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IMPORTANCE OF SMART MANUFACTURING TECHNOLOGY IN BERNAS FACTORY: BERNAS SUNGAI LIMAU, KEDAH

KEPENTINGAN PEMBUATAN PINTAR DI KILANG BERNAS: KILANG BERNAS SUNGAI LIMAU, KEDAH

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Abstract: *This study looks at the importance of smart manufacturing technology at the BERNAS Sungai Limau factory to meet the full needs of Malaysians in terms of demand rice which is 2.69 million tons per year. This study was conducted on 10 BERNAS Sungai Limau factory employees using a qualitative method where data collection and data interpretation are done in depth before being analyzed to the conclusion of the study. With the existence of artificial intelligence, Iot and cloud computing in smart manufacturing it can open new opportunities for innovation to various sectors. The results of the study found that there are four importance of smart manufacturing to BERNAS factory in Sungai Limau, Kedah namely time effective, increase productivity, maintaining the sustainability and increase rural development. This study was conducted at the BERNAS Sungai Limau factory only, where it involved a very limited study sample. This causes a lack of diversity in research findings. Policy implications in the context of the three policies involved, namely the National Agro-Food Policy 2021-2030, the Rural Development Policy 2021-2020 and the Science, Technology and Industry Policy 2021-2020.*

Keywords: *Smart Manufacturing, BERNAS, Innovation, Rice Factory*

Abstract: *Kajian ini melihat kepentingan teknologi pembuatan pintar di kilang BERNAS Sungai Limau bagi memenuhi keperluan penuh rakyat Malaysia dari segi permintaan beras iaitu 2.69 juta tan setahun. Kajian ini dijalankan ke atas 10 orang pekerja kilang BERNAS Sungai Limau menggunakan kaedah kualitatif di mana pengumpulan data dan interpretasi data dilakukan secara mendalam sebelum dianalisis sehingga rumusan kajian. Dengan kewujudan kecerdasan buatan, Iot dan pengkomputeran awan dalam pembuatan pintar ia boleh membuka peluang baharu untuk inovasi kepada pelbagai sektor. Hasil kajian mendapati terdapat empat kepentingan pembuatan pintar kepada kilang BERNAS di Sungai Limau, Kedah iaitu berkesan masa, meningkatkan produktiviti, mengekalkan kelestarian dan meningkatkan pembangunan luar bandar. Kajian ini dijalankan di kilang BERNAS Sungai Limau sahaja yang melibatkan sampel kajian yang sangat terhad. Ini menyebabkan kekurangan kepelbagaian dalam dapatan*

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penyelidikan. Implikasi dasar dalam konteks tiga dasar terbabit iaitu Dasar Agromakanan Negara 2021-2030, Dasar Pembangunan Luar Bandar 2021-2020 dan Dasar Sains, Teknologi dan Industri 2021-2020.

Kata kunci: *Pembuatan Pintar, BERNAS, Inovasi, Kilang Beras*

Introduction

The rice manufacturing industry is a cornerstone of Malaysia's agricultural sector which playing a vital role in ensuring the country's food security. However, the industry faces significant challenges due to the reliance on traditional rice milling methods in which are often inefficient and unable to meet the growing demands of the market. These challenges are exacerbated by outdated machinery, labor-intensive processes and inconsistent quality control practices. As Malaysia's population grows, the need for more efficient and sustainable rice production systems becomes increasingly urgent. In light of these challenges, smart manufacturing technology offers a promising solution. Smart manufacturing integrates digital technologies such as automation, real-time data analytics, the Internet of Things (IoT) and artificial intelligence (AI) to optimize production processes, reduce costs and improve product quality. While this approach has already been successfully implemented across various industries, its adoption in the rice sector particularly in Malaysia remains underexplored. In particular, BERNAS is one of the largest rice processing companies in the country has yet to fully integrate these technologies into its operations. There is a lack of empirical research examining the implementation of smart manufacturing in this sector as well as its potential impact on operational efficiency and workforce adaptability. The extent to which these technologies can address the existing inefficiencies and improve rice production processes in Malaysia remains an open question.

