



## **Delivery Accuracy, Robotics, and Logistics Information System Integration in Operational Performance Through Sorting Optimization**

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**Abstract**

**Background:** Logistics transformation at *Sentral Pengolahan Pos* (SPP) Jakarta, a high-volume mail-processing hub within PT Pos Indonesia (Persero), is taking place amid rising shipment volumes and persistent challenges in national logistics performance.

**Objective:** This study examines the relationships between delivery accuracy, robotic technology implementation, and logistics information system integration and logistics operational performance, with sorting process optimization tested as a mediating variable.

**Method:** The study employed a quantitative explanatory, cross-sectional design using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4. Primary data were collected through a 5-point Likert-scale questionnaire administered to 80 employees and operators at SPP Jakarta using total sampling (census).

**Results:** All ten hypothesized structural paths were statistically supported. Delivery accuracy, robotic technology implementation, and logistics information system integration were positively and significantly associated with sorting process optimization and logistics operational performance. Robotic technology implementation showed the largest path coefficient for sorting process optimization (0.471), while logistics information system integration showed the largest direct path coefficient for logistics operational performance (0.434). Sorting process optimization demonstrated statistically significant but limited partial mediation, with Variance Accounted For (VAF) values ranging from 20.31% to 26.05%, indicating that most of the modeled relationships remained direct rather than being transmitted through the mediator.

**Conclusion:** The findings suggest that PT Pos Indonesia should strengthen robotic technology utilization, information system interoperability, and sorting process optimization as complementary operational capabilities. Because the data are cross-sectional and perception-based, the results should be interpreted as structural associations rather than definitive causal effects.

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### **INTRODUCTION**

The national logistics industry is undergoing a significant transformation in line with the growth of e-commerce, which has driven an exponential increase in shipping volumes and created greater demand for logistics service providers to deliver fast, accurate, and efficient services to meet increasing customer expectations (Akl & Ungan, 2022; Hafez et al., 2021).

PT Pos Indonesia (Persero) is also facing this transformation pressure, particularly at the

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Jakarta Post Processing Center (SPP), which functions as a major shipment-processing node within the company's network. The organization has introduced robotic technology into sorting operations, while prior evidence from the postal context shows that the benefits of automation depend on workforce adaptation and operational readiness (Putri & Nurhadi, 2025). Because the available manuscript data do not provide separate time-series data on site-level delay, mis-sorting, or downtime indicators for SPP Jakarta, the operational problem is framed conservatively around the need to understand how accuracy, robotics, information-system integration, and sorting capability are associated within this high-volume processing environment.

The value of national e-commerce transactions increased from IDR 205.5 trillion in 2019 to IDR 487.01 trillion in 2024, while PT Pos Indonesia's package volume was reported at approximately 300,000–400,000 items per day. At the national level, Indonesia's Logistics Performance Index score declined from 3.15 in 2018 to 3.0 in 2023, indicating continuing pressure on logistics performance (Bank, 2023). These broader indicators establish the operational context for examining SPP Jakarta without treating national indicators as direct measurements of the site's own performance.

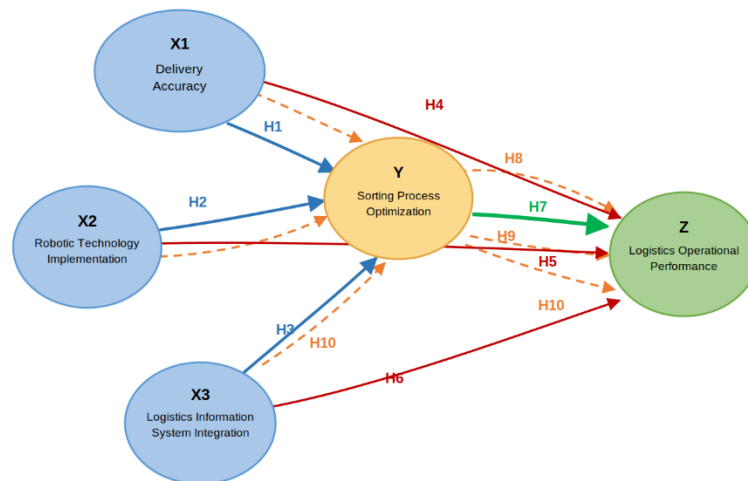
Previous research has shown that integrated systems increase productivity and data accuracy (Alamsah et al., 2024), consistent with the positive relationship between automation and logistics efficiency (Kembro & Norrman, 2022), but they do not guarantee improved performance if the sorting process is not optimized. Intermodal collaboration in freight forwarding increases performance by up to 18% (Pratama & Indrasari, 2022), while customer integration contributes to supply chain performance (Ruzo-Sanmartín et al., 2023). At PT Pos Indonesia, process management that is not optimized remains a constraint on cost efficiency (Rohyana & Wulandari, 2023).

Previous studies have discussed automation, information-system integration, and internal processes largely as separate drivers of logistics performance, leaving limited evidence on the mechanism through which these resources are translated into operational outcomes in a state-owned postal processing unit. The present study therefore positions sorting process optimization as a mediating organizational capability rather than merely combining variables in a single model. Under the Resource-Based View, technological and information resources create value when they are organized into routines and capabilities that convert resources into operational outcomes. (Bag & Rahman, 2023; Komakech et al., 2025; Nour, 2022). Testing sorting process optimization as the mediator consequently examines whether this internal capability explains part of the relationship between delivery accuracy, robotic technology, logistics information system integration, and logistics operational performance at SPP Jakarta.

