Indonesian Impression Journal (JII)
Vol. 4, No. 9, September 2025
p-ISSN: 2828-1284 e-ISSN: 2810-062x
Website: https: //rivierapublishing

Designing an RFID System to Improve Stock Accuracy and Supply Chain Efficiency of PT Bap in the Context of Industry Digitalization 4.0

Bunga Ayu Pitaloka, Oviyan Patra, Rinto Yusriski, Hendy Suryana
Universitas Jenderal Achmad Yani Bandung, Indonesia
Email: bungayupitaloka@gmail.com, oviyan.patra@lecture.unjani.ac.id, rinto.yusriski@lecture.unjani.ac.id, hendies.free@gmail.com

Abstract

This research focuses on designing a Radio Frequency Identification (RFID) system to enhance stock management accuracy and supply chain efficiency at PT Bap , a manufacturing company in the automotive sector. At present, PT Bap still relies on manual inventory methods that are time-consuming, labor-intensive, and prone to recording errors, leading to inefficiencies in warehouse operations. Considering the large volume of part items, these inefficiencies create significant challenges for productivity and operational effectiveness. To address this, the research adopts a case study approach combined with benchmarking of PT TMMIN, a company that has successfully implemented RFID technology for inventory management. Data collection includes interviews, observations, and documentation of the inventory system at PT Bap , along with comparative studies on RFID adoption at PT TMMIN. The design integrates RFID devices with the existing Warehouse Management System (WMS), automating the inventory process. To strengthen the research foundation, the author also participated in Lean Manufacturing 4.0 training held by the Ministry of Industry of the Republic of Indonesia, which deepened knowledge of digitalization and automation principles in Industry 4.0. The expected outcomes include improved stock accuracy above 90%, inventory time reduction of up to 50%, and lower dependence on manual labor. Ultimately, RFID implementation contributes to operational efficiency and supports digital transformation in the automotive industry.

Keywords: RFID; inventory management; supply chain efficiency; digitalization; Industry 4.0; warehouse automation; lean manufacturing.

INTRODUCTION

PT Bap is a manufacturing company in the automotive industry that focuses on the production and distribution of motor vehicle components. One of the important aspects of its operations is the management of inventory stock which determines the smooth running of the company's supply chain (Arnold, Chapman, & Clive, 2012). Currently, although PT Bap has used the Warehouse Management system (WMS) as part of the digitization of work processes, the stock management method still involves many manual activities such as physical calculation and manual stock recording into *the stock list*, which is then re-input into the WMS (Almeida & Santos, 2023).

Currently, PT Bap is still using manual methods in the form of physical calculations and recording stock into the stock list which is then re-input into the WMS (Prasetyo & Nugroho, 2021; Sari & Wijaya, 2020; Shahin, Chen, Bouzary, & Krishnaiyer, 2020). There are 7,881 part items divided into several categories, namely Part Supplies as many as 3,754 items consisting of imported and local parts, WIP (Work In Process) Parts as many as 3,100 items that are produced internally, Good Finish Parts as many as 705 items in the form of finished goods ready to be sent to customers, and Raw Materials as many as 322 items used as basic materials in the internal production process (Chen & Liu, 2022).

Varied item parts make the process in this manual way not only time-consuming but also requires the involvement of employees from different parts (Hidayat & Susanto, 2023). For one item part, it can also exist in various different locations so that the total number of items calculated each month becomes many times in number (Kagermann, Wahlster, & Helbig, 2013). Every step, from physical calculation, recording, to data input to the WMS, is carried out by different employees, so the need for human resources is high (Hopp & Spearman, 2011).

If a company wants to accelerate these activities, adding employees is a temporary solution that increases operational costs (Khan & Yu, 2020; Kim & Lee, 2023). Additionally, reliance on manual methods increases the risk of data input errors, which can impact stock accuracy, item availability, and supply chain smoothness (Wang & Zhang, 2020; Wibowo & Setiawan, 2022; Zhang & Chen, 2021; Zhou & Piramuthu, 2019).

The following is an overview of the Item Parts at PT Bap :

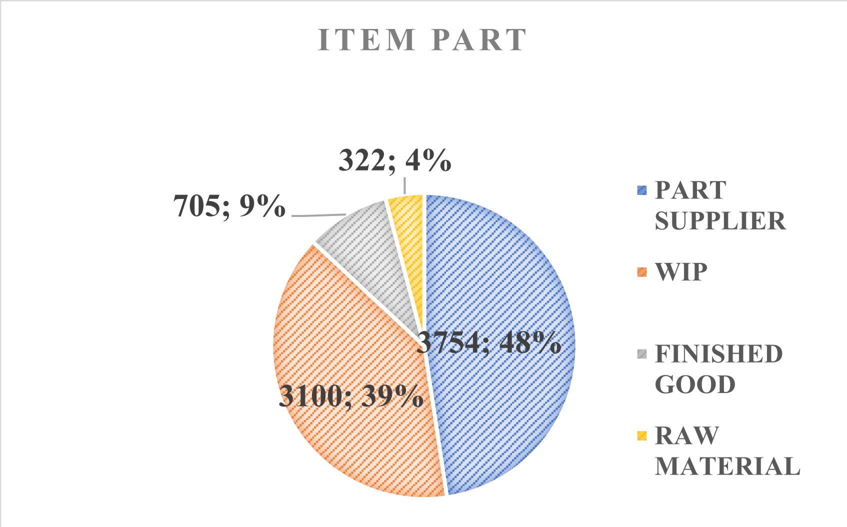

Figure 1. Item Part PT. Bap
Source : 2024 Inventory Data

The inventory process takes place every month, to carry out this activity, production must be stopped for 8 hours. This is because to avoid errors in calculations, the inventory process is carried out when there is no movement of parts or goods. includes 4 hours for physical calculation and 4 additional hours for recording and inputting data into the WMS System.

