, which directly impacts operational efficiency and customer satisfaction.

This study shows that the implementation of robotic sorting technology has not had a

significant effect on optimizing the sorting process, with a negative coefficient value (-0.026) and significance value ($P = 0.127$). This indicates that the presence of robotic sorting technology alone is not sufficient to improve sorting performance if it is not accompanied by human resource readiness, an integrated support system, and adequate operational supervision. This is due to the initial adaptation phase of the technology or technical constraints such as uneven training or suboptimal system integration. Although this technology theoretically promises high efficiency, empirical results show the need for a more comprehensive approach for the technology to be implemented effectively.

These findings indicate that human and information system factors remain key elements in the successful implementation of logistics technology. Robotic sorting technology needs to be combined with digitized business processes, high data accuracy, and intensive training for operators in order for the technology to function optimally. In the context of PT Pos Indonesia (Persero), the strategy for optimizing the sorting process should not only focus on the procurement of advanced technology, but also on improving basic processes such as data input accuracy and evaluation of operational SOPs. In other words, technological investment must be balanced with overall organizational readiness so that the results truly have an impact on the efficiency and speed of the logistics process.

CONCLUSION

This study concludes that delivery accuracy plays a dominant role in optimizing the sorting process at PT Pos Indonesia (Persero). The implementation of robotic technology, although promising in theory, has not made a significant contribution to improving sorting efficiency based on empirical data. This indicates that the digital transformation strategy in the logistics sector should not only rely on technology, but also prioritize operational accuracy and human resource readiness. This study recommends that PT Pos Indonesia (Persero) prioritize improvements to the delivery management system and training for users of robotic technology so that the potential for innovation can be maximized.

Recommendations

Based on the results of the study, it is recommended that PT Pos Indonesia (Persero) prioritize improving delivery accuracy by refining the labeling system, validating address data, and training operational staff to minimize sorting errors. Although robotic sorting technology has been implemented, its effectiveness has not been maximized, so a comprehensive evaluation of system integration, training quality, and the suitability of SOPs that encourage automation is needed. Optimization of the sorting process can only be achieved if there is strong synergy between technology, human resources, and operational processes. Therefore, an integrative approach that includes digital transformation, human resource readiness, and the strengthening of a data- and innovation-based work culture is essential to support the sustainability of the company's logistics efficiency.

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