Based on this description, this study aims to examine: (1) the relationships of X1, X2, and X3 with sorting process optimization; (2) the relationships of the three variables with logistics operational performance; (3) the relationship between sorting process optimization and logistics operational performance; and (4) the mediating role of sorting process optimization. PLS-SEM is used to estimate the proposed structural relationships and mediation paths in the available sample (Hair & Alamer, 2022; Hair Jr. et al., 2021).

This research is based on the Resource-Based View (RBV), which explains performance differences through the possession and organization of valuable internal resources and capabilities (Bag & Rahman, 2023; Komakech et al., 2025). In this model, delivery accuracy, robotic technology, and logistics information systems represent operational resources, whereas sorting process optimization is conceptualized as an integrating capability that coordinates those resources within the processing flow. This distinction is theoretically important because it tests not only whether resources are associated with performance but also whether part of that association operates through an internal capability that organizes resource use (Nour, 2022).

Based on the theoretical framework, the conceptual model places delivery accuracy (X1), robotic technology (X2), and logistics information system integration (X3) as exogenous variables that affect sorting process optimization (Y) and logistics operational performance (Z), resulting in ten hypotheses: seven direct effects (H1–H7) and three mediating effects (H8–H10). The conceptual framework of the research is presented in Figure 1.



**Figure 1.** Research Conceptual Framework

The position of this research among previous studies is presented in Table 1.

**Table 1**

*Summary of Past Research (State of the Art)*

| Researcher (Year)            | Research Focus                                                                     | Key Findings                                                                               | Differences from This Study                                                                 |
|------------------------------|------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|
| Pratama and Indrasari (2022) | Intermodal collaboration in freight forwarding in East Java.                       | Intermodal collaboration boosts operational performance by up to 18%.                      | Focuses on private companies; does not test the mediating role of the sorting process.      |
| Guntuka et al. (2024)        | Supply chain disruption recovery and internal process complexity.                  | Internal process complexity determines the success of performance recovery.                | Context of supply chain disruption, not technological transformation.                       |
| Ruzo-Sanmartín et al. (2023) | Relational commitment and customer integration regarding supply chain performance. | Process integration significantly contributes to supply chain performance.                 | Focuses on customer relations, not internal information system integration.                 |
| Alamsah et al. (2024)        | Implementation of warehouse management systems and FMCG productivity.              | Integrated systems enhance productivity and data accuracy.                                 | Focuses on private FMCG companies; does not test the mediating role of the sorting process. |
| Kembro and Norrman (2022)    | Adoption of warehouse automation and logistics efficiency.                         | Automation adoption positively correlates with logistics efficiency.                       | No mediation variables or SEM-PLS approach used.                                            |
| Putri and Nurhadi (2025)     | Robotic technology in logistics distribution at SPP Surabaya.                      | Robotics offers time and cost efficiencies, though workforce adaptation poses a challenge. | Does not link to delivery accuracy and information systems.                                 |
| Rohyana and Wulandari (2023) | Operational cost efficiency of PT Pos Indonesia branch offices.                    | Suboptimal process management hinders cost efficiency.                                     | Does not test an SEM-PLS model with mediation variables.                                    |

Previous research has generally examined intermodal collaboration, internal process complexity, customer integration, automation, or information-system integration in relation to operational performance. (Alamsah et al., 2024; Guntuka et al., 2024; Kembro & Norrman, 2022; Pratama & Indrasari, 2022; Ruzo-Sanmartín et al., 2023). The unresolved issue is not simply whether these resources are associated with performance, but how their operational value is converted within a postal processing workflow. Sorting process optimization is therefore tested as the mediating mechanism because it represents the immediate process capability through which delivery accuracy, robotic capacity, and information connectivity converge. Theoretically, this tests the RBV proposition that resources create greater value when they are organized through capabilities; operationally, it identifies whether improving the sorting process explains a meaningful share of the resource–performance relationship rather than assuming that technology investment translates directly into performance.

## METHOD

This study used an explanatory quantitative approach with a cross-sectional design, in which data were collected at one point in time (Sugiyono, 2022). Accordingly, the model was used to estimate theoretically specified associations among constructs and was not interpreted as establishing temporal or experimental causality. Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS 4 was used to estimate the measurement and structural models, including mediation paths, for the available sample (Hair & Alamer, 2022; Hair Jr. et al., 2021). The unit of analysis was the individual employee or operator directly involved in sorting, robotic technology operations, or logistics information system activities at the Jakarta Post Processing Center (SPP).

Primary data were collected through a structured 5-point Likert-scale questionnaire (1 = Strongly Disagree to 5 = Strongly Agree) measuring five constructs: delivery accuracy (X1), robotic technology implementation (X2), logistics information system integration (X3), sorting process optimization (Y), and logistics operational performance (Z), with four indicators for each construct. The indicators were compiled from the theoretical literature and subjected to expert judgment and an initial respondent test before online distribution through Google Forms. The available study documentation does not specify the number of experts or pilot-test participants; therefore, those procedural quantities were not reconstructed or reported beyond the documented validation stages.

