JPPIPA 9(6) (2023)

Jurnal Penelitian Pendidikan IPA

*Journal of Research in Science Education*

http://jppipa.unram.ac.id/index.php/jppipa/index

# Design of Integrated Warehouse Control Tower (WCT) Digitalization by the Internet of Things Architectures

M. Tirtana Siregar[1*]

[1]Logistics Management Study Program for Electronics Industry, Politeknik APP Jakarta, Jakarta, Indonesia

Received: April 25, 2023
Revised: June 20, 2023
Accepted: June 25, 2023
Published: June 30, 2023

Corresponding Author:
M. Tirtana Siregar
tirtana.mts@poltekapp.ac.id

DOI: 10.29303/jppipa.v9i6.3781

© 2023 The Authors. This open access article is distributed under a (CC-BY License)

**Abstract:** The problem that often occurs in information systems, especially in the logistics process, is improper management because the machine is not connected to inventory control and not integrated with the operator, so it takes a long time to analyze errors in the logistics process. This study develops warehouse logistics control information to speed up and accurate inventory processes. This study designed the Warehouse Control Tower (WCT) as a strategic development based on Wireless Sensor Network that is connected to a warehouse system and integrated with a computer connected to the RFID (Radio Frequency Identification) system, AI (Artificial Intelligence) cameras, and barcodes. Value stream mapping is used to map the process flow of warehousing activities and information flow at the level of the total warehouse process flow. Overall, the results of the analysis using the value stream mapping method indicate that the process flow using RFID and Artificial intelligence is more efficient than before implementation.

**Keywords:** Information Systems; Inventory; Sensor technology

## Introduction

Industry 4.0 encourages the expansion of the digital world and the internet into business life. One way to grow competitive power is by adopting information technology to stabilize and ensure the speed of information up to the top management level (Perifanis & Kitsios, 2023). The management process in a warehouse is the most important thing for the continuity of business processes in a company. Where warehousing itself becomes a place that is used to store an asset and also the availability of goods to ensure that production processes and other business processes can run smoothly because the availability of raw materials and assets is well maintained. As a company develops, of course, it will also be accompanied by the increasing number of assets needed and also owned. It course this will also affect the amount of goods that must be stored in a warehouse and also the size of the warehouse will also be bigger.

This will certainly require a lot of human resources in it to be able to ensure the warehousing operational process can run well. However, new problems arise when the incoming goods that will enter the warehouse are in large quantities and all must be entered into the information system manually, as a result, the process required to carry out this process requires quite a long time (Tejesh & Neeraja, 2018). likewise also in the process of monitoring the availability of goods in the warehouse and also the process of goods that will leave the warehouse for the distribution process, the time and human resources needed will be even greater which will hinder the business processes in it.

The information must be fast, precise, and efficient so that it supports strategic policies decided by top management (Saderova et al., 2021). Thus, the accuracy of the goods data will determine the optimal production activity process. Modern business competition has an impact on changing the focus of competition from competition between companies independently to competition between business networks such as the supply chain (Tukamuhabwa et al., 2021). Industrial and technological developments have developed very rapidly, especially in the field of automation. Based on a survey by (Dwivedi et al., 2021), the total cost spent on automation globally in 2016 was 152 billion dollars. Meanwhile, the costs incurred for automation in the

**How to Cite:**
Siregar, M.T. (2023). Design of Integrated Warehouse Control Tower (WCT) Digitalization by the Internet of Things Architectures. *Jurnal Penelitian Pendidikan IPA*, *9*(6), 4368–4374. https://doi.org/10.29303/jppipa.v9i6.3781

food and beverage sector was 5.8% of the total automation globally.