This study focuses on the BERNAS factory in Sungai Limau, Kedah which despite being one of the largest rice processing facilities in the region, has not yet fully embraced smart manufacturing technologies. The factory's operations still rely heavily on traditional methods which have led to inefficiencies and challenges in meeting increasing production demands. This study aims to highlight the specific challenges faced by the current manufacturing methods, assess the potential benefits of smart technologies and evaluate the readiness of the workforce in adopting these advancements. By addressing these gaps, this study contributes to a better understanding of how Malaysia's rice manufacturing sector can transition towards a more efficient and technologically advanced production system. Understanding how the adoption of smart manufacturing could address these challenges is crucial for the future of Malaysia's rice industry. Therefore, this study aims to fill this knowledge gap by examining the importance of smart manufacturing technology at the BERNAS factory in Sungai Limau, Kedah. The objectives of the study are as follows:

1. Identify the effectiveness of current technology
2. Assess the importance of smart manufacturing at the BERNAS Sungai Limau factory

Literature Review

There are five points will be discussed in literature review which are Overview of Smart Manufacturing, Smart Manufacturing in The Global Food Industry, The Adoption of Smart Manufacturing in Malaysia's Rice Industry, Key Challenges in Implementing Smart Manufacturing in Malaysia's Rice Sector and Research Gap

Overview of Smart Manufacturing

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Smart manufacturing is an advanced approach that integrates digital technologies to enhance productivity, efficiency and flexibility across industries. It leverages interconnected systems, data analytics and automation to streamline operations, reduce costs and improve product quality (Glowniak, 1998; Phuyal et al., 2020; Terry et al., 2020). Technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and Augmented Reality (AR) enable real-time decision-making, optimizing operations and improving production capabilities (Akhigbe et al., 2021; Huang, 2022). Globally, industries in sectors such as automotive, electronics and food processing have successfully incorporated smart technologies to reduce downtime, improve maintenance efficiency, and enhance product quality (Bani et al., 2023; Barrett & Rose, 2022; Kusiak, 2023). For instance, in the food processing industry, AI-driven predictive maintenance has been used to forecast equipment failures before they occur, reducing downtime and improving overall operational efficiency (Gnoni et al., 2020). Augmented reality tools further enhance workforce productivity by offering real-time, interactive support for equipment maintenance and production processes, minimizing human error and improving the quality of output (Bun et al., 2021; Clough & Stammers, 2021). These applications have been critical in optimizing the production environment and are relevant for the potential application in Malaysia's rice industry specifically in BERNAS factories.

Table 1: Summarised of The Importance of Smart Manufacturing to Consumers

Source	Purpose	Results
(Namjoshi & Rawat, 2022)	This paper discusses the five main components of the Cyber-Physical Production System, otherwise known as Industry 4.0. These are intelligent design, intelligent machining, intelligent monitoring, intelligent control and intelligent scheduling.	The results of the study found that smart factories have great potential, and this technology can be used to optimize efficiency, minimize errors and save costs in the long run. Industry 4.0 brings a revolution with developments in data technology, cloud computing, 5G internet and advances in hardware technology. Manufacturers can deliver products with increased speed, flexibility, quality and improved productivity. There is a drastic reduction in costs in the long run. Many challenges need to be overcome but with additional research and improvements in technology over time, smart factories are very successful and profitable, both for manufacturers and the environment.
(De Pace et al., 2018)	This paper summarizes Augmented Reality (AR) which is now the industry choice after the fourth industrial revolution. This study also looks at the reasons for the growing need for smart technology from industries.	This study proves that the terms "Industry 4.0" and "smart factory" are often associated with the concept of the Internet of Things (IoT), which refers to networked devices that can exchange data. IoT is one of the key technologies of Industry 4.0. AR increases the reliability and safety of robotic systems that show robot workers aiming to reduce costs and improve the performance of maintenance systems. It also accurately points out any product discrepancies that superimpose the model

