ISSN 2409-2665
Journal of Logistics, Informatics and Service Science
Vol. 11 (2024) No. 4, pp. 269-284
DOI:10.33168/JLISS.2024.0416

Can Barcodes Enhance Efficiency and Productivity in Oil Palm Companies? a Mixed Methods Study

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Abstract. This mixed methods study investigates the implementation of barcode technology and its influence on efficiency and productivity within oil palm plantation companies. Interviews with 37 employees and surveys of 237 workers examined barcode applications for inventory, production tracking, maintenance, and data capture. Qualitative results revealed barcodes improved time efficiency, reduced errors, and enhanced traceability. Quantitative findings showed a significant positive relationship between barcodes and efficiency, with efficiency strongly driving productivity. Cost efficiency, labor productivity, and supply chain efficiency emerged as key efficiency indicators in the oil palm context. The study provides novel empirical evidence that tailored barcode systems can increase operational efficiency and productivity in oil palm plantations based on local stakeholder perspectives. Further research can build on these context-specific insights by quantitatively modeling barcode adoption drivers and performance outcomes across plantations. Overall, the analysis offers practical implications for leveraging barcodes in agriculture while highlighting the need for qualitative insights when introducing new technologies

Keywords: Agribusiness Management, Barcode System, Efficiency, Oil Palm Company

1. Introduction

In manufacturing firms, the production process is a component of processes and costs. To maximize production results, businesses must certainly focus on resource efficiency and effectiveness. The debate over resource efficiency, particularly waste reduction and management, is a concern not just for researchers and eco-warriors, but also for corporate management. Management recognizes and understands the limitations of the current traditional system. If the system is integrated into managerial functions, its limits will become apparent quickly (Bait et al., 2020; Davis et al., 2016; Wilts et al., 2016).

Palm oil producers must forecast the amount of palm oil they will produce over a given time period. These forecasts are made so that a company's strategies and work plans can increase palm oil production and optimize cost allocation during the production process. Furthermore, applicating ICT is an excellent choice for assisting in the increase of oil palm production. An expert system for diagnosing oil palm plant diseases, a system for recommending oil palm seeds, a system for recommending areas for oil palm mill development (Annisa et al., 2020), and an information system for oil palm production are examples of ICT applications (Bakti, 2020).

In today's fast-paced business environment, C-suite executives and managers are constantly on the lookout for tools and technologies that can improve operational efficiency (Vass et al., 2018). From mobile devices to cloud-based software, there are numerous options available. Nevertheless, a technology that continually enhances efficiency and production in several businesses is the barcode label. When utilized in conjunction with an appropriate barcode scanning system, barcode labels have the potential to enhance data collecting procedures, resulting in consistent and streamlined workflows that have a positive influence on both the business and the entirety of the supply chain.

Barcode labels and scanning systems have a wide range of applications in many industries, contributing to enhanced operational efficiency through various means. In order to augment our understanding of how barcodes optimize processes and promote overall efficiency inside enterprises, some significant benefits are outlined below.

1. Barcodes Significantly Reduce Human Error

Manual data entry is prone to high occurrences of human error, which can have significant repercussions for companies, warehouses, and other facilities. Human errors can include inverting numbers, skipping lines, misreading information, or even having poor handwriting that others struggle to decipher. On average, people make an error in one out of every 300 characters they write, resulting in approximately 18 mistakes per hour.

In contrast, barcodes significantly mitigate the potential for human error, typically resulting in a near-complete eradication of such occurrences. Barcode scanning is characterized by its rapidity, dependability, and efficiency in comparison to the labor-intensive process of human data entry. When barcodes are scanned using suitable barcode scanners, their graphical representation is rapidly and precisely converted into a software application on a computer or portable device, thereby eliminating the inaccuracies typically encountered during human data entry.

Employees that make use of barcode systems demonstrate a higher level of efficiency compared to those who rely on manual data entry. Considering the possibility of human fallibility, the typical employee's capacity to generate precise numerical outputs throughout a span of one hour is around 432. In contrast, it has been observed that the mean duration for the identification and scanning of a barcode is roughly two seconds, resulting in a rate of 1,800 scans per hour. Research has demonstrated that the utilization of barcodes can lead to a substantial enhancement in productivity, with an estimated rise ranging from eight to 10 times.

In healthcare facilities, the adoption of barcode software and equipment as a replacement for human data entry has been found to effectively mitigate avoidable errors, which have been identified as a significant contributor to inpatient mortality rates. When effectively deployed, barcode scanning technologies have been found to contribute to the reduction of drug mistakes across many healthcare settings.

2. Barcodes Increase Efficiency to Conserve Resources, Save Money, and Improve Productivity

Barcode systems play a significant role in promoting resource conservation by effectively lowering the training time needed for new staff. Instead of necessitating comprehensive familiarity with a whole inventory or pricing system, staff utilizing handheld scanners for barcode scanning just necessitate a brief period of time to acquire proficiency in operating the scanner. As a result, there is a notable decrease in the duration of employee training, hence enhancing the efficiency and cost-effectiveness of the onboarding procedures.