The average amount of PT Bap production in 2024 is 50,354 units/day with average monthly sales of 246 billion rupiah or 12.4 billion/day, then if you take into account the time lost during inventory calculation activities for 8 hours is equivalent to a production of 16,785 units or if calculated against sales the amount of loss is 4.12 billion per month.

This downtime causes significant operational losses, thus accelerating the inventory process into an urgent need.

Here is an overview of sales and production volume:

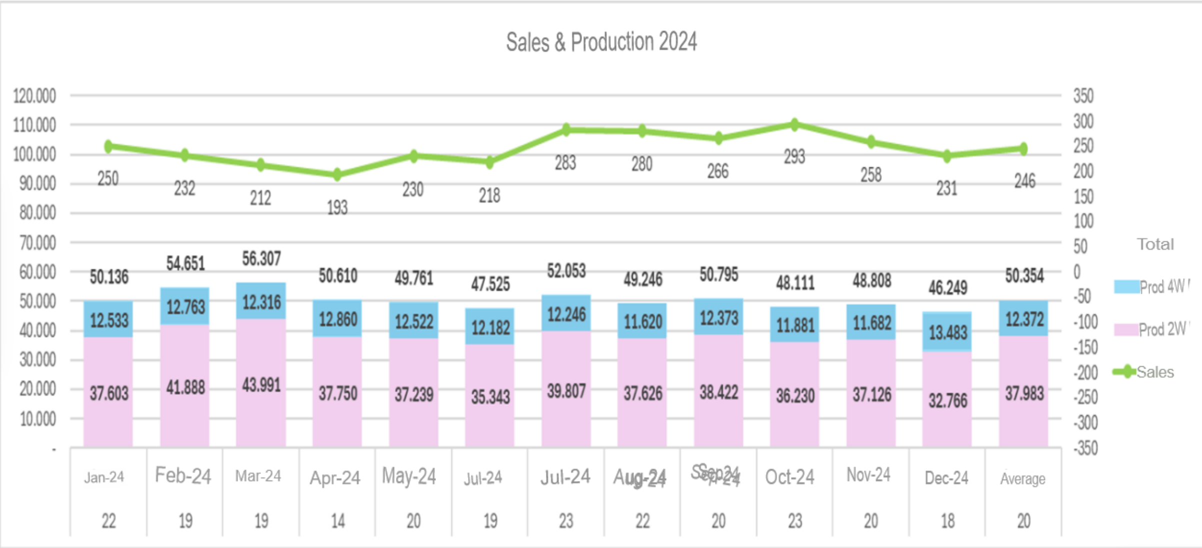

Figure 2. Sales & Production Data of PT. Bap

Source : Sales & Production Data 2024

During the inventory process, employees show inconsistencies in the use of existing WMS systems due to the perception that they add workload, especially when manual methods are still used in parallel (Moraes, Carvalho, & Sampaio, 2023). This shows that the existing system has not been optimized to provide the expected ease and efficiency.

Here's a root cause analysis with the Fishbone Diagram:

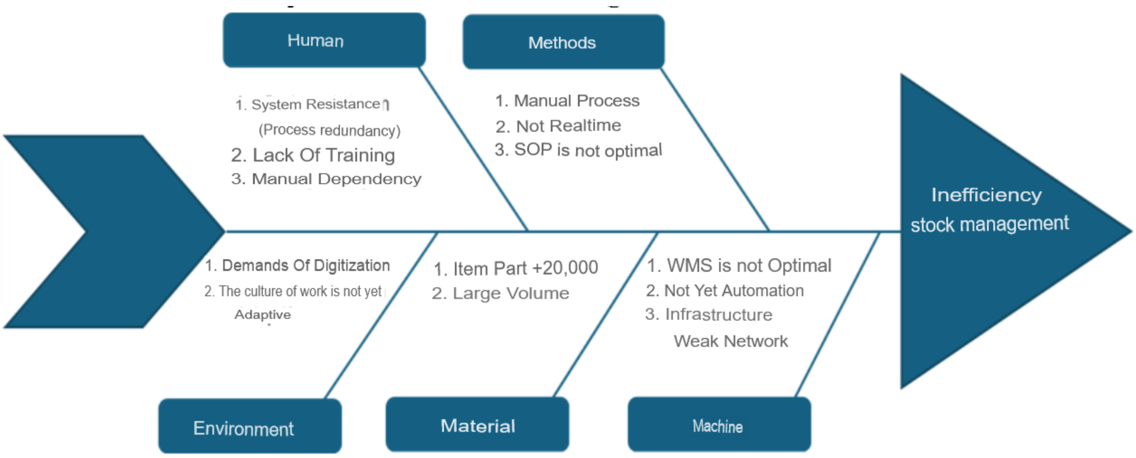

Figure 4. Diagram of the Root of the Problem of PT. Bap

Source : Interview of PT. Bap 2024

Several previous studies have discussed the application of technology to improve inventory management and supply chain efficiency. Zhou & Piramuthu (2019) highlighted the role of RFID in enabling real-time inventory management within smart supply chains, which significantly reduces manual errors and operational delays. Similarly, Wang & Zhang (2020) conducted a case study in the automotive industry demonstrating that RFID implementation leads to substantial improvements in inventory accuracy and process efficiency. Furthermore, research by Nguyen & Tran (2024) emphasized the synergistic effect of combining lean manufacturing principles with RFID technology to eliminate waste and enhance supply chain responsiveness. These studies collectively underscore the potential of RFID technology to address common inefficiencies in manual inventory systems, supporting its relevance for PT Bap context.

In an effort to improve the accuracy of stock data and supply chain efficiency, PT Bap recognizes the importance of process optimization before moving on to more advanced automation implementations. The initial step is focused on applying the principles *of lean manufacturing* in accordance with the theory of Lean Waste (Ohno, 1988) to identify and eliminate activities that do not provide added value, simplify workflows, and optimize the utilization of existing WMS systems (7 Waste: Waiting: 8 Hours Downtime, Motion: Repetitive Recording, Defect: Data input error).