The research population comprised employees and operators of SPP Jakarta who were directly involved in sorting, robotic technology operations, or logistics information system activities across work shifts. The accessible population was reported to comprise approximately 70–80 eligible personnel; therefore, total sampling (census) was used (Sugiyono, 2022). Eligibility required: (1) at least one year of work in the relevant unit; (2) direct involvement in sorting, robotic technology, or logistics information systems; and (3) routine understanding and use of logistics information systems. A total of 80 complete questionnaires were analyzed. Thus, the sample was determined primarily through the census approach. For descriptive comparison, the achieved sample also exceeded the minimum of 40 observations indicated by the 10-times rule; however, this rule was not the primary basis for sample selection (Hair & Alamer, 2022; Hair Jr. et al., 2021).

The outer model was evaluated through convergent validity (outer loading  $\geq 0.70$ ; Average Variance Extracted [AVE]  $\geq 0.50$ ), construct reliability (Composite Reliability and Cronbach's Alpha  $\geq 0.70$ ), and discriminant validity (Fornell–Larcker criterion and Heterotrait–Monotrait Ratio [HTMT]  $< 0.90$ ) (Hair & Alamer, 2022; Hair Jr. et al., 2021). Because all constructs were measured through a single self-report questionnaire at one time point, common method bias was treated as a methodological risk. The available study records do not document separate procedural remedies beyond the questionnaire administration process; consequently, the manuscript does not claim unreported procedural controls. Statistical assessment was performed post hoc using Harman's single-factor test, with first-factor variance below 50% interpreted as not indicating serious common-method dominance, together with structural VIF inspection. The inner model evaluation included  $R^2$ , VIF ( $< 5$ ),  $f^2$ , bootstrapping with 5,000 resamples ( $t > 1.96$ ;  $p < 0.05$ ),  $Q^2 > 0$ , and mediation assessment through the variance accounted for (VAF) criterion ( $> 80\%$  = full mediation;  $20\%$ – $80\%$  = partial mediation;  $< 20\%$  = no mediation) (Hair & Alamer,

2022; Hair Jr. et al., 2021).

A summary of the evaluation criteria for the measurement model (outer model) and structural model (inner model) used in this study is presented in Table 2.

**Table 2**

*Evaluation Criteria for Measurement Models and Structural Models*

| Evaluation                   | Indicator                                | Criteria/Threshold                               | Source                                              |
|------------------------------|------------------------------------------|--------------------------------------------------|-----------------------------------------------------|
| Convergent Validity          | Outer Loading                            | $\geq 0.70$                                      | Collier (2026) Hair Jr. et al. (2021);              |
|                              | Average Variance Extracted (AVE)         | $\geq 0.50$                                      | Collier (2026) Hair Jr. et al. (2021);              |
| Construct Reliability        | Composite Reliability (CR)               | $\geq 0.70$                                      | Hair and Alamer (2022)                              |
|                              | Cronbach's Alpha                         | $\geq 0.70$                                      | Hair and Alamer (2022)                              |
| Discriminant Validity        | Fornell-Larcker criteria                 | Square root of AVE > inter-construct correlation | Collier (2026) Hair Jr. et al. (2021);              |
|                              | Heterotrait-Monotrait Ratio (HTMT)       | $< 0.90$                                         | Collier (2026) Hair Jr. et al. (2021);              |
| Common Method Bias           | Harman's Single-Factor Test              | Single-factor variance < 50%                     | Podsakoff in Collier (2026) Hair Jr. et al. (2021); |
| Coefficient of Determination | R <sup>2</sup>                           | 0.75 (strong); 0.50 (moderate); 0.25 (weak)      | Collier (2026) Hair Jr. et al. (2021);              |
| Path Significance            | t-statistics & p-value (bootstrap 5,000) | $t > 1.96$ and $p < 0.05$                        | Collier (2026) Hair Jr. et al. (2021);              |
| Effect Size                  | f <sup>2</sup>                           | 0.02 (small); 0.15 (medium); 0.35 (large)        | Collier (2026) Hair Jr. et al. (2021);              |
| Predictive Relevance         | Q <sup>2</sup> (blindfolding)            | Q <sup>2</sup> > 0                               | Collier (2026) Hair Jr. et al. (2021);              |
| Multicollinearity            | Variance Inflation Factor (VIF)          | < 5                                              | Collier (2026) Hair Jr. et al. (2021);              |
| Mediating Role               | Variance Accounted For (VAF)             | > 80% (full); 20–80% (partial); < 20% (none)     | Collier (2026) Hair Jr. et al. (2021);              |

This research model tested ten hypotheses (H1–H10): seven direct influence hypotheses (H1–H7) and three mediation hypotheses (H8–H10), as shown in the following conceptual framework: X1, X2, and X3 affect Y (H1–H3); X1, X2, X3, and Y affect Z (H4–H7); and Y mediates the influence of X1, X2, and X3 on Z (H8–H10).