Barcodes are also found to be advantageous in the context of inventory management, facilitating enterprises of various scales to enhance operational effectiveness and achieve cost savings. Barcodes are widely employed by businesses to facilitate cost reduction in the context of inventory management. This technology enables efficient tracking of various types of inventories, including products, raw materials, office supplies, and other things. Barcodes facilitate the identification, retrieval, and acquisition of pertinent information, including but not limited to cost, pricing, and supplier details, through a singular scanning process (Putra Arianto et al., 2021).

The implementation of barcode systems can provide significant benefits to companies facing challenges in reducing inventory carrying expenses. Barcodes facilitate the real-time updating of inventory for organizations, hence enabling prompt and exact changes that yield accurate inventory counts. Accurate inventory counts have a direct correlation with enhanced operational efficiency, as they enable organizations to generate more precise predictions for delivery times, better ascertain inventory costs, and identify suitable pricing strategies.

The integration of inventory control software and warehouse management software solutions, along with the use of barcode scanning software, results in enhanced capabilities. These solutions have the capability to provide reports that cater to the needs of managers. These reports aid in the identification of top-selling items, establishment of reorder points for certain items, and offer vital insights to facilitate improved decision-making processes.

The research on the implementation of barcodes in oil palm plantation companies is still limited, making this study a valuable contribution to the scientific community. The scarcity of research in this area highlights the significance and usefulness of the findings for various stakeholders involved in the oil palm industry.

By examining the application of barcodes in oil palm plantations, this research fills a crucial knowledge gap and expands the understanding of how barcode technology can be effectively utilized in the context of palm oil production. The findings of this study have the potential to offer valuable insights and practical recommendations to oil palm plantation companies, industry practitioners, policymakers, and researchers.

For oil palm plantation companies, the research outcomes can provide valuable guidance on the benefits and challenges associated with implementing barcode systems. The findings can help these companies make informed decisions about adopting and optimizing barcode technology in their operations (Zulham et al., 2023a). By understanding the potential improvements in inventory management, traceability, maintenance processes, workforce management, and safety compliance, companies can enhance their operational efficiency, reduce costs, and improve overall performance (Zulham et al., 2023b).

Industry practitioners, including managers, supervisors, and workers in oil palm plantation companies, can benefit from the research by gaining a deeper understanding of the advantages and implications of barcode implementation. They can learn about the potential productivity gains, error reduction, and improved data accuracy that can be achieved through the use of barcode systems. This knowledge can empower practitioners to effectively utilize barcode technology and contribute to the overall success of their organizations.

Policymakers involved in the regulation and governance of the oil palm industry can utilize the research findings to inform policy development and decision-making processes. Understanding the benefits and challenges of implementing barcodes in oil palm plantations can aid in formulating policies that promote sustainable practices, traceability, and quality control throughout the supply chain. Policymakers can also consider incentivizing the adoption of barcode systems to encourage industry-wide improvements in efficiency, productivity, and sustainability.

Despite the widespread use of barcode technology in various industries, there is a noticeable gap in research specific to its implementation in oil palm plantations. The existing scarcity of research highlights a crucial knowledge gap that this study seeks to address comprehensively. This research aims to contribute significantly to the scientific community by investigating and documenting the implications, challenges, and benefits of implementing barcode systems in the oil palm industry.

Finally, researchers and scholars in the field of agriculture, supply chain management, and technology can benefit from the research by expanding their knowledge base. The primary objective of this research is to examine the application of barcode technology in oil palm plantations and its potential impact on various aspects of palm oil production. The study contributes to the academic literature by offering empirical evidence and insights into the implementation of barcodes in oil palm plantation companies. This can stimulate further research and encourage more comprehensive investigations into the potential applications, limitations, and future developments of barcode technology in the palm oil industry (Zulham et al., 2022).

2. Literature Review

Barcodes are a widely used technology for encoding and representing data in a visual format (Melgar & Farias, 2019). They consist of a series of parallel lines, bars, or dots that vary in width and spacing. These patterns can be easily scanned and decoded using barcode scanners or mobile devices equipped with barcode scanning capabilities. Barcodes are commonly used in various industries, including retail, logistics, healthcare, manufacturing, and more, to streamline processes, enhance efficiency, and improve data accuracy.

2.1. Types of Barcodes

There are several types of barcodes, each with its own specific format and purpose. Some popular barcode symbologies include UPC (Universal Product Code), EAN (European Article Number), Code 39, Code 128, QR Code, and Data Matrix. Each symbology is designed for specific applications and can encode different types of information (Fröschle et al., 2009).

Barcodes can encode various types of information, such as product identifiers, serial numbers, prices, inventory data, website URLs, and more. The encoded data is represented by the varying widths and spacings of the bars or dots within the barcode.

Barcode scanners use a light source and a photosensitive receiver to capture the reflected light from the barcode. The scanner interprets the patterns of light and dark areas in the barcode to decode the encoded information. Modern barcode scanners can be handheld, fixed-mounted, or integrated into mobile devices, allowing for easy and efficient scanning in different environments.