Once the manual process is simplified and the existing system is optimized, the final step in this efficiency effort is the implementation of the RFID system design concept. RFID is designed as a final touch to enable real-time integrated stock management. With the application of this technology, PT Bap can not only eliminate reliance on manual methods but also create significant efficiencies in the supply chain.

Because stock inaccuracies can increase the bullwhip effect in the supply chain (Supply Chain Uncertainty: Chopra & Meindl, 2016) With RFID, the inventory process that previously took up to 8 hours can be drastically shortened, *reducing production downtime, and improving the accuracy of inventory data.*The adoption of RFID is not only about the adoption of new technologies but also part of digitalization efforts that are aligned with the vision of Industry 4.0. By integrating this technology into its operations, PT Bap not only improves supply chain efficiency but also strengthens the company's competitiveness in the face of global challenges. With this approach, PT Bap can leverage RFID technology to create sustainable efficiencies, reduce operational risks, and increase the company's overall productivity.

The main problem faced by PT Bap is the reliance on manual methods in stock management which causes inefficiencies, data inaccuracies, and operational losses. This is shown by the high operational costs due to the use of manual labor, long production downtime because inventory takes up to eight hours each month, and data input errors that have an impact on the availability of goods and the smooth supply chain. Based on these conditions, the formulation of this research problem includes the identification of activities that are not value-added in the inventory process, the optimization strategy of the Warehouse Management System (WMS), and the design of an RFID system that is integrated with WMS to improve stock accuracy and supply chain efficiency.

The purpose of this research is to design an RFID system as a digital solution in overcoming the problem of manual stock management at PT Bap . In detail, this study aims to analyze the stock management process and identify non-value-added activities, develop WMS optimization strategies to improve efficiency and effectiveness, and design RFID integration with WMS to improve stock data accuracy and supply chain efficiency in the framework of industrial digital transformation.

The benefits of this research are divided into three aspects. For companies, the results of the research can improve the accuracy of stock management, reduce production downtime, and become the basis for strategic decision-making in logistics automation. For the academic world, this research enriches the literature on lean-digital integration in the manufacturing industry as well as the application of RFID in logistics. As for industry practitioners, this study offers an applicative case study and a systematic approach in the implementation of integrated RFID to improve operational efficiency based on digital technology and lean principles.

METHOD

This research was conducted with a case study approach using descriptive and quantitative analysis to analyze stock management at PT Bap , especially in the inventory and logistics areas. The research stages include object determination, problem formulation, literature study, initial observation, primary data collection through interviews, observations, and documentation, as well as secondary data through literature studies and benchmarking at PT TMMIN that has implemented RFID. The main focus of this research is to analyze the weaknesses of manual systems and optimize the Warehouse Management System (WMS), then design an integrated RFID system to improve the accuracy and efficiency of the supply chain.

The analysis was carried out using the Value Stream Mapping (VSM) method to identify non-value-added activities and waste in the stock management process, followed by measuring the impact of RFID application on process speed, data accuracy, and labor efficiency. Simulations of RFID systems show the potential for inventory acceleration by up to 40%, an increase in data accuracy of more than 90%, as well as a significant reduction in the need for manual labor.

Indicators of research success are measured from accelerating the inventory process, increasing data accuracy, and workforce efficiency. The results of the research are expected to be the basis for the implementation of an RFID-based automation system integrated with WMS, in accordance with the principles of Lean Manufacturing and Industry 4.0 digitalization, so as to not only improve PT Bap operational efficiency but also make a practical contribution to digital transformation in the Indonesian automotive manufacturing sector.

RESULTS AND DISCUSSION

Analysis of Existing Stock Management Processes at PT Bap

The monthly inventory process at PT Bap is currently still manual. The activity is carried out by stopping production for ±8 hours every month so that there is no movement of goods during stock counting. The time is divided into ±4 hours for physical calculation and ±4 hours for recording and input data into the Warehouse Management System (WMS). This activity involves a lot of workers from various divisions, so operational costs increase. In addition, manual methods are prone to recording errors, which impact stock accuracy and supply chain smoothness.

Based on sales and production data in 2024, downtime for 8 hours caused an opportunity loss of ±IDR 4.12 billion per month. With an average production of 50,354 units/day and sales of IDR 246 billion per month, the loss of 16,785 units due to manual stock taking had a significant economic impact.

Table 1. Inventory Implementation Process

No	Kegiatan	Metode	MP	CT (Menit)	Remark
1	Logistic menerima Form List Stock dari PPC Dept	-	-	-	Diisi manual dengan informasi Part Name, Part No, Lokasi, Kanban No

2	Logistic membuat Slip STO per Area untuk ditempel di part yang akan dihitung	Manual	3	60	
3	Logistic menghitung actual qty Part berdasarkan area	Manual	15	270	Hitung menggunakan kalkulator
4	Logistic membuat summary hasil perhitungan manual ke excel	Manual	2	30	Input ke Excel manual
5	Logistic compare data actual perhitungan dengan monitoring harian	Manual	1	20	Compare data by excel
6	Logistic input data perhitungan yang sudah dicompare ke dalam WMS	Manual	5	60	input ke WMS manual
7	Logistic compare data actual input WMS dengan summary excel yang sudah	Manual	1	20	Compare data by excel
8	Logistic RPA dari WMS ke excel	Auto	2	480	Dilakukan di shift 2 secara automation
9	Logistic compare data RPA dengan summary excel yang sudah diverifikasi	Manual	1	20	Compare data by excel
Total MP			30	960	