**Table 3**  
*Operational Definition of Research Variables*

| Variable                              | Dimensions                                                        | Example Indicators                                                                             | Scale      |
|---------------------------------------|-------------------------------------------------------------------|------------------------------------------------------------------------------------------------|------------|
| Delivery Accuracy (X1)                | Quantity and condition accuracy; destination and timing accuracy. | Mis-destination rate; mis-sorting rate; item condition compliance; delivery punctuality.       | Likert 1–5 |
| Robotic Technology (X2)               | Capacity utilization; operator readiness.                         | Sorting machine utilization; processing speed; machine reliability; operator competence.       | Likert 1–5 |
| Logistics Information System (X3)     | Interoperability; data visibility.                                | System connectivity; data update speed; data accuracy; ease of access.                         | Likert 1–5 |
| Sorting Process Optimization (Y)      | Sorting accuracy; processing speed and capacity.                  | Reduction in mis-sorting; processing time per unit; throughput; resource efficiency.           | Likert 1–5 |
| Logistics Operational Performance (Z) | Cost efficiency; speed and reliability.                           | Operational cost efficiency; delivery lead time; service reliability; operational flexibility. | Likert 1–5 |

## RESULTS AND DISCUSSION

### Result

#### *Characteristics of Respondents*

Using the total sampling approach described in the Method section, 80 complete questionnaires were obtained and analyzed. Most respondents were staff members (88.75%), followed by managers (8.75%), while the Deputy OGM and OGM positions were each represented by one respondent (1.25%). Based on work unit, respondents were primarily assigned to the Process unit (63.75%) and Distribution unit (31.25%). Respondents from General Oversight/Audit accounted for 2.50%, Administration and General Support accounted for 1.25%, and one respondent did not report a work unit.

In terms of age, most respondents were 35–44 years old (60.00%), followed by those aged 45 years or older (35.00%) and those aged 25–34 years (5.00%). Regarding length of service, 60.00% had worked for 1–3 years, 27.50% for 4–6 years, and 12.50% for more than 10 years. In terms of education, 82.50% had completed senior high school or vocational school, 10.00% held a bachelor's degree or D4 qualification, and 7.50% held a diploma qualification. Overall, the respondent profile was dominated by staff members assigned to the Process and Distribution units. The recapitulation of respondent characteristics based on position, work unit, age, working period, and last education is presented in Table 4.

**Table 4**  
*Characteristics of Research Respondents (n = 80)*

| Category          | Sub-category                     | Number (People) | Percentage (%) |
|-------------------|----------------------------------|-----------------|----------------|
| Position/Position | Staff                            | 71              | 88,75          |
|                   | Manager                          | 7               | 8,75           |
|                   | Deputy OGM                       | 1               | 1,25           |
|                   | OGM                              | 1               | 1,25           |
| Work Unit/Section | Process                          | 51              | 63,75          |
|                   | Distribution                     | 25              | 31,25          |
|                   | General Oversight/Audit          | 2               | 2,50           |
|                   | Administration & General Support | 1               | 1,25           |
|                   | Unfilled                         | 1               | 1,25           |
| Age               | 25–34 Years                      | 4               | 5,00           |
|                   | 35–44 Years                      | 48              | 60,00          |
|                   | ≥ 45 Years                       | 28              | 35,00          |

| Category        | Sub-category                                  | Number (People) | Percentage (%) |
|-----------------|-----------------------------------------------|-----------------|----------------|
| Working Period  | 1–3 Years                                     | 48              | 60,00          |
|                 | 4–6 Years                                     | 22              | 27,50          |
|                 | > 10 Years                                    | 10              | 12,50          |
| Final Education | High School/Vocational School (or equivalent) | 66              | 82,50          |
|                 | Diploma (D1/D2/D3)                            | 6               | 7,50           |
|                 | Bachelor's Degree (S1/D4)                     | 8               | 10,00          |

### Descriptive Analysis

Descriptive analysis was conducted on respondents' scores using a 5-point Likert scale. The interpretation intervals were 1.00–1.80 (very low), 1.81–2.60 (low), 2.61–3.40 (medium), 3.41–4.20 (high), and 4.21–5.00 (very high). As presented in Table 5, delivery accuracy had a mean of 2.98, robotic technology implementation 2.96, logistics information system integration 3.00, sorting process optimization 3.03, and logistics operational performance 2.98. All five constructs were therefore classified in the medium category. The reported standard deviations ranged from 0.91 to 0.97. Among the exogenous constructs, robotic technology implementation recorded the lowest mean value.