The problem that arises for companies in the logistics system, especially in warehouse activities, is getting an effective inventory control method to reduce the lead time in the inventory process (Chan et al., 2017). An accurate logistic control system in the manufacturing business is essential for smoothing the production process so that it can guarantee the effectiveness of production activities (Syahputri et al., 2018), Just-In-Time-oriented, providing satisfaction to customers, because if the goods are not available, the company loses the opportunity to seize the market and the company cannot supply the goods at optimal levels. In order for the company to continue to guarantee the continuity of operations and maximize the company value, it is necessary to take a directed action in controlling the production system (Ivanova, 2022)

In a previous study, in 2015, researchers developed supply chain information system applications that can be implemented in industry. The application, which is named "Industrial Supply Chain Application", can be customized according to industry needs, so that small and medium enterprises can use this information system application. The application has been copyrighted by Ministry of Law and Human Rights (KEMENKUMHAM) No. HKI. 2-01-000007457 in 2016. Furthermore, in 2017, researchers changed the system that was originally operated using a web-based information system to become an android information system to make it easier for operators to run information systems online using both computers and cellphones or tablets. Then, in 2019, researchers developed prototype simulators for incoming goods to the wareshouse.

The researcher identified an apparent evidence gap in the prior resarch concerning industrial supply chain application. Previous research entitled "Production Record Management System No. P00199700939" by Honda Giken Kogyo Kabushiki Kaisha 1-1, Minamiaoyama 2-Chome, Minato-Ku, Tokyo Japan, the production record management system has operating terminal equipment to control operations at the processing stage from the production department, to classifying products entering the processing stage, to observing products at the processing stage. Production record data file stores production record data showing actual operations on products based on operation tables stored in operation table files. However, this research does not reveal that this technology can be used for logistics systems in warehousing activities.

RFID systems, Artificial Intelligence, and dashboard screens are used as a connector between the operator and the control system in warehouse activities (Tan & Sidhu, 2022). Warehouse Control Tower (WCT) can be used as a warehouse activity monitoring device so that operators will easily monitor conditions in the warehouse to take appropriate actions (Mashayekhy et al., 2022). The dashboard system is also needed to monitor the actual inventory of goods so that the company can easily find out the actual condition of the goods in the warehouse (Reinartz et al., 2019).

Based on the problems and opportunities for developing industrial supply chain system applications to improve planning activities and controlling production needs, researchers had an interest in developing integrated applications (software) with barcode sensor devices and Wireless Sensor Network (WSN) systems that are connected to RFID systems and Artificial Intelligence camera, which is named Warehouse Control Tower (WCT). Therefore, a study with the title "Design of Integrated Warehouse Control Tower (WCT) Digitalisation by Internet of Things Architectures" is neeeded.

## Method

This study designed the Warehouse Control Tower (WCT) as a strategic development based on Wireless Sensor Network that is connected to a warehouse system and integrated with a computer connected to the RFID (Radio Frequency Identification) system (Kihel, 2022), AI (Artificial Intelligence) cameras, and barcodes. Value stream mapping is used to map the process flow of warehousing activities and information flow at the level of the total warehouse process flow.

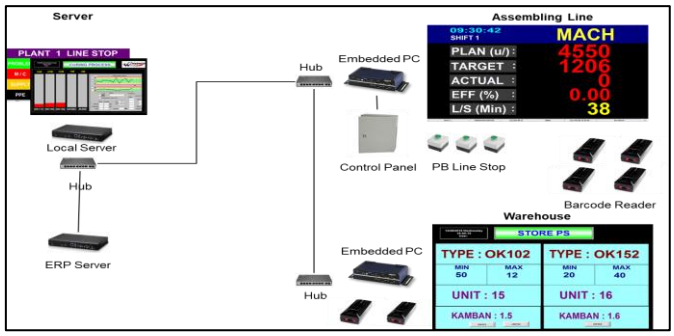


**Figure 1.** Design of Warehouse Control Tower (WCT) System

The detailed description of Warehouse Control Tower (WCT) System are as follows (Zhen & Li, 2022):

(1) HMI *(Human Machine Interface)* System

The HMI system functions as automation between machine operation and operator (Pohl & Oehm, 2022). With the use of HMI, it is hoped that operators do not have to worry about the outgoing and incoming inventory because they use a material handling device (forklift) which will be recorded on an integrated HMI device.