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		on the actual object. AR will definitely be one of the key technologies of Industry 4.0, it will give advantages to both the tasks of managers/supervisors and employees.
(Ihekoronye et al., 2021)	This research paper presents the benefits of IoT in achieving smooth manufacturing operations. Furthermore, a brief discussion of challenges, relevant practical concerns and future directions is provided.	The results of the study found that IoT has helped many industrial domains in the effective purchase of raw materials up to the support and services provided to their customers. Industrial revolution 4.0 has IoT as its main player in terms of technology, with the prospective feature of building influential services and applications for manufacturing. In addition, the use of IoT enables communication through the collection and transmission of data between intelligent machines which is essential for complex systems in making decisions in a real-time environment.
(Fauzi Ahmad et al., 2022)	The purpose of this research is to examine the level of Critical Success Factors (CSF) in industry 4.0 in manufacturing companies and examine the differences in CSF in Industry 4.0 in terms of practice and expectations.	Findings show, the overall level is FKK and the effect on performance is where it can be seen as a whole is above 5.50. There is no significant difference between expectations and practice except for the takbir of data management. The benefit from this study is being able to find out the FKK Industry 4.0 that plays an important role in influencing the performance of manufacturing companies.

Source: Field Study

Smart Manufacturing in The Global Food Industry

The global food industry has embraced smart manufacturing technologies to address challenges such as operational inefficiency, inconsistent quality and high production costs. The integration of IoT and AI has been particularly beneficial in tracking inventory, monitoring environmental conditions and automating production lines. For example, in rice milling, IoT sensors are used to monitor grain moisture levels in real-time, ensuring optimal milling conditions and minimizing post-harvest losses (Ihekoronye et al., 2021). Additionally, automated sorting systems powered by AI have significantly improved quality control in the rice processing sector by reducing human error and ensuring uniformity in the final product (Namjoshi & Rawat, 2022; Phuyal et al., 2020). These advancements in the global food industry have led to reduced wastage, more sustainable energy usage and improved product consistency. In countries like India and Thailand, the adoption of such technologies has helped to address inefficiencies in rice milling and processing, contributing to both cost savings and higher quality rice production. However, despite the global success, the application of these smart manufacturing technologies in Malaysia's rice industry remains limited. This gap presents an opportunity to explore how

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such technologies can be leveraged within the context of Malaysia's rice sector specifically in BERNAS to overcome existing production inefficiencies.

The Adoption of Smart Manufacturing in Malaysia's Rice Industry

Malaysia's rice industry particularly the operations within BERNAS faces several challenges stemming from reliance on manual labor, outdated machinery and suboptimal production techniques. The rice sector's dependency on traditional methods has led to inconsistent product quality, high operational costs and delays in meeting growing market demand (Fauzi Ahmad et al., 2022; Haricha et al., 2020). While smart manufacturing has shown promise in other industries, its adoption in Malaysia's rice sector is still in its infancy. Research in other regions has shown that the adoption of Industry 4.0 technologies including automation and AI-based quality control can significantly improve efficiency and product quality in food processing industries. For example, the use of IoT to monitor rice quality and automation in sorting systems has been shown to reduce operational costs and improve consistency in rice quality in other countries (Ihekoronye et al., 2021; Phuyal et al., 2020). These applications have the potential to address similar issues faced by Malaysia's rice industry such as reducing labor dependency, improving product uniformity and increasing processing speed.

However, Malaysia's rice industry still faces significant barriers to the adoption of these technologies. High initial investment costs for automated machinery and IoT systems, coupled with workforce skill gaps, present substantial challenges for BERNAS and other rice processors in Malaysia (Bokhorst et al., 2022; Haricha et al., 2020). Furthermore, the current state of Malaysia's digital infrastructure and data security concerns add additional complexity to the integration of smart technologies (Chonsawat & Sopadang, 2020; Guo et al., 2022).

Key Challenges in Implementing Smart Manufacturing in Malaysia's Rice Industry

Malaysia's rice industry particularly the operations within BERNAS faces several challenges stemming from reliance on manual labor, outdated machinery and suboptimal production techniques. The rice sector's dependency on traditional methods has led to inconsistent product quality, high operational costs and delays in meeting growing market demand (Fauzi Ahmad et al., 2022; Haricha et al., 2020).