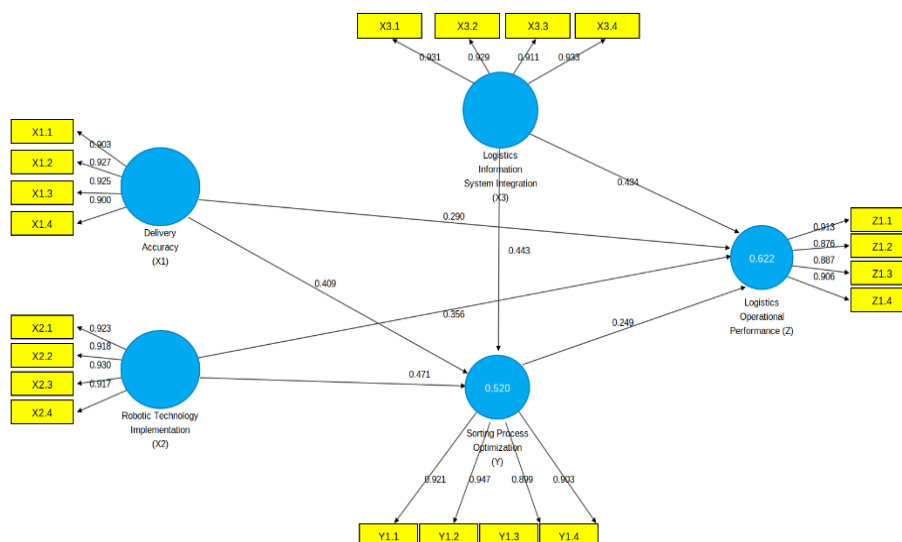
**Table 5**

*Descriptive Statistics of Research Variables*

| Variable                                      | Mean | Std. Deviation | Category |
|-----------------------------------------------|------|----------------|----------|
| Delivery Accuracy (X1)                        | 2,98 | 0,97           | Medium   |
| Robotic Technology Implementation (X2)        | 2,96 | 0,96           | Medium   |
| Logistics Information System Integration (X3) | 3,00 | 0,94           | Medium   |
| Sorting Process Optimization (Y)              | 3,03 | 0,94           | Medium   |
| Logistics Operational Performance (Z)         | 2,98 | 0,91           | Medium   |

### Evaluation of Measurement Models (Outer Model)

The results of data processing using the PLS algorithm in SmartPLS 4 are visualized in the following path diagram, which displays the outer loading value of each indicator, the interconstruct path coefficient, and the  $R^2$  value for both endogenous variables.



**Figure 2.** Output Results of Measurement Models and Structural Models (PLS Algorithm, SmartPLS 4)

The test results showed that all 20 indicators had an outer loading value above the minimum threshold of 0.70, with a range of 0.876–0.947 (Table 6), so that all indicators were declared to be valid convergently (Collier, 2026; Hair Jr. et al., 2021).

**Table 6***Outer Loading All Research Indicators*

| Variable                              | Indicator                    | Outer Loading                    | Information |
|---------------------------------------|------------------------------|----------------------------------|-------------|
| Delivery Accuracy (X1)                | X1.1 / X1.2 /<br>X1.3 / X1.4 | 0,903 / 0,927 /<br>0,925 / 0,900 | Valid       |
| Robotic Technology (X2)               | X2.1 / X2.2 /<br>X2.3 / X2.4 | 0,923 / 0,918 /<br>0,930 / 0,917 | Valid       |
| Logistics Information System (X3)     | X3.1 / X3.2 /<br>X3.3 / X3.4 | 0,931 / 0,929 /<br>0,911 / 0,933 | Valid       |
| Sorting Process Optimization (Y)      | Y1.1 / Y1.2 /<br>Y1.3 / Y1.4 | 0,921 / 0,947 /<br>0,899 / 0,903 | Valid       |
| Logistics Operational Performance (Z) | Z1.1 / Z1.2 /<br>Z1.3 / Z1.4 | 0,913 / 0,876 /<br>0,887 / 0,906 | Valid       |

**Table 7***AVE, Cronbach's Alpha, and Composite Reliability Values*

| Construct                             | AVE   | Cronbach's Alpha | Composite Reliability | Description        |
|---------------------------------------|-------|------------------|-----------------------|--------------------|
| Delivery Accuracy (X1)                | 0,835 | 0,934            | 0,953                 | Valid and Reliable |
| Robotic Technology (X2)               | 0,850 | 0,941            | 0,958                 | Valid and Reliable |
| Logistics Information System (X3)     | 0,858 | 0,943            | 0,960                 | Valid and Reliable |
| Sorting Process Optimization (Y)      | 0,842 | 0,938            | 0,955                 | Valid & Reliable   |
| Logistics Operational Performance (Z) | 0,802 | 0,917            | 0,942                 | Valid & Reliable   |

All constructs have AVE values above 0.50 (0.802–0.858), Cronbach's Alpha above 0.70 (0.917–0.943), and Composite Reliability above 0.70 (0.942–0.960), so that the research instrument is declared to be convergently valid and reliable ([Hair & Alamer, 2022](#)).

**Table 8***Fornell-Larcker Criterion (Diagonal Number = AVE Square Root)*

| Construct | X1     | X2     | X3    | Y     | Z     |
|-----------|--------|--------|-------|-------|-------|
| X1        | 0,914  |        |       |       |       |
| X2        | 0,015  | 0,922  |       |       |       |
| X3        | -0,040 | -0,136 | 0,926 |       |       |
| Y         | 0,399  | 0,417  | 0,363 | 0,918 |       |
| Z         | 0,377  | 0,405  | 0,464 | 0,671 | 0,896 |

**Table 9***Heterotrait-Monotrait Ratio (HTMT)*

| Interconstruct Relationships | HTMT Value | Information |
|------------------------------|------------|-------------|
| X1 <-> X2                    | 0,050      | Qualify     |
| X1 <-> X3                    | 0,064      | Qualify     |
| X1 <-> Y                     | 0,424      | Qualify     |
| X1 <-> Z                     | 0,407      | Qualify     |
| X2 <-> X3                    | 0,145      | Qualify     |
| X2 <-> Y                     | 0,442      | Qualify     |
| X2 <-> Z                     | 0,436      | Qualify     |
| X3 <-> Y                     | 0,384      | Qualify     |
| X3 <-> Z                     | 0,497      | Qualify     |
| Y <-> Z                      | 0,722      | Qualify     |

Table 8 shows that the square root of the AVE for each construct (0.896–0.926) is greater than its correlations with the other constructs, with the highest interconstruct correlation being 0.671 between Y and Z. Therefore, the Fornell–Larcker criterion is satisfied. Table 9 also shows that all HTMT values are below the threshold of 0.90, with the highest value found for the Y–Z relationship (0.722). This relationship corresponds to the direct structural path specified in H7. Based on these criteria, the measurement model satisfies the requirements for discriminant validity.