2.2. Advantages of Barcodes: Barcodes Offer Numerous Benefits

Barcodes enable rapid and accurate data capture, significantly reducing manual data entry errors and improving efficiency in processes such as inventory management, product tracking, and point-of-sale transactions.

Barcodes eliminate the risk of human error associated with manual data entry. Scanning barcodes ensures accurate and reliable data capture, reducing the chances of mistakes and improving data quality (Kubáňová et al., 2022).

Barcodes enable automation of various processes, such as inventory control, order fulfillment, and asset tracking. They can be integrated with software systems to streamline operations, enhance productivity, and facilitate real-time data visibility (Marthiana & Jalinus, 2018).

Barcodes facilitate traceability by providing a unique identifier for each product or item. This enables companies to track and trace the movement of goods throughout the supply chain, ensuring transparency, quality control, and compliance with regulations (León-Duarte & ..., 2020).

Implementing barcode systems is generally cost-effective compared to alternative data capture methods. Barcode labels are inexpensive to produce, and barcode scanners are affordable and widely available (Kansanga et al., 2021).

Barcodes can be printed on various materials, such as labels, tags, or directly on products or packaging. Barcode printers use thermal transfer or direct thermal printing technologies to create high-quality, scannable barcodes (Chucks et al., 2020).

2.3. Applications of Barcodes

Manuscript Barcodes have become an indispensable tool across various industries, revolutionizing processes and enhancing efficiency. In retail, barcodes streamline product identification, pricing, and point-of-sale transactions, enabling seamless checkout experiences. In logistics and supply chain, barcodes facilitate accurate shipment tracking, efficient inventory management, and optimized warehouse operations. The healthcare sector benefits from barcodes for patient identification, medication tracking, and inventory control, ensuring patient safety and streamlined healthcare operations. Manufacturing industries leverage barcodes for asset tracking, quality control, and improved production line efficiency. Document management sees improved organization and retrieval with barcodes, while ticketing and access control industries rely on barcodes for secure entry and efficient validation. These applications showcase the versatility and effectiveness of barcodes, making them a valuable asset in enhancing productivity and operational processes across diverse sectors.

In each of these industries, barcodes play a crucial role in streamlining processes, enhancing efficiency, and improving data accuracy. Their versatility, ease of use, and widespread adoption have made barcodes an essential tool in various sectors, contributing to increased productivity and better overall management.

In summary, barcodes are a versatile and widely adopted technology for encoding and representing data in a visual format. They offer numerous advantages, including efficiency, data accuracy, automation, traceability,

The user has the option to select and modify four levels of correction based on the operating environment. Enhancing the correction rate has the potential to augment the system's ability to handle errors, but it also leads to an increase in the data size within the Code System (Kella Price, 2013).

2.4. Synthesis of Sources

While barcodes have demonstrated their effectiveness across various industries, it is essential to delve into empirical studies that specifically apply barcode technology in the context of agriculture, with a particular focus on oil palm plantations. Unfortunately, the literature in this specific domain is limited, emphasizing the need for further exploration and research.

A study by Istiqomah et al. (2020) conducted empirical research to assess the implementation of barcode systems in warehouse. The research aimed to evaluate the impact of barcode technology on inventory management, traceability, maintenance processes, workforce management, and safety compliance within the unique operational environment of oil palm cultivation. Findings from this study could shed light on the practical challenges and benefits of adopting barcodes in a sector with distinct characteristics and requirements.

The literature reviewed thus far presents a comprehensive overview of barcodes, their types, advantages, and applications across industries. However, the transition between topics could benefit from smoother integration. Additionally, the sources emphasize the general benefits of barcodes but lack specific discussions on their empirical applications in agriculture, particularly in oil palm plantations.

The synthesis of sources highlights the need for a more nuanced exploration of barcode technology within the unique challenges and opportunities presented by the agriculture sector. By bridging the gap between general discussions on barcodes and their specific implementation in oil palm cultivation, future research can contribute to a more holistic understanding of the technology's impact on agricultural practices.

3. Method System

Please acknowledge collaborators or anyone who has helped with the paper at the end of the text. The research employed a mixed methods approach to gather comprehensive data and insights on data and information quality management in a palm oil processing factory in Indonesia. By combining qualitative and quantitative methods, the researchers aimed to obtain a more holistic understanding of the topic.

3.1. Qualitative Component

The qualitative component of the study involved direct interviews with 37 respondents who held various roles in data and information quality management in the factory. The interviews were conducted using a semi-structured approach, which allowed the researchers to ask open-ended questions and elicit detailed responses from the participants. This qualitative data collection method enabled the researchers to capture the perspectives, experiences, and insights of the respondents regarding data and information quality management practices in the factory. The open-ended nature of the interviews provided flexibility for participants to provide in-depth information and share their opinions freely.

Qualitative methods, such as interviews, allow researchers to delve deeply into the experiences, perspectives, and insights of participants. This richness is especially valuable when exploring nuanced topics like data and information quality management, where diverse viewpoints and contextual understanding are crucial (Parry et al., 2014).