Source: Internal Data of PT Bap , 2024

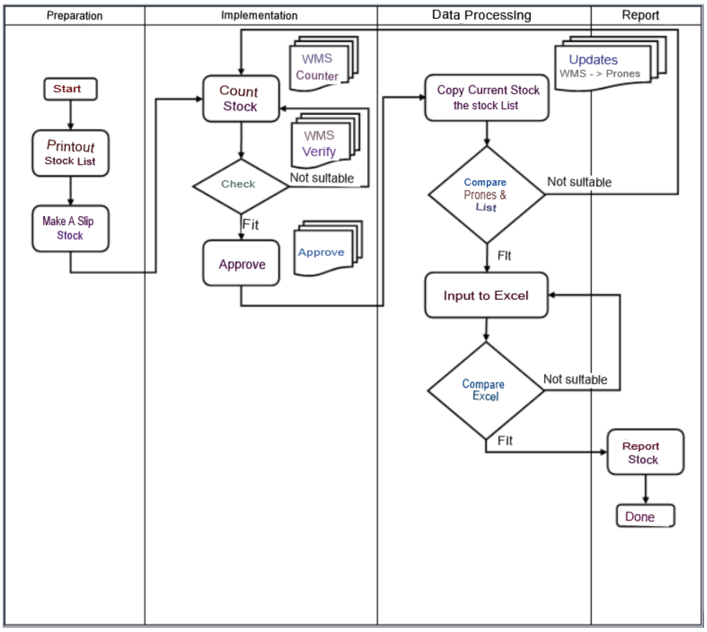

Figure 5. Current manual inventory process flow

Source: Internal Data of PT Bap , 2024

From the data, it can be seen that the implementation of automation systems such as **RFID** has the potential to significantly reduce NVA activities. The identification of this waste is the main basis for designing a process improvement system which will be discussed in the next section. In addition, a waste analysis using the **7 Waste Lean Manufacturing** framework shows that:

1. **Waiting** – long wait times during the inventory process (8 hours/month).
2. **Motion** – inefficient employee movement due to manual validation.
3. **Overprocessing** – repetitive logging on both paper and WMS.

Benchmarking RFID Implementation (Case Study of PT. TMMIN)

To support the design of the RFID system at PT Bap, benchmarking was carried out to PT Toyota Motor Manufacturing Indonesia (PT TMMIN), an automotive manufacturing company that has successfully implemented the RFID system in its logistics and warehousing processes.

PT TMMIN uses RFID to track automotive components from the arrival of raw materials to the delivery process of finished goods. The implementation of RFID is carried out thoroughly in the main warehouse, equipped with RFID readers at the entrance (*inbound*), storage, and delivery area (*outbound*). RFID integration with Warehouse Management System (WMS) and ERP systems allows for real-time and automated data logging.

Benchmarking Results:

Table 2. Banchmark Comparison

Aspek	PT TMMIN	PT Bap (Before)
Sistem	RFID + WMS + ERP	WMS Manual
Akurasi stok	> 95%	± 85%
Waktu Inventarisasi	± 30 menit real-time	± 8 jam/bulan
Downtime produksi	Tidak ada	Ada

Source: PT TMMIN Benchmarking Results and PT Bap Data, 2024

Learning from Benchmarking:

1. Time efficiency increases significantly after RFID systems are used.
2. Reduction of non-value-added activities such as manual searches and repeated verification.
3. There is a need for an initial investment in RFID devices and system integration, but the ROI is achieved in < 2 years.
4. Training support and new SOPs are crucial in changing work culture.

Based on the results of the benchmarking, the RFID system has been proven to be able to answer challenges in managing stock effectively, and is a valid basis for the system design that will be adapted by PT Bap .

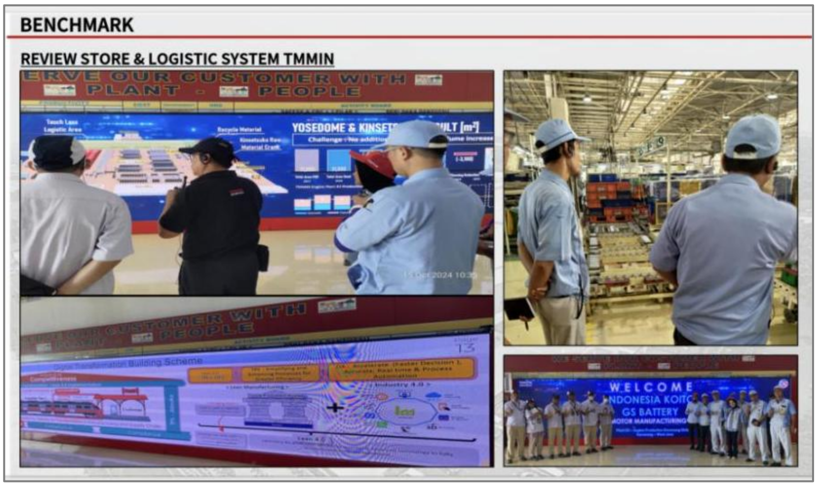

Figure 6. Activities during PT TMMIN Benchmark

Source: Author's Documentation during PT TMMIN Benchmarking, 2024

RFID System Design for PT Bap

1. *Lean Manufacturing Principles as a Foundation*

Before designing an automation system, it is necessary to ensure that the processes to be automated are efficient. This is in line with the principle of Lean Manufacturing, which is to eliminate non-value added activities. From the results of the Ministry of Industry's training, it is emphasized that automation will only provide maximum benefits if the basic process is streamlined. In the context of PT Bap inventory, the results of the analysis show that there are main wastes in the form of:

1. Waiting – production stops 8 hours each month during stock taking.
2. Motion – excessive labor movement during manual counting.
3. Overprocessing – double logging (paper form → re-input to WMS).

With a Lean approach, the first step is to redesign the inventory flow to eliminate the waste, then automate it using RFID. Based on the results of the identification of existing processes and benchmarking to PT TMMIN, the RFID system designed for PT Bap aims to improve stock accuracy and warehouse process efficiency through the automation of goods tracking and the reduction of non-value-added activities.