Table 2: Key Challenges

Challenges	Explaination	Source
High Initial Investment	The cost of implementing smart manufacturing technologies, including automated machinery, IoT devices, and AI-based systems, is a significant barrier for small and medium-sized rice processing facilities. The financial constraints faced by these facilities make the transition to smart manufacturing a difficult undertaking.	(Bokhorst et al., 2022; He & Bai, 2021).
Workforce Readiness and Skill Gaps	The shift to smart manufacturing requires a highly skilled workforce capable of managing advanced technologies. In Malaysia, there is a notable skills gap in digital technologies, particularly within the	(Haricha et al., 2020)

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	agricultural sector, where labor is still predominantly manual. This gap poses a challenge in equipping workers with the necessary skills to adapt to new technologies.	
Infrastructure Limitations	Malaysia's agricultural sector faces limitations in digital infrastructure, particularly with the need for robust cloud computing systems, 5G connectivity, and big data analytics to support real-time monitoring and data exchange. The lack of these foundational technologies makes it difficult to implement smart manufacturing systems effectively.	(Chonsawat & Sopadang, 2020; Kaya et al., 2021)
Data Security Concerns	With the increase in interconnectivity between machines, data privacy and cybersecurity concerns become more pronounced. The reliance on cloud-based systems and interconnected networks in smart manufacturing raises the risk of data breaches, which could undermine the integrity of production processes and supply chains	(Guo et al., 2022; Meng et al., 2018)

Source: Literature Review

Research Gap

While global research has demonstrated the benefits of smart manufacturing in various industries, there is a notable lack of empirical research on its application within Malaysia's rice sector. Most studies have focused on the implementation of smart manufacturing in industries such as automotive and general food processing, leaving a significant gap in the understanding of how these technologies can be specifically applied to rice milling (De Pace et al., 2018; Namjoshi & Rawat, 2022). Moreover, while previous studies highlight the potential benefits of smart manufacturing, they do not adequately address the specific challenges faced by the rice sector in Malaysia such as moisture content variability, labor-intensive sorting processes and supply chain inefficiencies. By exploring the potential of smart manufacturing in BERNAS Sungai Limau, this study seeks to bridge the gap in research and offer practical solutions for enhancing Malaysia's rice production capabilities. The findings will contribute valuable insights to policymakers, industry stakeholders, and researchers, providing a foundation for future Industry 4.0 adoption in the Malaysian rice industry.

Research Methods

This study uses qualitative methods to obtain views from informants regarding the importance of smart manufacturing in BERNAS Factory in Sungai Limau, Kedah. This study was conducted on 10 BERNAS employees as detailed in Table 2. This study uses a qualitative method where data collection and data interpretation are done in depth before being analyzed to the conclusion of the study. Qualitative methods allow researchers to conduct in-depth and

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detailed investigations of the development of an event, situation or individual over a period of time. Qualitative methods are methods that focus the researcher's understanding in understanding social reality in more depth related to the topic under study (Dwi Kristanto & Sri Padmi, 2020; Ridder et al., 2014). Looking at the concept of qualitative method, it is very suitable to be used in this study which aims to obtain more detailed data and information in understanding more deeply about the importance of smart manufacturing in BERNAS Factory in Sungai Limau, Kedah.

Table 3: List of Informants

Informant Code	Position	Work Experience
101	Head of Operations Department BERNAS	23
102	Operations Officer BERNAS	17
103	Head of Operations at BERNAS Sungai Limau Factory	29
104	Employee of BERNAS Sungai Limau Factory	9
105	Employee of BERNAS Sungai Limau Factory	11
106	Employee of BERNAS Sungai Limau Factory	4
107	Employee of BERNAS Sungai Limau Factory	6
108	Employee of BERNAS Sungai Limau Factory	2
109	Employee of BERNAS Sungai Limau Factory	6
110	Employee of BERNAS Sungai Limau Factory	8

Source: Field Study

10 informants were interviewed in a semi-structured interview. After 10 people were interviewed, data saturation was reached. The sample size of 10 informants was carefully chosen to provide in-depth insights into the importance of smart manufacturing in BERNAS Factory, Sungai Limau. While qualitative studies typically utilize smaller sample sizes to allow for rich, detailed data collection, the sample size in this study is considered sufficient to address the research questions. This is because data saturation was reached after interviewing 10 employees, meaning no new themes or insights were emerging after the final interviews (Guest et al., 2006). Data saturation is a key indicator that the sample size is adequate for capturing the diversity of views on the topic, thus ensuring that the study's objectives are met. Given the qualitative nature of this study, the focus is on understanding the depth and complexity of participants' experiences rather than seeking statistical representativeness. The informants were selected based on their direct involvement with technology management in the rice processing sector,ensuring that their insights are relevant and directly related to the research questions. This targeted selection strategy ensures that the findings are grounded in real-world experiences, which are key to answering the study's objectives.