The semi-structured approach in qualitative interviews provides flexibility. Researchers can adapt their questions based on the responses, allowing for a more organic and participant-driven exploration. This adaptability is vital in addressing unforeseen insights that may emerge during the interviews.

3.2. Quantitative Component

In addition to the qualitative interviews, the study also incorporated quantitative data collection methods, Specifically, through observations and direct interviews with 237 respondents using a structured interview technique assisted by a questionnaire. The researchers employed observations of the usage of the information system (SI) in the factory. By observing how the SI was utilized in real-time operations, the researchers could gather objective data on its actual implementation and effectiveness. This quantitative data collection method allowed for the measurement of specific metrics, such as system usage patterns, response times, or error rates. The observations provided valuable insights into the practical aspects of data and information quality management in the factory. The quantitative component of this study involved direct interviews with 237 respondents. Testing hypotheses about direct and indirect relationships between variables by combining regression and path analysis. The Partial Least Squares (PLS) analytic approach can be employed to integrate regression and path analysis, which are both intricate techniques. Please provide a comprehensive description of the relationship between the dependent and independent variables within a single

The analysis SMART PLS 4 program is one of the software applications that may be utilized for Partial Least Squares (PLS) analysis. In order to conduct an analysis, it is important for the program to possess a comprehensive description of all the relationships that have been established within the theoretical model. The initial stage involves evaluating the external reflective indicator model. The assessment of the outer reflective indicator model involves three criteria: Convergent validity, Composite reliability, and Discriminant validity. Once all the necessary criteria have been met, the subsequent phase involves evaluating the inner model. R-squared, Q-squared, GoF, and F-squared are used for this analysis. The significance of the dependent latent variable is evaluated using R-squared. Q-square is used to assess the quality of the model-generated observation value. In order to determine if the structural model is sound, researchers employ a statistic called the "goodness of fit" (GoF) (Hair et al., 2017).

3.3. Document Tracing

Furthermore, the researchers traced relevant documents related to factory operations as an additional source of data. These documents could include records, reports, or other written materials that shed light on the data and information quality management practices in the factory. By analyzing these documents, the researchers could gain a deeper understanding of the formal procedures, policies, and guidelines that govern data and information quality in the factory.

3.4. Integration of Data

Once the qualitative interviews, quantitative observations, and document tracing were completed, the researchers integrated the data from both components. This integration involved comparing and contrasting the qualitative and quantitative findings to identify patterns, discrepancies, or convergence. By combining the two types of data, the researchers could enrich their understanding of data and information quality management in the factory and develop a more comprehensive analysis of the topic.

By employing a mixed methods approach, the researchers were able to gather rich qualitative insights from the interviews, objective quantitative data from the observations, and contextual information from the document tracing. This integration of data sources allowed for a more robust analysis and interpretation of the findings, enhancing the overall validity and reliability of the research. The mixed methods approach provided a comprehensive understanding of data and information quality management in the palm oil processing factory, taking into account both subjective perspectives and objective measurements.

3.5. Location and Time

In selecting the research location was done purposively refer to the affordability of respondents and location of research. The time of research was carried out for 3 (three) months from April to June 2022.

3.6. Sampling Method

All estates at PT Langkat Nurasantara Kepong which consisted of Padang Brahrang, Bekiun, Tanjung Keliling, Marike, Bukit Lawang, Gohor Lama, Tanjung Beringin, Basilam estates were the population in this study. The sample of this research was chosen by 4 estates: Basilam, Bekium, Padang Brahrang, and Gohor Lama Estates. The total number of employees in the 4 estates is 1,870 people. The total samples is 237 people for quantitative survey and 37 respondent for qualitative interviews.

4. Result and Discussion

4.1. Qualitative Survey

Qualitative survey in the research on barcode technology and efficiency involves gathering in-depth, subjective insights and perspectives from participants. It aims to understand the experiences, perceptions, and attitudes of individuals related to the implementation of barcode technology in improving efficiency.

4.1.1 Efficiency

Based on open-ended interviews with respondents, several indicators of efficiency in palm oil plantation companies were identified. These indicators assess various aspects of the company's operations and performance. Here are some variables or indicators of efficiency in an oil palm plantation company:

1. Labor Productivity. Labor productivity measures the output or yield achieved per unit of labor input, such as the number of palm fruit bunches harvested or processed per worker. It reflects the efficiency of human resources in contributing to production.
2. Time Efficiency. Time efficiency refers to the effective utilization of time in carrying out various activities within the oil palm plantation company. It involves minimizing idle time, reducing delays, and optimizing the timing of tasks to ensure smooth operations and maximize productivity. Time efficiency can be measured by factors such as the time taken to complete specific activities, the cycle time for different processes, or the overall time required to achieve certain production targets.
3. Energy Efficiency. Energy efficiency measures the amount of energy consumed per unit of output, such as palm oil produced or processed. It assesses the efficiency of energy usage in various processes, including milling, refining, or biomass utilization.
4. Water Usage Efficiency. Water usage efficiency measures the amount of water consumed per unit of output, such as palm fruit bunches or palm oil. It assesses the effectiveness of water management practices, irrigation systems, and water conservation measures.
5. Machinery Utilization. This indicator evaluates the utilization and efficiency of machinery and equipment used in palm oil production, such as harvesters, tractors, or processing machinery. It assesses factors such as equipment uptime, utilization rates, and maintenance effectiveness.
6. Cost Efficiency. Cost efficiency measures the ability to achieve desired outputs while minimizing costs. It assesses the cost per unit of output, such as the cost of producing a ton of palm oil or palm fruit bunches. Factors such as labor costs, material costs, and operational expenses are considered in this indicator.
7. Supply Chain Efficiency. Supply chain efficiency evaluates the effectiveness of the overall supply chain management, including processes such as procurement, transportation, and distribution. It measures factors such as lead times, inventory turnover, and delivery reliability.
8. Environmental Sustainability. Environmental sustainability indicators assess the company's adherence to sustainable practices, such as land conservation, biodiversity preservation, and responsible water and chemical usage. It reflects the company's commitment to sustainable and eco-friendly operations.
9. Compliance with Regulatory Standards. This indicator assesses the company's compliance with regulatory requirements, certifications, and industry standards related to environmental, labor, and quality aspects. It reflects the company's commitment to meeting legal and industry obligations.

These indicators provide a comprehensive assessment of efficiency in an oil palm plantation company. By monitoring and improving these variables, companies can identify areas for optimization, enhance performance, and achieve higher levels of efficiency.

4.1.2 Barcode Technology

Barcode technology can be implemented in various aspects of palm oil plantation companies. Here are the key aspects where barcode technology can be applied:

1. Inventory Management: Barcode systems can be utilized for efficient tracking and management of inventory. Each item, such as palm fruit bunches, fertilizers, pesticides, or equipment, can be labeled with a unique barcode. By scanning these barcodes during receipt, storage, and dispatch processes, the company can accurately record and track inventory levels, locations, and movements (Oldland et al., 2015).
2. Harvesting and Production: Barcodes can be used to label palm fruit bunches during harvesting. Scanning the barcodes at various stages, such as collection, weighing, and processing, enables accurate tracking of the yield, origin, and processing details of each batch. This facilitates traceability, quality control, and production optimization (Yang & Zhao, 2014).

3. Asset Tracking: Barcode labels and scanning systems can be employed to track and manage assets in the plantation, including vehicles, machinery, tools, and equipment. Each asset can have a unique barcode, allowing easy identification, tracking, and maintenance scheduling. This streamlines asset management, reduces loss or theft, and optimizes asset utilization (Xin et al., 2021).
4. Supply Chain and Logistics: Barcodes can be used to label and track palm oil products throughout the supply chain. Each product can be assigned a unique barcode that carries relevant information such as batch details, packaging dates, and certifications. Scanning these barcodes during shipping, receiving, and storage processes ensures accurate inventory management and efficient supply chain operations (Kang et al., 2018).
5. Maintenance and Repair: Barcode technology can be applied to track maintenance and repair activities for equipment and machinery. By labeling maintenance parts and creating work order barcodes, the company can streamline maintenance processes, track equipment downtime, and manage spare parts inventory more efficiently (Mukopi & Iravo, 2015).
6. Data Capture and Analysis: Barcode systems facilitate accurate and efficient data capture. Scanning barcodes enables real-time recording of information related to inventory, production, assets, and other operational processes. The collected data can be analyzed to identify trends, optimize workflows, and make data-driven decisions to improve overall efficiency (Ampatzidis et al., 2011).
7. Quality Control and Traceability: Barcode labels enable accurate and reliable traceability of palm oil products. By scanning barcodes at different stages, from plantation to processing and distribution, the company can track the origin, processing details, and quality metrics of each batch. This enhances quality control, supports compliance with sustainability standards, and enables prompt issue identification and mitigation (Liu et al., 2018).

Implementing barcode systems in these aspects of palm oil plantation companies improves efficiency, accuracy, and productivity. It streamlines processes, optimizes inventory management, enhances traceability, and facilitates data-driven decision-making, ultimately leading to better operational performance and profitability.

By implementing barcode technology, oil palm companies can improve operational efficiency, reduce errors, enhance inventory management, optimize asset utilization, and ensure better traceability and quality control throughout the production process (Miralam, 2017).

Incorporating barcode labels and scanning systems into the operations of an oil palm company can provide numerous benefits, including improved inventory management, enhanced traceability, streamlined maintenance processes, optimized harvesting practices, efficient workforce management, and enhanced safety compliance. By leveraging barcode technology, oil palm companies can increase operational efficiency, reduce costs, and meet the growing demands for sustainability and responsible supply chain management in the palm oil industry.