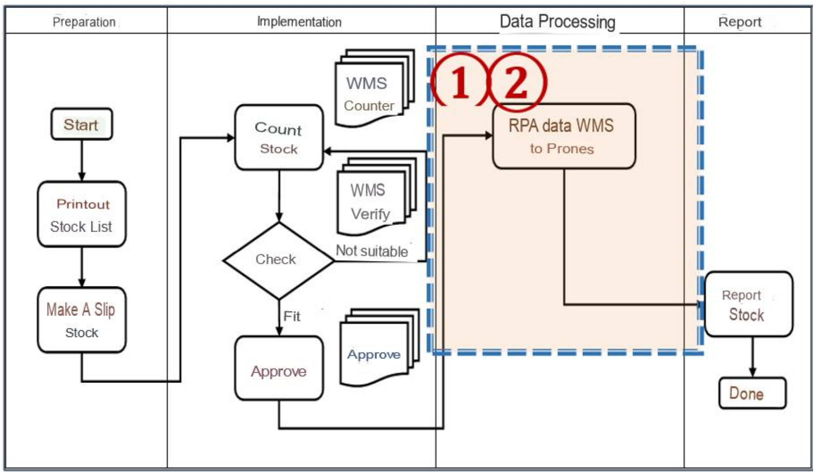

Figure 7. Inventory process flow with Lean Manufacturing concept

Source: Author's Analysis, 2024

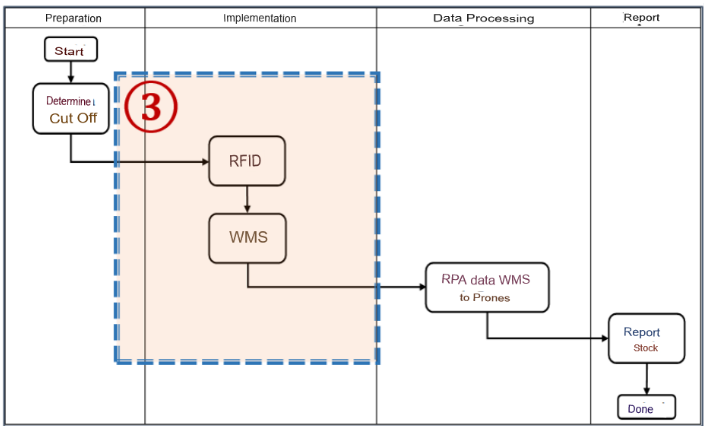

Figure 8. Inventory process flow with Lean + RFID concept

Source: Author's Analysis, 2024

Purpose of RFID System Design

The design of the RFID system at PT Bap has a dual purpose:

1. Lean objective: ensuring that inventory flows are streamlined by removing activities that are not value-added.
2. Automation objective: implementing RFID to minimize manual intervention, speed up processes, and improve stock accuracy.

Specifically, the goals to be achieved are:

1. Reduce the duration of stock taking from 8 hours to 2 hours.
2. Eliminates repetitive manual logging activities.
3. Ensuring inventory no longer requires production downtime.
4. Improves stock accuracy by 95%.

New Inventory Process Flow

The new pipeline is designed with the principles of Lean before Automation:

1. NVA (Non-Value Added) activity removed: manual physical counting and double logging.
2. VA (Value Added) activity is maintained: verification of actual stock.
3. The process is then atomized with RFID so that verification is carried out automatically.
4. Monitoring and Auditing, Dashboard shows stock status in real-time. No more regular manual recording stock.

Integration with WMS Systems

RFID systems do not stand alone, but are integrated directly with WMS.

1. Manual data input → deleted
2. Automatic update of the stock quantity & location → from RFID.
3. Supervision & validation → done through the WMS dashboard.

Thus, there is no more waste due to double recording. The inventory process changes from *a batch process* to *a continuous process*, according to **the principles of Lean Manufacturing**: faster, leaner, and waste-free

Lean + RFID Added Value

This design not only answers the problem of downtime, but also confirms that PT BAP has implemented a combination of **Lean Manufacturing + Automation**.

Lean → ensure that automated processes are streamlined.

RFID → provide speed, accuracy, and digital integration.

With this combination, the monthly inventory process at PT Bap is not only faster, but also more efficient and sustainable in the long run

System Design Scheme

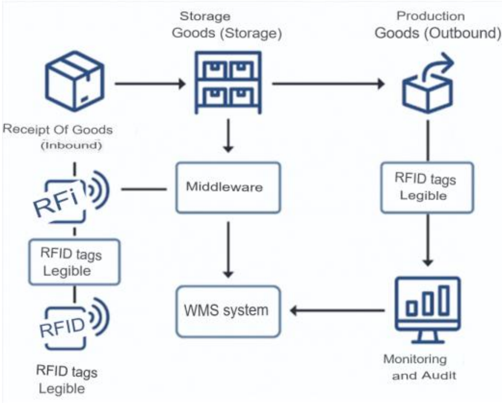

Figure 9. System Design Scheme
Source: Author's Analysis, 2024

With the design of this system, it is hoped that PT Bap can reduce manual activities, increase stock visibility, and support the acceleration of logistics process digitalization in the Industry 4.0 era.

System Efficiency Simulation and Evaluation

After the RFID system is designed, a simulation based on quantitative comparison between the existing conditions and the RFID application scenario at PT Bap is carried out. The goal is to measure the impact on **stock accuracy**, **processing time efficiency**, and **reduction of non-value-added (NVA) activities**.