Because all data were collected from a single self-report source, Harman’s single-factor test was performed on all 20 indicators. The unrotated first factor explained 38.91% of total variance, below the 50% screening threshold. Structural VIF values ranged from 1.002 to 2.085, also below the threshold of 5 used in the structural-model assessment. These diagnostics are summarized in Table 9A. They do not prove the absence of all common method bias, but they provide a robustness check showing that neither a single dominant factor nor problematic structural collinearity is evident in the reported results.

**Table 9A***Common Method Bias and Collinearity Robustness Checks*

| Assessment                  | Reported Result              | Criterion | Interpretation                                   |
|-----------------------------|------------------------------|-----------|--------------------------------------------------|
| Harman’s single-factor test | 38.91% first-factor variance | < 50%     | No dominant single factor indicated              |
| Structural VIF              | 1.002–2.085                  | < 5       | No problematic structural collinearity indicated |

**Evaluation of Structural Models (Inner Model)****Table 10***R-Square value ( $R^2$ )*

| Endogenous Variables                  | R-Square | Category                      |
|---------------------------------------|----------|-------------------------------|
| Sorting Process Optimization (Y)      | 0,520    | Moderate                      |
| Logistics Operational Performance (Z) | 0,622    | Moderate (approaching strong) |

The  $R^2$  value of 0.520 indicates that 52.0% of the variance in sorting process optimization is explained jointly by delivery accuracy, robotic technology implementation, and logistics information system integration. The  $R^2$  value of 0.622 indicates that 62.2% of the variance in logistics operational performance is explained jointly by delivery accuracy, robotic technology implementation, logistics information system integration, and sorting process optimization. Based on the criteria presented in Table 3, both  $R^2$  values are classified as moderate (Collier 2026; Hair Jr. et al. 2021). Structural VIF values ranged from 1.002 to 2.085, which are below the threshold of 5 and indicate no problematic structural collinearity.

**Table 11***f-Square value ( $f^2$ )*

| Track   | $f^2$ | Category |
|---------|-------|----------|
| X1 -> Y | 0,349 | Medium   |
| X2 -> Y | 0,454 | Large    |
| X3 -> Y | 0,402 | Large    |
| X1 -> Z | 0,165 | Medium   |
| X2 -> Z | 0,226 | Medium   |
| X3 -> Z | 0,349 | Medium   |
| Y -> Z  | 0,079 | Small    |

Table 11 shows that the implementation of robotic technology (X2) provides the largest effect size on the optimization of the sorting process ( $f^2 = 0.454$ , large category), followed by the integration of logistics information systems ( $f^2 = 0.402$ ) and delivery accuracy ( $f^2 = 0.349$ ). On the path to logistics operational performance, the integration of logistics information systems has the

greatest influence ( $f^2 = 0.349$ , large category), while the optimization of the sorting process has a direct influence with the small category ( $f^2 = 0.079$ ).

**Table 12**

*Results of Direct Influence Hypothesis Testing (H1–H7)*

| Hypothesis | Relationships<br>Between<br>Variables | Path<br>Coefficient | t-Statistic | p-Value | Decision |
|------------|---------------------------------------|---------------------|-------------|---------|----------|
| H1         | X1 → Y                                | 0,409               | 6,473       | < 0.001 | Accepted |
| H2         | X2 → Y                                | 0,471               | 7,183       | < 0.001 | Accepted |
| H3         | X3 → Y                                | 0,443               | 5,293       | < 0.001 | Accepted |
| H4         | X1 → Z                                | 0,290               | 4,318       | < 0.001 | Accepted |
| H5         | X2 → Z                                | 0,356               | 4,185       | < 0.001 | Accepted |
| H6         | X3 → Z                                | 0,434               | 4,983       | < 0.001 | Accepted |
| H7         | Y → Z                                 | 0,249               | 2,892       | 0,004   | Accepted |

Table 12 shows that all seven direct influence hypotheses have a t-statistic above 1.96 and a p-value below 0.05, so they are entirely accepted.

**Table 13**

*Results of Mediation Role Testing for Sorting Process Optimization (H8–H10)*

| Hypothesis | Mediation<br>Process | Indirect<br>Coefficient | t-Statistic | p-Value | VAF<br>(%) | Types of<br>Mediation |
|------------|----------------------|-------------------------|-------------|---------|------------|-----------------------|
| H8         | X1 → Y → Z           | 0,102                   | 2,472       | 0,013   | 26,05      | Partial               |
| H9         | X2 → Y → Z           | 0,117                   | 2,667       | 0,008   | 24,82      | Partial               |
| H10        | X3 → Y → Z           | 0,111                   | 2,417       | 0,016   | 20,31      | Partial               |

All three indirect effects were statistically significant, with t-statistics greater than 1.96 and p-values below 0.05. The VAF values ranged from 20.31% to 26.05%, placing the three indirect relationships within the partial-mediation category based on the criteria used in this study (Collier, 2026; Hair Jr. et al., 2021). However, because these values are close to the lower boundary of 20%, sorting process optimization should be interpreted as providing limited partial mediation.