The implementation of the barcode system at the study location has occurred within the past five years. The installation of the system has garnered satisfaction from numerous stakeholders, mostly owing to its positive impact on operational efficiency and enhanced productivity. However, it is important to acknowledge that there exists a subset of individuals who express discontentment with the system's influence on employee income. It is possible that this concern may not have been well communicated to the organization. Despite the potential for the barcode system to enhance performance in all palm oil enterprises, it is important to consider its applicability as a management tool in the context of agribusiness. The efficacy of the barcode system has also been examined in numerous research pertaining to material production. For instance, a study conducted by Ong et al., (2019) demonstrates that the use of a barcode system can yield cost savings by reducing the need for physical paper procurement. Additionally, this technological intervention has been found to have a substantial positive impact on employee performance in the execution of routine tasks. According to Misron et al., (2017), it is crucial to harvest fresh fruit bunches in oil palm when they have reached their ideal level of ripeness.

The implementation of the Barcode system results in the rejection of immature produce. The implementation of a barcode system facilitates enterprises in the production of high-quality certified sustainable palm oil (CPO).

Research by Istiqomah et al., (2020) shows that the application of barcodes in warehouses can minimize errors in receiving goods, speed up the receipt of goods, determine storage locations, minimize errors in storing goods, minimize retrieval of wrong goods by pickers, speed up pickers in retrieving goods, aid in figuring out if there's a deficiency or surplus of goods if the shipment can go ahead as planned if the goods are of sufficient quality if too much paper is being used if human error is being introduced and if the delivery manifests are being issued quickly enough. Barcodes can also be used to speed up the distribution of reports containing information or data.

4.2. Quantitative Survey

Quantitative survey in the research on barcode technology and efficiency involves collecting structured and measurable data from a large number of participants. It aims to quantify the impact of barcode technology on efficiency in a systematic and statistically valid manner.

4.2.1 Indicator of Variable (Outer Loading Value)

Outer loading values measure how well each indicator reflects or "loads" the latent construct it is supposed to measure in Partial Least Squares (PLS) analysis. It indicates the strength of the relationship between a latent variable and its observed indicators. In practice, researchers often make decisions based on a combination of outer loading values and theoretical considerations. High outer loading values indicate that an indicator effectively represents the latent construct, while low values may signal issues with indicator or construct validity. Outer loading values serve as indicators of the quality of indicators in a PLS model, guiding researchers in evaluating and interpreting the results of path analysis. Specifically, in the context of efficiency and barcode technology analysis, we can examine the loading factor values for the efficiency and barcode technology variable in Table 1. Meanwhile, for the productivity indicator, secondary data on yield per hectare is utilized as the sole indicator, and therefore, outer loading values are not displayed in the table.

Table 1. Outer Loading Value

Indicator of Barcode Technology	Outer Loading	Indicator of Efficiency	Outer Loading
Analysis	0.910	Compliance	0.564
Asset Tracking	0.882	Cost Efficiency	0.849
Data Capture	0.854	Energy Efficiency	0.653
Harvesting	0.917	Environmental Sustainability	0.556
Inventory Management	0.938	Labor Productivity	0.776
Logistic	0.759	Machinery Utilization	0.757
Maintenance	0.878	Supply Chain Efficiency	0.781
Production	0.832	Time Efficiency	0.818
Quality Control	0.914	Water Usage Efficiency	-0.601
Repair	0.866		
Supply Chain	0.846		
Tracebility	0.732		

Quantitative survey in the research on barcode technology and efficiency involves collecting structured and measurable data from a large number of participants. It aims to quantify the impact of barcode technology on efficiency in a systematic and statistically valid based on the criterion for outer loading, values below 0.700 are considered weak and may not contribute significantly to the latent construct (Hair et al., 2017).

Indicator of Efficiency Variable

1. Compliance: This indicator has a moderate positive outer loading of 0.564, which suggests a relationship with the latent construct of efficiency. However, it does not meet the criterion of 0.700 or higher. Therefore, the relationship between compliance and efficiency may be relatively weaker compared to other indicators.
2. Cost Efficiency: With a high outer loading of 0.849, cost efficiency demonstrates a strong positive relationship with the efficiency construct. This indicates that effectively managing costs and minimizing expenses significantly contributes to overall efficiency in palm oil plantation companies.
3. Energy Efficiency: The outer loading of 0.653 indicates a moderate positive relationship between energy efficiency and efficiency. However, it falls below the criterion of 0.700 and may have a relatively weaker impact on overall efficiency.
4. Environmental Sustainability: This indicator shows a moderate positive outer loading of 0.556, which is below the criterion of 0.700. While it suggests a relationship between environmental sustainability and efficiency, the strength of this relationship may be relatively weaker compared to other indicators.
5. Labor Productivity: With a high outer loading of 0.776, labor productivity demonstrates a strong positive relationship with efficiency. This indicates that maximizing output per unit of labor input significantly enhances overall efficiency in palm oil plantation operations.
6. Machinery Utilization: The outer loading of 0.757 suggests a strong positive relationship between machinery utilization and efficiency. Effectively utilizing machinery and equipment contributes to improved overall efficiency in the palm oil industry.
7. Supply Chain Efficiency: With a high outer loading of 0.781, supply chain efficiency demonstrates a strong positive relationship with the efficiency construct. Efficient management of the supply chain, including procurement, logistics, and distribution, positively impacts overall efficiency.
8. Time Efficiency: The outer loading of 0.818 indicates a strong positive relationship between time efficiency and efficiency. Minimizing delays, optimizing task scheduling, and maximizing productivity within a given timeframe significantly contribute to overall efficiency.
9. Water Usage Efficiency.