Process Speed Formula

$$= \frac{\textbf{Waktu Manual} - \textbf{Waktu RFID}}{\textbf{Waktu Manual}} \textbf{ x } 100\% \qquad \textbf{(V.1)}$$

$$= \frac{960 - 570}{960} \textbf{ x } 100\%$$

= 40%

Labor Efficiency Formula

$$= \frac{\textbf{Waktu Manual} - \textbf{Waktu RFID}}{\textbf{Waktu Manual}} \textbf{ x } 100\% \qquad \textbf{(V.2)}$$

$$= \frac{30 - 9}{30} \textbf{ x } 100\%$$

= 70%

Evaluation Parameters

The evaluation of the system is carried out by comparing the conditions before (manual) and after the implementation of RFID based on the following indicators:

1. Duration of stock withdrawal (hours).

2. Stock accuracy (%).
3. The amount of labor involved.
4. Production downtime loss (Rp).
5. Waste elimination based on the 7 Waste Lean Manufacturing framework

Before–After Simulation Results

Table 3. Comparison of Inventory System Efficiency

Indicator	Before RFID (Manual)	After RFID (Lean + Automation)	Change
Duration of stock withdrawal	8 hours	±1.5 hours	↓ 81%
Stock accuracy	±85%	±97%	↑ 12%
Number of Workforce	30 MP	9 MP	↓ 40%
Production downtime	±IDR 4.12 billion/mo	Almost zero	↓ Drastic
Dominant types of waste	Waiting, Motion, Overprocessing	Almost eliminated	Eliminate Waste

Source: Author's Simulation based on PT Bap Data, 2024

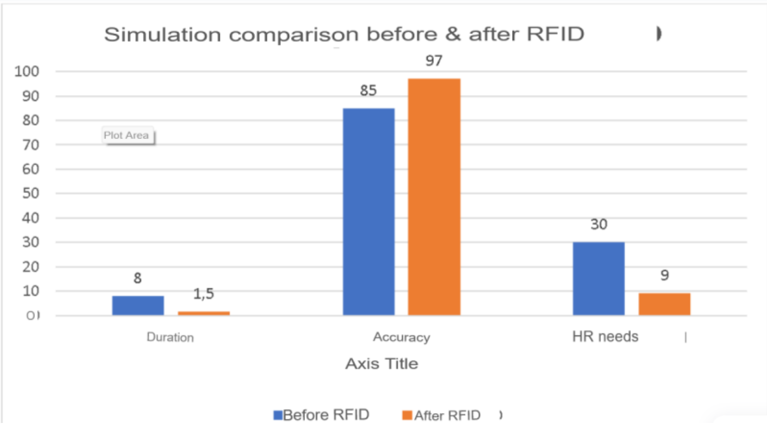

Figure 12. Comparison Before & After RFID Adoption

Source: Author's Simulation based on PT Bap Data, 2024

Efficiency Analysis

The simulation results show that the application of RFID with the Lean before Automation principle is successful:

1. Reduced the duration of stock taking from 8 hours to only ±1.5 hours → 81% time efficiency.
2. Eliminating production downtime so that opportunity losses ±Rp 4.12 billion/month can be suppressed.
3. Increased stock accuracy from ±85% to ±97% thanks to the elimination of manual record-keeping.
4. Reduce employee workload as manual input is removed → labor can be diverted to value-added activities.
5. Waste elimination: waiting (lost downtime), motion (manual movement lost), overprocessing (double logging lost)

RFID Implementation Cost Estimation

The design of the RFID system for PT Bap takes into account both technical and financial aspects to ensure that the system designed is not only operationally efficient but also feasible in terms of investment. Cost estimates are compiled based on the main components of RFID: hardware, software, infrastructure, implementation, training, and *maintenance* support.

Cost Estimate Details

Table 4. Cost Estimates

Komponen	Item	Kuantitas	Estimasi Biaya (IDR)	Keterangan
Hardware	RFID UHF Tag	20.000 unit	Rp 3,2 – 8 juta / unit	Tahan logam (metal-mount)
Hardware	Fixed RFID Reader	6 unit	Rp 24 – 48 juta / unit	Pintu gudang dan conveyor
Hardware	Handheld Reader	4 unit	Rp 16 – 40 juta / unit	Untuk mobile stock opname
Hardware	Antena & Kabel	12 set	Rp 3,2 – 8 juta / set	
Software	Middleware RFID	1 paket	Rp 240 – 480 juta	Integrasi real-time ke WMS
Software	Custom Interface WMS	1 paket	Rp 160 – 320 juta	Modul khusus penghubung
Infrastruktur	Server & Storage	1 cluster	Rp 128 – 240 juta	Database dan pemrosesan
Infrastruktur	Jaringan & Keamanan	1 paket	Rp 80 – 160 juta	Proteksi sistem dan IoT
Implementasi	Konsultan Implementasi	3 bulan	Rp 320 – 640 juta	Konfigurasi dan pengujian
Implementasi	Pelatihan Karyawan	30 orang	Rp 48 – 96 juta	Training operator dan admin
Maintenance	Support Tahunan	1 tahun	Rp 200 – 400 juta	Update software dan garansi

Source: Author's Cost Analysis based on Market Study, 2024

Total Estimated Cost:
IDR 1.3 – 2.7 billion
(Assuming USD 1 exchange rate = IDR 16,000)

Phased Implementation Scheme

In order for the system implementation process to run more flexibly, measurably, and with minimal risk, the recommended approach is through a phased scheme. This approach allows companies to evaluate at each stage, as well as make adjustments before moving on to the next phase. Here are the suggested stages:

Phase 1: Pilot Project at Inbound Warehouse

The initial stage began with a pilot project in the inbound warehouse area. At this stage, a fixed RFID reader and around 5,000 RFID tags will be used. The goal is to test the effectiveness of the system in automatically receiving and recording incoming goods, while also identifying potential technical challenges in the field.

Phase 2: Expansion to Outbound Area and Finished Goods Warehouse

After the initial stage was successful, the implementation continued by expanding the system to outbound areas as well as finished goods warehouses. This aims to ensure that the process of tracking and recording goods can run thoroughly, both when goods enter and exit the system.

Stage 3: Full Integration of RFID with WMS and HR Training

The third stage focuses on full integration between the RFID system and the Warehouse Management System (WMS). At this stage, comprehensive training is also carried out for all related human resources, so that the use of the system can run optimally and evenly in all warehouse operational lines.

Stage 4: ERP System Customization and Security Strengthening

The final stage includes long-term customization of the ERP system to support real-time cross-departmental data integration. In addition, the security aspect of the system is also strengthened, both in terms of data and devices, to ensure the sustainability and reliability of the system in the long term.