(2) *Warehouse Monitor*, Andon, Kanban

The monitor functions as a provider of information about outgoing and incoming inventory (S Pasaribu, 2021). If there is a problem with the outgoing and incoming inventory system, the TV monitor will inform via the Andon system, which functions as a light and alarm system about an event that is not in accordance with the outgoing and incoming inventory process. Kanban serves to inform the under or over stock needed by the operator to find out the amount of stock in the warehouse needed.

## Result and Discussion

*Warehouse Re-Engineering*

Re-engineering activities were carried out to find differences between the actual condition of the warehouse and the conditions of the warehouse that have been implemented with the system created, namely the Warehouse Control Tower (WCT). In this case, the simulation was carried out on one of the customers who provided services to PT. YCH to manage the distribution of goods which functions as a Central Distribution Center (CDC). The company initially had an information system in administrative activities in the form of a Warehouse Management System (WMS) (Khan et al., 2022), where the company already felt the value of efficiency in each process. Value Stream Mapping (VSM) was used to determine the time conditions for each process that occurs, it is known that the total time for ordering goods from suppliers to consumers takes 1,328.6 hours or about 6 weeks, this is of course a lot of time wasted on ordering goods. The following is an overview of the initial conditions of the information system using WMS and the Value Stream Mapping of the initial conditions (Kihel et al., 2022).

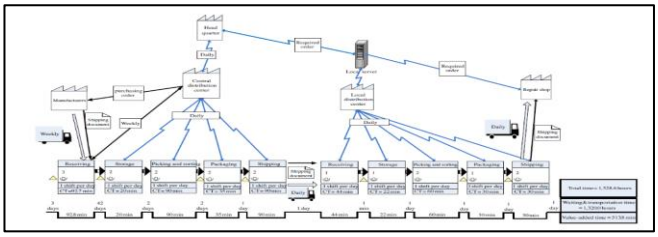

**Figure 2.** Actual Value Stream Condition

In the display of operational conditions, the Warehouse Management System (WMS) has been implemented in every line of departments, namely the Central Distribution Center (3PL PT. YCH), Local Distribution Center, and repair shop or customer care. In this study, warehouse re-engineering was carried out in PT. YCH as the Central Distribution Center (CDC) and simulated as follows.

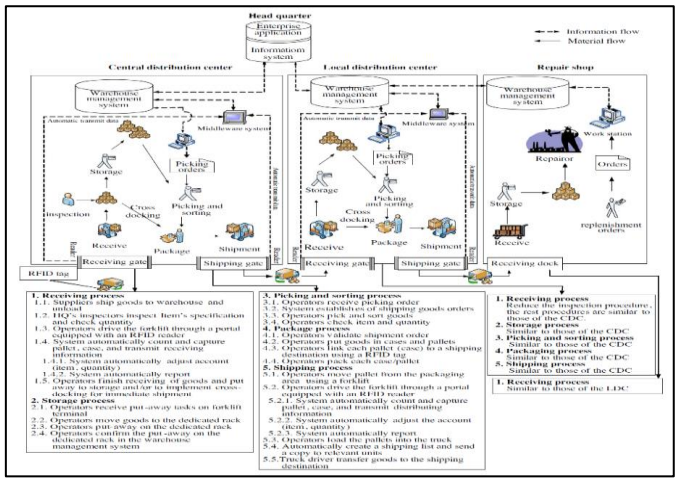


**Figure 3.** Actual Condition

Re-engineering was carried out only at the Central Distribution Center (CDC) process, namely at PT. YCH logistics using RFID (radio frequency identification) device and Artificial Intelligence (AI) camera. Both devices will provide real-time information which is presented through a dashboard in the form of a website, and a dashboard in the form of an android display. So that everyone in the company can see the warehouse condition in real-time without having to come to the warehouse (Jarašūnienė et al., 2023).

*Inventory management system integrated with Industry 4.0 technology*

The inventory management system integrated with Industry 4.0 technology was developed using RFID technology and Artificial Intelligence (AI) to detect the availability of goods or materials in the warehouse in real-time. This system used the camera with AI computer vision technology to detect the availability of materials in the warehouse according to the specified parameters (for example volume or stock quantity). Automatic detection results will be sent in real-time to the dashboard system which can be monitored directly by the user. The dashboard system will provide an alert system if there is a detection outside the predetermined parameters (for example under or over stock).