The data obtained was then analyzed using thematic analysis. This study uses thematic analysis to achieve the objectives of the study. Thematic analysis aims to identify themes through data obtained from informants (Dwi Kristanto & Sri Padmi, 2020; Maguire & Delahunt, 2017). Based on the views of scholars (Braun & Clarke, 2021; Byrne, 2022; Clarke & Braun, 2017; Dwi Kristanto & Sri Padmi, 2020; Maguire & Delahunt, 2017; Scharp & Sanders, 2019), thematic analysis is an approach used to analyze data which aims to find themes from the data that has been collected by the researcher. It is an approach that allows researchers to conduct a more in-depth analysis.

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The chosen location is the BERNAS factory in Sungai Limau, Kedah because it is one of the largest factories in processing rice paddy in Kedah. This factory was also chosen because it has not yet fully used smart technology in the factory.

This study uses a random sampling method. Sampling is a process of selecting a group for a research from a group of individuals that represent a large group selected (Trinczek, 2009). Sampling aims to obtain more in-depth information related to the topic the researcher is studying. So, in this study, sampling was carried out by selecting a sample of informants who understand and face technology management in the paddy rice sector.

Each interview session has an average duration of 15 minutes. To refine the interview process and questions, a pilot study was conducted with three interviewees, and the researcher made some adjustments accordingly. This study conducted a total of 8 interviews on October 2022 and 2 interviews on Mac 2023 finally reaching data saturation. The interviewees were given information about the main objectives of the research and expressed their willingness to participate without feeling pressured. The study strictly adhered to ethical best practices, and participants submitted their responses anonymously. In the process of data analysis, the study used open coding of meaning units from the collected data. Coding using the nVivo application. A total of 18 codes were generated, which were then reorganized based on their frequency, reference and occurrence. From these codes, four subthemes were developed, and these subthemes were further organized into four overarching themes.

While the study focuses on BERNAS Factory in Sungai Limau, Kedah, it provides valuable insights that may be applicable to other BERNAS factories across Malaysia particularly those that are in the early stages of adopting smart manufacturing technologies. Given that BERNAS is one of the largest rice suppliers in the country, the findings from this study offer a practical understanding of the challenges and opportunities that may be present in similar contexts. However, it is important to note that while the findings may be informative for other BERNAS factories, generalization must be done with caution due to the study's context-specific nature. Each factory within BERNAS may have its unique operational environment, infrastructure, and workforce characteristics. Nonetheless, the themes identified in this study particularly those related to workforce readiness, the adoption of digital technologies and the potential benefits of automation, are likely to resonate with other facilities within the BERNAS network that are considering or undergoing similar transitions to smart manufacturing. Furthermore, the findings of this study could serve as a reference point for future research on the adoption of Industry 4.0 technologies in Malaysia's rice industry, contributing to a broader understanding of how smart manufacturing can enhance operational efficiency in the sector as a whole.

Findings and discussions

It is hard to deny that smart manufacturing certainly provides benefits and benefits for its users. With the existence of artificial intelligence, Iot and cloud computing in smart manufacturing it can open new opportunities for innovation to various sectors. It is a concept that will give great importance to its users (Bani et al., 2023; Bokhorst et al., 2022; Deslonde & Becerra, 2018; He & Bai, 2021; Huang, 2022; Liu et al., 2021; Matt, Modrák, et al., 2020; Namjoshi & Rawat, 2022; Phuyal et al., 2020; Sahoo & Lo, 2022; Saqlain et al., 2019; Schultz-Wild & Köhler, 1985; Terry et al., 2020). The results of the study found that there are four importance of smart manufacturing to BERNAS factory in Sungai Limau, Kedah.