With this phased approach, companies can not only minimize implementation risks, but also build a robust, efficient, and ready system to be fully integrated in the company's digital ecosystem.

Economic Considerations

In every implementation of a new system, the economic aspect is the main consideration. Although the initial investment in the implementation of RFID systems and their integration with WMS is relatively large, the potential for long-term efficiencies is significant and can provide real added value for companies. Some of the key economic benefits that can be achieved include:

1. Reduction of Logistics Waste. With a more accurate and automated system, companies can reduce waste in the logistics process, such as shipping errors, lost goods, and unproductive lead times.
2. Up to 50% reduction in processing time. Process automation via RFID and WMS allows for much faster workflows. The time required for recording, tracking, and verification of goods can be drastically reduced, even up to 50% compared to manual methods.
3. Elimination of Duplication of Work and Stock Errors. Integrated systems help prevent double recording and errors in stock management. This not only improves data accuracy, but also reduces administrative workload and improves the reliability of inventory information.

Thus, while the initial investment requires careful planning, the resulting return on investment value (ROI) in the form of operational efficiencies, increased productivity, and long-term cost reductions make this implementation a strategic step worth considering (Li & Wang, 2021; Nguyen & Tran, 2024).

Economic Analysis and Return on Investment (ROI)

The investment in the RFID system designed for PT Bap aims to generate long-term benefits in the form of process efficiency, data accuracy, and reduced warehouse operational costs. To measure the financial feasibility of this project, an analysis of the Return on Investment (ROI) and the estimated time of return on capital (Payback Period) were carried out.

Annual Savings Estimates

Based on historical data and simulations that have been carried out in Subchapter 4.4, the following potential savings are obtained:

Table 5. Comparison of Inventory System Efficiency

Sources of Savings	Estimated Savings per Year	Information
Labor time efficiency	IDR 300,000,000	Reduced operational time ± 50%
Elimination of stock errors	IDR 500,000,000	Reduction of loss of goods & correction costs
Reduced logging activity	IDR 150,000,000	Elimination of manual logging duplication
Optimization of the stock recording process	IDR120,000,000	No need for regular manual cycle count
Total Savings per Year	**IDR 1,070,000,000**	—

Source: Author's Economic Simulation based on PT Bap Data, 2024

Initial Investment

Based on Subchapter 4.5, the estimated cost of RFID implementation at PT Bap is around:

IDR 1,300,000,000 – IDR 2,700,000,000

For the purpose of financial simulation, investment assumptions are used on a medium scale: **IDR 2,000,000,000** (realistic estimate for implementation in large warehouses with integration to WMS)

ROI and Payback Period Calculation

ROI (Return on Investment) is calculated by the formula:

$$\mathrm{ROI} = \frac{\text{Total Penghematan per Tahun}}{\text{Investasi Awal}} x\ 100\% \tag{V.3}$$

- Total Savings per Year Rp. 1,070,000,000
- Initial Investment Rp. 2,700,000,000

$$\mathrm{ROI} = \frac{1.070.000.000}{2.700.000.000} x\ 100\%$$

$$\mathrm{ROI} = 0.3963 x\ 100\%$$

$$\mathrm{ROI} = 39.63\ \%$$

With an investment of Rp. 2,700,000,000, the return on investment rate is 39.63% per year. This figure shows a fairly good figure, an estimated return on capital of 2.5 years.

Payback Period:

$$\text{Payback Period} = \frac{\text{Investasi Awal}}{Penghematan\ per\ Tahun} \tag{V.4}$$

$$\text{Payback Period} = \frac{2.700.000.000}{1.070.000.000}$$

$$\text{Payback Period} = 2.52\ Tahun$$

Payback Period of 2.52 Years or about 2 years and 6 months, meaning return to capital within 2.5 years, after which the annual savings can be considered as a net profit from the investment.

Interpretation of Results

With an ROI of 39.63**%,** RFID systems are considered **very economically feasible**.

The return on capital time **is less than 3 years**, indicating the potential for large long-term profits.
After the 3rd year, all the savings become a net profit for the company.

Strategic Recommendations for RFID Implementation at PT Bap

Based on the results of process analysis, benchmarking studies, system design, and technical and economic evaluations, the following are strategic recommendations in implementing the RFID system so that it runs effectively, efficiently, and sustainably in PT Bap operational environment.

Phased Implementation Strategy

Implementation should be done in several phases to minimize risk, optimize learning, and manage costs:

Phase 1: Pilot Project
- Location: Main warehouse inbound area
- Components: Fixed reader, 5.000 tag, 1 handheld reader
- Objective: Limited trial and validation of new processes

Phase 2: System Expansion
- Location: Outbound area and finished goods storage
- Addition of tags and readers at critical points

Phase 3: Full Integration with WMS
- Development of custom middleware and interfaces
- Intensive training for logistics and IT teams

Phase 4: SOP and Audit Adjustments
- Regular revision of work standards, retraining, and system audits

Success Support Needs

In order for the implementation to run optimally, PT Bap needs to pay attention to the following supporting factors:
1. Top Management Commitment. Formal budget, policy, and project time allocation support
2. Training & Change Management. Thorough socialization, technical training, and user resistance mitigation
3. Selection of the Right Vendor. Prioritize RFID vendors who are experienced in the automotive manufacturing sector and able to provide Long-term technical support

Monitoring & Evaluation

After the implementation of the RFID system, the next important step is to conduct periodic monitoring and evaluation to ensure that the system runs according to its purpose as well as being the basis for improvement and strategic decision-making. This evaluation needs to refer to relevant key performance indicators (KPIs), including stock accuracy to assess the accuracy of recording the quantity and location of goods, processing time to measure efficiency in receiving, storing, and shipping goods, and logistics downtime to monitor potential disruptions that hinder operations. With these indicators, companies can objectively evaluate system performance, make necessary adjustments, and ensure the benefits of RFID in improving the efficiency and reliability of warehouse management.