**Table 14**

*Q-Square ( $Q^2$ ) Predictive Relevance Value*

| Endogenous Variables                  | $Q^2$ | Description               |
|---------------------------------------|-------|---------------------------|
| Sorting Process Optimization (Y)      | 0,471 | Good Predictive Relevance |
| Logistics Operational Performance (Z) | 0,574 | Good Predictive Relevance |

The cross-validated redundancy procedure yielded  $Q^2$  values of 0.471 for sorting process optimization and 0.574 for logistics operational performance. Because both values are greater than zero, the model demonstrates predictive relevance for the two endogenous constructs based on the criterion used in this study (Collier, 2026; Hair Jr. et al., 2021). Overall, the measurement model satisfies the reported validity and reliability criteria, while the structural-model results provide statistical support for the ten hypothesized paths. These  $Q^2$  results indicate predictive relevance within the model and should not be interpreted as evidence of out-of-sample predictive performance.

## Discussion

As a reading map before the following detailed description, Table 15 summarizes the coefficients, effect size categories/VAF, and brief interpretations for all ten hypotheses.

**Table 15***Summary of Interpretation of Hypothesis Testing Results (H1–H10)*

| Hypothesis | Track      | Coefficient | Category                  | Brief Interpretation                                                                         |
|------------|------------|-------------|---------------------------|----------------------------------------------------------------------------------------------|
| H1         | X1 → Y     | 0,409       | $f^2 = 0,349$<br>(Large)  | Delivery accuracy reduces the need for rework and accelerates the sorting process            |
| H2         | X2 → Y     | 0,471       | $f^2 = 0,454$<br>(Large)  | Robotic technology is the primary driver for optimizing the sorting process                  |
| H3         | X3 → Y     | 0,443       | $f^2 = 0,402$<br>(Large)  | Information system integration supports the accuracy and speed of the sorting process        |
| H4         | X1 → Z     | 0,290       | $f^2 = 0,165$<br>(Medium) | Delivery accuracy contributes directly to operational performance                            |
| H5         | X2 → Z     | 0,356       | $f^2 = 0,226$<br>(Medium) | Robotic technology contributes directly to operational performance                           |
| H6         | X3 → Z     | 0,434       | $f^2 = 0,349$<br>(Large)  | Information system integration has the greatest direct impact on performance                 |
| H7         | Y → Z      | 0,249       | $f^2 = 0,079$<br>(Small)  | The sorting process serves as an additional channel, not the primary one                     |
| H8         | X1 → Y → Z | 0,102       | VAF = 26,05%<br>(Partial) | Part of the impact of delivery accuracy is mediated through the sorting process              |
| H9         | X2 → Y → Z | 0,117       | VAF = 24,82%<br>(Partial) | Part of the impact of robotic technology is mediated through the sorting process             |
| H10        | X3 → Y → Z | 0,111       | VAF = 20,31%<br>(Partial) | Part of the impact of information system integration is mediated through the sorting process |

The statistical support for all ten hypothesized paths indicates that the proposed RBV-based model has explanatory value in the SPP Jakarta sample, but the cross-sectional self-report design requires cautious interpretation. The pattern is substantively differentiated: robotic technology is most closely tied to the sorting stage because automation is deployed directly in repetitive processing activities, whereas logistics information system integration has a broader operational reach across visibility, coordination, and distribution decisions. The small  $f^2$  for sorting optimization (0.079) indicates that it adds limited incremental explanatory power once the three resource variables are modeled directly, which is consistent with its role as a complementary rather than dominant capability. Harman's single-factor result (38.91%) and the structural VIF range (1.002–2.085) provide additional diagnostics against a single-factor or collinearity explanation, although they do not eliminate all possible common-method bias.

Delivery accuracy is positively associated with sorting process optimization (H1: coefficient 0.409) and logistics operational performance (H4: coefficient 0.290). Operationally, this pattern is consistent with a lower-rework mechanism: fewer mis-sorting or mis-destination events reduce the need for repeated sorting, manual tracking, and manifest correction, thereby

aligning accuracy with smoother processing. The cross-sectional design does not demonstrate that accuracy itself caused the observed performance differences, but the direction of the paths is consistent with prior logistics-service evidence emphasizing accuracy and reliability (Akil & Ungan, 2022; Do et al., 2023; Masudin et al., 2022).

Robotic technology shows the strongest association with sorting process optimization (H2: coefficient 0.471;  $f^2 = 0.454$ , large category). This result is operationally plausible because sorting automation standardizes repetitive routing tasks, increases processing consistency, and supports scalable throughput, making the sorting stage the point at which robotics is most directly utilized. At the same time, the mean score for robotic technology implementation is only 2.96, the lowest among the exogenous constructs, showing that respondents assessed current implementation at a medium level despite its comparatively strong structural relationship. The questionnaire did not directly measure the causes of this utilization level; therefore, specific explanations such as downtime or uneven operator competence cannot be inferred from these data. The finding is nevertheless consistent with Wamba and Queiroz (2022), who emphasize that digital and automation benefits depend on organizational capabilities, and with Said et al. (2023), regarding the role of automation in speed- and reliability-oriented logistics services.