Based on the revised explanations, indicators such as cost efficiency, labor productivity, machinery utilization, supply chain efficiency, time efficiency, and yield per hectare have stronger and more significant relationships with the efficiency construct in palm oil plantation companies.

Compliance, Energy Efficiency, and Environmental Sustainability are not able to serve as measures of efficiency in oil palm plantation companies due to the analysis of data indicating that these three variables do not meet the criteria for outer loading values. This confirms the findings of the qualitative survey, suggesting that not everything obtained qualitatively can be accepted quantitatively.

Indicator of Barcode Technology Variable

1. Analysis: This indicator exhibits a very high outer loading of 0.910, indicating a robust and positive relationship with the latent construct of Barcode Technology. This suggests that effective analysis processes significantly contribute to the overall implementation of barcode technology in palm oil plantation companies.
2. Asset Tracking: With a high outer loading of 0.882, asset tracking demonstrates a strong positive relationship with the Barcode Technology construct. This implies that efficient tracking of assets is a key component of successful barcode technology implementation in the palm oil industry.
3. Data Capture: The outer loading of 0.854 indicates a strong positive relationship between data capture and Barcode Technology. Effective data capture processes significantly contribute to the successful utilization of barcode technology in palm oil plantation operations.

4. Harvesting: This indicator shows a very high outer loading of 0.917, suggesting a robust and positive relationship between harvesting processes and Barcode Technology. Efficient barcode implementation plays a crucial role in optimizing harvesting activities in the palm oil industry.
5. Inventory Management: With an extremely high outer loading of 0.938, inventory management demonstrates an exceptionally strong positive relationship with the Barcode Technology construct. This highlights the critical role of barcode technology in enhancing inventory management practices in palm oil plantation companies.
6. Logistic: The outer loading of 0.759 indicates a positive relationship between logistic processes and Barcode Technology. While the relationship is positive, it falls slightly below the criterion of 0.800 and may have a relatively strong but not exceptionally robust impact on barcode technology implementation.
7. Maintenance: With a high outer loading of 0.878, maintenance demonstrates a strong positive relationship with the Barcode Technology construct. Efficient maintenance practices significantly contribute to the successful implementation of barcode technology in the palm oil industry.
8. Production: The outer loading of 0.832 suggests a strong positive relationship between production processes and Barcode Technology. Effective barcode implementation contributes to streamlined production activities in palm oil plantation operations.
9. Quality Control: This indicator exhibits a very high outer loading of 0.914, indicating a robust and positive relationship between quality control processes and Barcode Technology. Barcode technology significantly enhances quality control practices in the palm oil industry.
10. Repair: With a high outer loading of 0.866, repair processes demonstrate a strong positive relationship with the Barcode Technology construct. Efficient repair practices contribute to the overall success of barcode technology implementation in palm oil plantation companies.
11. Supply Chain: The outer loading of 0.846 indicates a positive relationship between supply chain processes and Barcode Technology. While the relationship is positive, it falls slightly below the criterion of 0.900 and may have a relatively strong but not exceptionally robust impact on barcode technology implementation.
12. Traceability: This indicator shows an outer loading of 0.732, indicating a positive relationship between traceability and Barcode Technology. While the relationship is positive, it falls slightly below the criterion of 0.800 and may have a relatively strong but not exceptionally robust impact on barcode technology implementation.

The barcode technology indicators, especially inventory management, asset tracking, harvesting, quality control, and maintenance, exhibit strong and significant relationships with the Barcode Technology construct in palm oil plantation companies. Logistic, supply chain, and traceability also show positive relationships, but they may have a relatively strong but not exceptionally robust impact on barcode technology implementation.

Table 2. Reliability and Validity of Data

Variable Independent	Composite reliability (rho_c)	Average variance extracted (AVE)	R-square
Barcode Technology	0.972	0.744	0.902
Efficiency	0.909	0.666	0.433

Based on table 2, the high composite reliability values and acceptable AVE values for both Barcode Technology and Efficiency indicate reliable and convergent measurement models. The R-square values suggest that the indicators effectively explain a substantial portion of the variability in the respective constructs (Hair et al., 2017).

4.2.2 The Impact of Barcodes on Efficiency and Productivity

Quantitative testing can use a t-table, it is 1.96 for alpha 5%. When the result is t-table < t-value means the hypothesis is accepted, and it is rejected if t-table > t-value. Table 1 shows the test result.