In the long term, the adoption of RFID is the first step towards a broader and deeper digital transformation across the supply chain. Strategic developments that can be carried out include full integration with ERP and MES systems to support cross-functional decisions, component tracking to the part level to ensure high accuracy in the automotive industry, and the implementation of an Internet of Things (IoT)-based dashboard so that RFID data can be visualized in real-time to monitor warehouse conditions and logistics performance. Through this development, PT Bap is not only adopting RFID as an efficiency solution, but also building a strong foundation for a sustainable and competitive logistics digital transformation.

CONCLUSION

Based on the results of the research, the design of the RFID system at PT Bap has been proven to be able to improve stock accuracy and supply chain efficiency, especially in the monthly inventory process which was previously manual, took an average of 8 hours, involved a lot of labor, caused production downtime with an opportunity loss of around IDR 4.12 billion per month, and resulted in stock accuracy of only ±85%. Lean Manufacturing analysis identifies waste in the form of waiting, motion, and overprocessing, so automation is needed. Benchmarking with PT TMMIN showed RFID's success in cutting inventory time to real-time with no downtime and increasing accuracy by up to >95%, which strengthens the solution for PT Bap . The results of the RFID design simulation showed that the efficiency of stock taking time decreased to ±1.5 hours (81%), the stock accuracy increased to 97%, the labor requirement was significantly reduced, and the downtime loss was almost eliminated. Economically, an investment of IDR 1.3-2.7 billion with a downtime saving of IDR 4.12 billion per month results in an ROI of 39.6% per year with a payback period of ±2.5 years, so that the implementation of RFID is technically and financially feasible. PT Bap is advised to implement RFID in stages starting from a pilot project, expanding the scope, to full integration with WMS, accompanied by change management through training and socialization, as well as monitoring KPIs such as stock accuracy, inventory time, and downtime costs. Going forward, development can be directed at the integration of RFID with ERP and IoT dashboards for broader real-time monitoring. The limitations of this study only include monthly inventory, so the next study is recommended to develop a simulation model for inbound-outbound, analyze the integration of RFID with IoT, and conduct a multi-company study to obtain a more comprehensive comparison in the Indonesian automotive industry.

REFERENCES

Almeida, R., & Santos, J. (2023). Digital transformation in supply chain management: The role of RFID and IoT. International Journal of Information Management, 69, 102521. https://doi.org/10.1016/j.ijinfomgt.2022.102521

Arnold, J. R. T., Chapman, S. N., & Clive, L. M. (2012). Introduction to materials management (7th ed.). Prentice Hall.

Chen, X., & Liu, Y. (2022). RFID adoption in supply chain management: A systematic review and future research directions. Supply Chain Management: An International Journal, 27(6), 631–647. https://doi.org/10.1108/SCM-05-2021-0223

Hidayat, A., & Susanto, E. (2023). Designing an RFID-based inventory management system to improve stock accuracy in the automotive industry. Journal of Industrial Technology and Management, 5(1), 67–78.

Hopp, W. J., & Spearman, M. L. (2011). Factory physics (3rd ed.). Waveland Press.

Kagermann, H., Wahlster, W., & Helbig, J. (2013). Recommendations for implementing the strategic initiative INDUSTRIE 4.0: Securing the future of German manufacturing industry (Final report of the Industrie 4.0 Working Group). acatech.

Khan, S. A., & Yu, Z. (2020). Lean and Industry 4.0: A systematic literature review on the integration of lean manufacturing and digital technologies. Journal of Manufacturing Systems, 54, 290–307. https://doi.org/10.1016/j.jmsy.2020.01.003

Kim, S., & Lee, H. (2023). The role of RFID in enhancing inventory accuracy and operational efficiency: A case study in the manufacturing sector. Journal of Manufacturing Technology Management, 34(3), 409–426. https://doi.org/10.1108/JMTM-07-2021-0271

Li, J., & Wang, H. (2021). The impact of RFID technology on supply chain efficiency: Evidence from the retail sector. The International Journal of Logistics Management, 32(4), 1234–1256. https://doi.org/10.1108/IJLM-07-2020-0291

Moraes, A., Carvalho, A. M., & Sampaio, P. (2023). Lean and Industry 4.0: A review of existing literature. Machines, 11(4), 443. https://doi.org/10.3390/machines11040443

Nguyen, T., & Tran, Q. (2024). RFID and lean manufacturing: A synergistic approach to improving supply chain efficiency. Journal of Cleaner Production, 387, 135853. https://doi.org/10.1016/j.jclepro.2023.135853

Prasetyo, A., & Nugroho, B. (2021). The application of lean manufacturing and RFID technology in improving supply chain efficiency in the manufacturing industry. Journal of Technology Management, 20(3), 233–245.

Sari, K., & Wijaya, T. (2020). The implementation of RFID technology in improving stock accuracy at PT TMMIN. Journal of Industrial Engineering, 21(2), 115–124.

Shahin, M., Chen, F. F., Bouzary, H., & Krishnaiyer, K. (2020). Integration of lean practices and Industry 4.0 technologies. The International Journal of Advanced Manufacturing Technology, 107(7–8), 2927–2936. https://doi.org/10.1007/s00170-020-05124-0

Wang, Y., & Zhang, X. (2020). RFID-based inventory management in the era of Industry 4.0: A case study in the automotive industry. Computers & Industrial Engineering, 150, 106891. https://doi.org/10.1016/j.cie.2020.106891

Wibowo, R., & Setiawan, D. (2022). Analysis of the impact of RFID implementation on warehouse operational efficiency at PT XYZ. Journal of Information Systems, 18(1), 45–56.

Zhang, L., & Chen, Y. (2021). RFID and IoT integration for smart warehouse management: A review. Journal of Industrial Information Integration, 22, 100194. https://doi.org/10.1016/j.jii.2021.100194

Zhou, W., & Piramuthu, S. (2019). RFID-enabled real-time inventory management in smart supply chains. International Journal of Production Economics, 208, 125–138. https://doi.org/10.1016/j.ijpe.2018.11.018