Logistics information system integration is positively associated with sorting process optimization (H3: coefficient 0.443) and has the largest direct path coefficient to logistics operational performance among the three exogenous constructs (H6: coefficient 0.434;  $f^2 = 0.349$ ). This pattern can be interpreted through the broader reach of integrated information: unlike robotic technology, which is concentrated at the sorting stage, information connectivity supports multiple operational decisions by improving visibility, data consistency, and coordination across processing and distribution activities. The stronger  $X3 \rightarrow Z$  path is therefore consistent with a resource that operates across several stages of the logistics process rather than only through sorting optimization. This interpretation accords with Alamsah et al. (2024), Hasan et al. (2021), and Zhao et al. (2023), on digitization, information resources, and operational performance.

Sorting process optimization is positively associated with logistics operational performance (H7: coefficient 0.249), but its effect size is small ( $f^2 = 0.079$ ) relative to the direct paths from the three exogenous constructs. This result suggests that sorting optimization contributes incremental explanatory power after delivery accuracy, robotic technology, and information-system integration are already included in the model. In RBV terms, the mediator functions as a complementary linking capability rather than a substitute for the underlying resources. The small  $f^2$  is therefore consistent with a model in which operational performance is associated with both resource-level factors and process capability, rather than being explained primarily by sorting optimization alone (Živičnjak et al., 2022).

The partial mediation results (H8–H10; VAF 20.31%–26.05%) reinforce this interpretation. Sorting process optimization accounts for only about one-fifth to one-quarter of each modeled total relationship, while the larger share is represented by the direct paths from  $X1$ ,  $X2$ , and  $X3$  to logistics operational performance. The VAF values are close to the lower boundary of the partial-mediation range, so the mediator should be described as statistically significant but limited rather than as the dominant mechanism. Importantly, the present model does not identify the specific unmeasured mechanisms underlying the remaining direct relationships. The contribution is therefore to show that sorting optimization is one complementary pathway through which resources are associated with performance, consistent with process-complexity and integration findings reported by Guntuka et al. (2024) and Ruza-Sanmartín et al. (2023).

### Research Implications

Theoretically, this study extends the Resource-Based View Bag & Rahman (2023) and Komakech et al. (2025) by distinguishing operational resources from the internal capability that organizes their use. Delivery accuracy, robotic technology, and logistics information systems are modeled as resources associated directly with performance, while sorting process optimization is modeled as a complementary linking capability. The consistent but limited partial mediation suggests that capability formation explains part, rather than all, of the resource–performance relationship. This adds an RBV nuance for logistics operations: performance may reflect both direct resource value and the extent to which resources are coordinated through an operational

process capability (Nour, 2022).

Managerially, these findings indicate three priorities for the management of SPP Jakarta and PT Pos Indonesia. First, considering that the implementation of robotic technology has the greatest influence on the optimization of the sorting process but its utilization score is still in the medium category and is classified as the lowest among exogenous variables, management needs to prioritize increasing the capacity utilization of robotic sorting machines and strengthening operator competence in handling technical problems. Second, considering that the integration of logistics information systems has the greatest direct influence on logistics operational performance, strengthening the interoperability of scanning, tracking, and distribution systems, including the speed of real-time data updates, needs to be a priority for future information technology investment. Third, given that sorting process optimization has been shown to partially mediate the influence of the three exogenous variables, management is advised to focus not only on strengthening resources individually, but also on structuring the sorting process flow itself as a connecting capability that strengthens the conversion of resources into better overall logistics operational performance.

### CONCLUSION

All ten hypothesized structural paths were statistically supported in the SPP Jakarta sample. Delivery accuracy, robotic technology implementation, and logistics information system integration were positively associated with sorting process optimization and logistics operational performance. Robotic technology had the strongest path to sorting process optimization, whereas logistics information system integration had the strongest direct path to operational performance. Sorting process optimization showed statistically significant but limited partial mediation, with VAF values of 20.31%–26.05%. The main contribution is to position sorting optimization as a complementary RBV-based capability that explains part of how operational and technological resources are related to performance, rather than treating the mediator as the sole mechanism.

These findings should be interpreted within the study's cross-sectional, single-site, and self-report design, which does not establish temporal or experimental causality and may not generalize beyond SPP Jakarta. The model also focuses on five constructs and does not include contextual variables such as workload or employees' digital readiness. Future research should test the model across multiple postal or logistics units, use longitudinal or repeated-measure designs, and examine additional contextual moderators or mediators. Such extensions would help determine whether the complementary role of sorting process optimization remains stable across settings and over time.

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### AUTHOR CONTRIBUTION STATEMENT

Iqbal Fahmi, Agus Purnomo, and Melia Eka Lestiani contributed to the conceptualization and development of the research framework, methodology, data collection, data analysis, and interpretation of the findings. All authors participated in drafting and critically reviewing the manuscript, approved the final version for publication, and agreed to be accountable for the accuracy and integrity of the work.

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