*Warehouse management system using Artificial Intelligence (AI) and RFID*

Artificial Intelligence (AI) and RFID (Radio Frequency Identification) systems were used to develop Warehouse Control Tower (WCT) which functions as an automatic and real-time end-to-end arrangement of outgoing and incoming inventory. This system consists of the following features:

*Time Slot Booking: as a Scheduling System*

Time slot booking is used for the scheduling process of receiving material goods (inbound). This system will contain information on all the scheduling of receiving material goods along with details of the material and quantity of goods that have been planned. This system will be integrated with the SAP system to synchronize Purchase Orders (PO) or Delivery Orders (DO).

*Good Receipt*

The confirmation system on receipt of goods is currently still performed manually to adjust the material information data from the SAP system. Detailed information that will be presented includes: Material Code, Material Name, PO Number, Material Quantity, Receipt Code, and Delivery Date.

*QR Code*

QR Code is digitization of travel documents, so that the logistic process becomes more concise, faster, and reduce paper usage. This QR code will have detailed information.

*Dashboard display system*

All information and data related to inventory reading through systems installed outside and inside the warehouse can be monitored through a dashboard located in the command center in a centralized and real-time manner. The dashboard will provide an alert system if there is an under or over stock. This alert system can be customized and integrated with other systems according to the needs of each company. The dashboard display will be created by fulfilling communicative information, and include graphic images, as well as colors that can make it easier for the information that appears on the dashboard. The output results generated by the RFID system and Artificial Intelligence cameras will all be listed quickly and in actual conditions, which are then converted into data that is easily understood by users and operators regarding the real conditions of ongoing warehouse activities.

The dashboard will provide an alert system in case of under or over stock, where this alert system can be customized and integrated with other systems according to the needs of each company. The dashboard system can also be used at the headquarter through to the internet (Dash et al., 2019). This condition makes it easier for the management to find out the immediate conditions that occur in the warehouse area. Management can find out information about the number of pallets in and out of the warehouse through the RFID and AI systems, and can also find out the condition of the storage area.

*Implementation results*

Device installation took approximately 1 month including installing camera devices that have been programmed with Artificial Intelligence (AI), RFID reader devices, antennas, Mini PC, and RFID tags. Here are some photos of device installation work. The warehouse-installed device consists of 2 AI cameras and 1 RFID device placed at the warehouse location to monitor pallet movements, which will then appear on the display dashboard containing real-time warehouse activity information.

*Web version of warehouse information system display (Warehouse Control Tower)*

Devices installed in the corners of the location, then connected to the Mini PC using an internet connection. The warehouse control tower has 4 pages consisting of the dashboard page, item page, row page, and pallet page which will provide information about the movement of outgoing and incoming inventory in real-time.

*WCT dashboard page*

The dashboard display provides five (5) pieces of information on inventory movements. The pallet counting camera will provide live video information about outcoming and incoming inventory using palette colors. The inventory camera will provide information in the form of live video on the condition of the storage location line whether it is filled or empty. The pallet shows the number of pallets detected using the RFID tag which will be read by the RFID reader. The row will provide information on which row is filled or empty. A pallet graph is a graph of outgoing and incoming pallets in the warehouse.

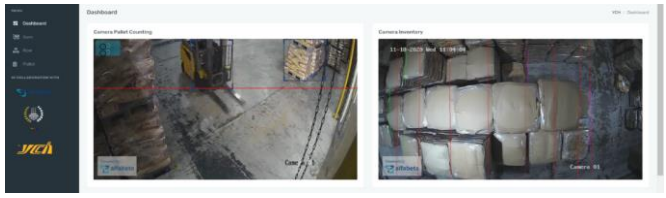

**Figure 4.** Pallet Counting Camera & Inventory Camera

*WCT item page*

The item page provides information about the types of items outgoing and incoming to the warehouse. This page is integrated with an AI camera which functions to read the types of physical goods outgoing and incoming in the warehouse, there are several types of physical goods in the warehouse, including drums, liquid sacks, wooden boxes, etc. Information is issued in real-time, with additional information regarding the date and time of outgoing or incoming inventory from the warehouse. The information on this page can also be exported into

excel and PDF format so that it can function as a report to management.