Table 3 Quantitative Testing

Path	std beta	mean	std error	t-value	p-value	effect	description
Barcode -> Efficiency	0.680	0.682	0.035	19.645	0.000	direct	significant
Barcode -> Productivity	0.030	0.029	0.033	0.906	0.365	direct	not sign.
Efficiency -> Productivity	0.924	0.924	0.024	39.048	0.000	direct	Significant
Barcode -> Productivity	0.628	0.630	0.034	18.252	0.000	indirect	significant

Note: *t(0.05): 1.96

The relationship between barcode technology and efficiency is significant and positive. The standard beta coefficient of 0.680 indicates a strong positive influence of barcode technology on efficiency. The low p-value suggests that the relationship is highly statistically significant. Efficient management of inventory and harvesting processes is facilitated by the Barcode System, contributing to sustainability in resource utilization (Istiqomah et al., 2020; Zulham et al., 2022). This is corroborated by Miralam (2017) study, wherein it is asserted that the integration of barcode technology enables the enhancement of operational efficiency, error reduction, improved inventory control, optimized asset utilization, and the establishment of superior traceability and quality management throughout the entire production cycle in oil palm enterprises (Dhanaraju et al., 2022).

The relationship between barcode technology and productivity is not significant. The standard beta coefficient of 0.030 indicates a weak positive influence, but the high p-value suggests that the relationship is not statistically significant. This lack of significance may be attributed to the possibility that the impact of barcode technology on productivity is mediated by other variables not included in the current analysis. Barcode technology might exert its influence on productivity through intermediary factors that were not directly examined in this study. Therefore, the absence of a direct significant relationship could be indicative of the need to explore and incorporate potential mediating variables to better understand the nuanced dynamics between barcode technology and productivity in the context under investigation.

The relationship between efficiency and productivity is significant and positive. The standard beta coefficient of 0.924 indicates a strong positive influence of efficiency on productivity. The low p-value suggests that the relationship is highly statistically significant. This finding underscores the critical role of efficiency in driving and enhancing overall productivity levels within the examined context. The results suggest that improvements in efficiency are directly associated with notable positive changes in productivity, highlighting the importance of focusing on efficiency-enhancing strategies to achieve significant gains in overall output (Ariyanto et al., 2020).

The indirect effect of barcode technology on productivity through efficiency is significant and positive. The standard beta coefficient of 0.628 indicates a strong positive indirect influence of barcode technology on productivity through its impact on efficiency. The low p-value suggests that the indirect relationship is highly statistically significant. This implies that the positive influence of barcode technology on productivity is, in part, explained by its ability to enhance efficiency within the operational processes. These findings highlight the mediating role of efficiency in the relationship between barcode technology and productivity, emphasizing the importance of efficiency improvements as a mechanism through which barcode technology contributes to enhanced overall productivity levels (Santoso & Siagian, 2019).

The results highlight the importance of adopting barcode technology in the oil palm industry. It can lead to increased efficiency, which, in turn, positively affects productivity. Stakeholders should consider investing in barcode systems, training employees, and integrating barcode technology into their operations to improve overall performance (Zulham et al., 2023).

5. Conclusion

This study offers important empirical contributions regarding barcode implementation in oil palm companies, addressing gaps in literature on agricultural technology adoption. The inquiry yielded critical perspectives from local employees, substantiating barcodes' benefits for efficiency, traceability, and productivity when applied to context-relevant operations like harvesting. The investigation methods revealed key differences between qualitative enthusiasm and quantified efficiency constructs. While qualitative data illuminated barcode advantages, quantitative findings evidenced the specific performance outcomes in oil palm's unique setting. These discoveries carry practical implications for plantation managers seeking to strategically implement barcodes for maximum efficiency gains. More broadly, the analysis highlights the value of mixed methods for obtaining a robust, multidimensional understanding of technological impacts within localized industries. Although limitations exist, the study provides a methodological blueprint and evidentiary base for driving optimal agricultural innovation through context-attuned application of emerging technologies.

Based on the findings and the significance of barcode implementation in oil palm companies, the following recommendations are proposed:

1. Employee Engagement and Training. To address concerns related to the impact on employees' income, oil palm companies should provide comprehensive training programs and engage employees in the implementation process. This will help them understand the benefits of barcode technology and how it can improve overall operational efficiency.
2. Transparent Communication. Clear and transparent communication is vital to ensure that employees fully understand the purpose and benefits of the barcode system. Companies should provide regular updates and address any concerns or misconceptions regarding the system's impact on employee compensation.
3. Continuous Improvement. Oil palm companies should continuously monitor and evaluate the effectiveness of the barcode system. This includes regularly reviewing and optimizing the system's performance, addressing any technical issues, and seeking feedback from employees and other stakeholders to identify areas for improvement.
4. Collaboration and Knowledge Sharing. Companies within the oil palm industry should collaborate and share best practices related to barcode implementation. This can be achieved through industry forums, conferences, or partnerships, allowing companies to learn from each other's experiences and optimize their use of barcode technology.
5. Research and Development. Continued research and development in barcode technology specifically tailored to the unique needs of the oil palm industry should be encouraged. This includes exploring innovative applications, integrating barcode systems with other technologies such as Internet of Things (IoT), and identifying potential areas where barcode technology can further enhance operational efficiency and sustainability practices.

By implementing these recommendations, oil palm companies can maximize the benefits of barcode technology while addressing any potential challenges or concerns, ultimately improving their overall operational efficiency, productivity, and sustainability practices in the palm oil industry

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