*WCT row page*

A row page is a system page providing information about a collection of filled or empty row information so that operators will easily find out which rows are empty to load goods. This can also be a report to management about lines that are often blank and filled. This process can be integrated into the warehouse turnover ratio. Information on filled and empty rows can be exported to excel and pdf. so it can be a report how many times the row is empty and filled.

*WCT pallet page*

The pallet page provides information about the number of pallets out of the warehouse detected by the RFID reader. The RFID tag is a sticker affixed to the palette, which can provide outgoing pallet information. The information generated in the form of palette number, palette color, time detected, and date detected. This information can also be exported into excel and pdf so that it can provide detailed information per day.

*Android version of 1. 5. 2. warehouse information system display (Warehouse Control Tower)*

Another form of dashboard system created is the Android version. This Android dashboard system is made to make it easier to view information from the system as a whole on one page, using Android technology. The information generated on this android version of the dashboard is a summary of information from the web version of the dashboard system (Angelia Destriana et al., 2020). This can make it easier for management and operators to know the real-time warehouse conditions without having to open a web page, just with the Android version on one page, all information regarding outgoing and incoming inventory can be fulfilled.

The information generated on this android version of the dashboard system is the type of goods that go in and out of the warehouse, row capacity filled with goods, pie chart charts regarding pallet and row information, and palette identity detected by the RFID device which displays the ID number and color palette. This dashboard information can be displayed via a smartphone or smart TV connected to the internet. Anyone will find it easy to know the condition of the warehouse in real-time using the Warehouse Control Tower (WCT) system created.

The benefits of the Warehouse Control Tower (WCT) can be felt by the management of PT. YCH. This can be proven by comparing the operational activity time to consumer products. This is explained in Table 1.

**Table 1.** Warehouse activity efficiency

| Item | Unit | Before WCT | After WCT | Improvement | Improvement percentage (%) |
|---|---|---|---|---|---|
| Average time of receipt and inspection of goods (operator/day) | Minute | 88. 9 | 16.2 | -72.7 | 82 |
| Average time to prepare reports (per order) | Second | 10.0 | 1.0 | -9.0 | 90 |
| Average time to submit the reports (per order) | Second | 10.3 | 1.0 | -9.3 | 90 |

Table 1 shows a significant increase in efficiency in warehouse operation activities for one consumer product, a large efficiency occurs because the WCT system provides real-time conditions, the system records outgoing and incoming inventory in the warehouse (Lubis et al., 2022), whereas before using the WCT system, it still uses operators to record and input data into the warehouse management system (WMS). The biggest efficiency was in the process of the average time of receipt and inspection of goods, namely an increase of 82%, this happened because the WCT system recorded quickly with the system that had been created, compared to the initial conditions (Touray, 2021), there was a duplication of activity, namely, the operator put the goods into in the warehouse, checking the number of goods after entering, writing a record of incoming goods, then inputting goods data into the system.

Re-engineered conditions into an integrated system should be carried out continuously so that the benefits will be felt after days. The WCT system will always be operational as long as the electricity and network conditions in the company are very stable (Imdadullah et al., 2021).

**Table 2.** Efficiency with 3 scenarios

| Item | Total activity time | Actual condition (minute) | Using RFID | Using RFID and AI camera |
|---|---|---|---|---|
| CDC (Central Distribution Center) | Total time | 55 | 18 (68%) | 10 (82%) |
| | Waiting and transfer time | 40 | 10 (75%) | 5 (87.50%) |
| | Value added time | 15 | 8 (47%) | 5 (67%) |

Furthermore, the analysis was carried out with 3 (three) scenarios in outgoing and incoming inventory in the warehouse, starting from recording activities of incoming to outgoing inventory in the warehouse, by reducing the time to store goods in the warehouse (Wijaya, 2022). It can be seen in scenario 1 that the total time required between the waiting time process and the value-added time results in about 55 minutes. Scenario 2 was tried using the only RFID, the result is that there is an increase in efficiency with a total time of 68%. Then scenario 3 by using RFID and Artificial Intelligence (AI) vision cameras, there was an increase in efficiency reaching 82% of the actual process conditions (Maraveas, 2022).

## Conclusion

This study used the Value Stream Mapping (VSM) method to analyze the factors that lead to the excess processing time in outgoing and incoming inventory in the warehouse and applies to both lean methods and RFID technology and Vision Artificial Intelligence (AI) cameras to improve supply chain efficiency and effectiveness. The preliminary results in the case study with the improvement process at the CDC (Central Distribution Center) showed that the total uptime from the initial stage to the final stage of lean and RFID resulted in a savings of 68%. Savings can be further increased to 82% with the implementation of RFID and Vision Camera.

**Acknowledgments**
Thanks to all parties who have supported the implementation of this research. I hope this research can be useful.

**Author Contributions**
Conceptualization, data curation, formal analysis, methodology, writing-original draft, supervision M. validation, project administration, writing-review & editing: M. Tirtana Siregar

**Funding**
This research was independently funded by researchers.

**Conflicts of Interest**
The authors declare no conflict of interest.

## References

Angelia Destriana, Kristoko Dwi Hartomo, & Hanna Prillysca Chernovita. (2020). Visualization of Sales Field Activity Data Using Operations Dashboard for ArcGIS. *Jurnal RESTI (Rekayasa Sistem Dan Teknologi Informasi)*, *4*(4), 697–703. https://doi.org/10.29207/resti.v4i4.2096

Chan, S. W., Tasmin, R., Nor Aziati, A. H., Rasi, R. Z., Ismail, F. B., & Yaw, L. P. (2017). Factors Influencing the Effectiveness of Inventory Management in Manufacturing SMEs. *IOP Conference Series: Materials Science and Engineering*, *226*, 012024. https://doi.org/10.1088/1757-899X/226/1/012024

Dash, S., Shakyawar, S. K., Sharma, M., & Kaushik, S. (2019). Big data in healthcare: Management, analysis and future prospects. *Journal of Big Data*, *6*(1), 54. https://doi.org/10.1186/s40537-019-0217-0

Dwivedi, Y. K., Ismagilova, E., Hughes, D. L., Carlson, J., Filieri, R., Jacobson, J., Jain, V., Karjaluoto, H., Kefi, H., Krishen, A. S., Kumar, V., Rahman, M. M., Raman, R., Rauschnabel, P. A., Rowley, J., Salo, J., Tran, G. A., & Wang, Y. (2021). Setting the future of digital and social media marketing research: Perspectives and research propositions. *International Journal of Information Management*, *59*, 102168. https://doi.org/10.1016/j.ijinfomgt.2020.102168

Imdadullah, Alamri, B., Hossain, Md. A., & Asghar, M. S. J. (2021). Electric Power Network Interconnection: A Review on Current Status, Future Prospects and Research Direction. *Electronics*, *10*(17), 2179. https://doi.org/10.3390/electronics10172179

Ivanova, N. (2022). People-centred business continuity: A case for inclusive design. *Design Management Journal*, *17*(1), 30–48. https://doi.org/10.1111/dmj.12076

Jarašūnienė, A., Čižiūnienė, K., & Čereška, A. (2023). Research on Impact of IoT on Warehouse Management. *Sensors*, *23*(4), 2213. https://doi.org/10.3390/s23042213

Khan, M. G., Huda, N. U., & Zaman, U. K. U. (2022). Smart Warehouse Management System: Architecture, Real-Time Implementation and Prototype Design. *Machines*, *10*(2), 150. https://doi.org/10.3390/machines10020150

Kihel, Y. E. (2022). Digital Transition Methodology of a Warehouse in the Concept of Sustainable Development with an Industrial Case Study. *Sustainability*, *14*(22), 15282. https://doi.org/10.3390/su142215282

Kihel, Y. E., Kihel, A. E., & Embarki, S. (2022). Optimization of the Sustainable Distribution Supply Chain Using the Lean Value Stream Mapping 4.0 Tool: A Case Study of the Automotive Wiring Industry. *Processes*, *10*(9), 1671. https://doi.org/10.3390/pr10091671

Lubis, R. H., Nasution, F. A., & Juledi, A. P. (2022). Design and Build Inventory System using EOQ and ROP Methods (Case Study: CV. Ziefa Karya).

*Sinkron*, *7*(2), 729–736. https://doi.org/10.33395/sinkron.v7i2.11419

Maraveas, C. (2022). Incorporating Artificial Intelligence Technology in Smart Greenhouses: Current State of the Art. *Applied Sciences*, *13*(1), 14. https://doi.org/10.3390/app13010014

Mashayekhy, Y., Babaei, A., Yuan, X.-M., & Xue, A. (2022). Impact of Internet of Things (IoT) on Inventory Management: A Literature Survey. *Logistics*, *6*(2), 33. https://doi.org/10.3390/logistics6020033

Perifanis, N.-A., & Kitsios, F. (2023). Investigating the Influence of Artificial Intelligence on Business Value in the Digital Era of Strategy: A Literature Review. *Information*, *14*(2), 85. https://doi.org/10.3390/info14020085

Pohl, R., & Oehm, L. (2022). Towards a New Mindset for Interaction Design—Understanding Prerequisites for Successful Human–Machine Cooperation Using the Example of Food Production. *Machines*, *10*(12), 1182. https://doi.org/10.3390/machines10121182

Reinartz, W., Wiegand, N., & Imschloss, M. (2019). The impact of digital transformation on the retailing value chain. *International Journal of Research in Marketing*, *36*(3), 350–366. https://doi.org/10.1016/j.ijresmar.2018.12.002

S Pasaribu, J. (2021). Development of a Web Based Inventory Information System. *International Journal of Engineering, Science and Information Technology*, *1*(2), 24–31. https://doi.org/10.52088/ijesty.v1i2.51

Saderova, J., Rosova, A., Sofranko, M., & Kacmary, P. (2021). Example of Warehouse System Design Based on the Principle of Logistics. *Sustainability*, *13*(8), 4492. https://doi.org/10.3390/su13084492

Syahputri, K., Sari, R. M., Anizar, Rizkya, I., Leviza, J., & Siregar, I. (2018). Improving Assembly Line Balancing Using Moodie Young Methods on Dump Truck Production. *IOP Conference Series: Materials Science and Engineering*, *288*, 012090. https://doi.org/10.1088/1757-899X/288/1/012090

Tan, W. C., & Sidhu, M. S. (2022). Review of RFID and IoT integration in supply chain management. *Operations Research Perspectives*, *9*, 100229. https://doi.org/10.1016/j.orp.2022.100229

Tejesh, B. S. S., & Neeraja, S. (2018). Warehouse inventory Management System using IoT and opensource framework. *Alexandria Engineering Journal*, *57*(4), 3817–3823. https://doi.org/10.1016/j.aej.2018.02.003

Touray, R. (2021). A Review of Records Management in Organisations. *OALib*, *08*(12), 1–23. https://doi.org/10.4236/oalib.1108107

Tukamuhabwa, B., Mutebi, H., & Kyomuhendo, R. (2021). Competitive advantage in SMEs: Effect of supply chain management practices, logistics capabilities and logistics integration in a developing country. *Journal of Business and Socio-Economic Development*. https://doi.org/10.1108/JBSED-04-2021-0051

Wijaya, E. (2022). Layout Analysis of Goods Storage: Case Study Spare Part Warehouse Z Company. *Jurnal Rekayasa Sistem Industri*, *11*(1), 47–56. https://doi.org/10.26593/jrsi.v11i1.5139.47-56

Zhen, L., & Li, H. (2022). A literature review of smart warehouse operations management. *Frontiers of Engineering Management*, *9*(1), 31–55. https://doi.org/10.1007/s42524-021-0178-9