Table 4 Summary Of The Theme

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Theme	Informant Code	Number of Informants
Time effective	101, 103, 104, 105, 106, 107, 108, 109	8
Increase Productivity	101, 102, 103, 104, 105, 106, 107, 108, 109, 110	10
Maintaining the Sustainability	101, 102, 103, 104, 105, 106, 107, 108, 109, 110	10
Rural Development	101, 102, 103, 104, 105, 106, 107, 108, 109, 110	10

Source: Field Study

Theme One: Time Effective

First and foremost, smart manufacturing increases productivity and efficiency. Automation of repetitive processes that require high precision can reduce production time and cost, as well as improve product quality. The use of IoT systems enables real-time monitoring of machines and processes, helping in early detection of problems and reduction of downtime (Sahoo & Lo, 2022). This all leads to more efficient and competitive production. Based on the opinions and arguments from informants, this is further reinforced by the study conducted by Terry et al., (2020), proving that smart manufacturing technology plays a role in reducing the duration of output production. Smart manufacturing is a system that involves IoT and cloud computing and is integrated with other subsystems through the internet network (Saqlain et al., 2019) where IoT plays a role in producing information (Abubakr et al., 2020; Sahoo & Lo, 2022), and then analyzed by cloud computing. The combination of these technologies will make it easier for a factory to run operations. Therefore, the operation will be easier and faster in addition to being able to reduce the period of output production.

Various views of these informants show that smart manufacturing plays an important role in the rice paddy sector to save operating time in the drying process. For example, a discussion with informant 109 who argued, "……we use smart technology to control and stabilize the temperature during the drying process. A stable temperature is very important to speed up the drying process". Informant 106 also gave the argument, "Since the advent of smart manufacturing technology, I feel that the tasks that need to be done are reduced and the time used to complete a drying process can also be reduced". The findings align with the conclusion drawn by (Davis et al., 2015; Etz et al., 2020; Fauzi Ahmad et al., 2022; Ganlin et al., 2021; Haricha et al., 2020; He & Bai, 2021; Namjoshi & Rawat, 2022; Nižetić et al., 2019; Salawu et al., 2023; Soori et al., 2023). He & Bai (2021) & Namjoshi & Rawat (2022) stated that smart manufacturing includes the use of the latest digital and automation technologies to drive increased productivity in the industrial sector. By combining technologies such as the Internet of Things (IoT), artificial intelligence (AI), and machine learning, Nižetić et al., (2019) stated that smart manufacturing enables closer monitoring and more effective management of the production process. This technology allows companies to identify and resolve problems in real time as stated by (Haricha et al., 2020; Nižetić et al., 2019), which reduces downtime (Etz et al., 2020; Salawu et al., 2023; Soori et al., 2023) and ensures operations run more smoothly. In addition, Fauzi Ahmad et al., (2022) & Soori et al., (2023) also stated that high automation in smart manufacturing speeds up production processes and reduces the need for manual labor leading to reduced operating costs. In conclusion, smart manufacturing can reduce the time it takes to produce rice at the BERNAS factory in Sungai Limau, Kedah.

Theme Two: Increase productivity

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Furthermore, this study found that the importance of smart manufacturing to the BERNAS Sungai Limau factory is increased productivity. Based on Parhi et al., (2021), there is a 30% higher increase in manufacturing output with the presence of smart manufacturing technology compared to before the advent of the system. This proves that the implementation of smart manufacturing is important because it plays a role in increasing productivity. The integration of big data and analytics also enables more accurate planning and forecasting, helping companies to adjust production to market demand more efficiently (Davis et al., 2015; Ganlin et al., 2021; Sahoo & Lo, 2022).

Apart from increasing the quantity for the benefit of smart manufacturing for the rice paddy sector, there are ten informants who agree that smart manufacturing is able to improve the quality of rice for this sector. This is proven by an argument by informant 106 who argues, "Rice produced after the advent of smart manufacturing is of better quality because less rice is damaged after the drying process". This is in line with the argument from informant 107 who argued, "I am confident that smart manufacturing technology can improve the quality of the rice that will be produced". Not only that, it is proven that the presence of smart manufacturing, the rice paddy sector can increase the quantity of rice produced. This is evidenced by the views of informant 103 who says, "Since the application of smart manufacturing in the drying process, the quantity of rice produced shows an increase. This is because, smart manufacturing applied in the drying process will stabilize the temperature for the process. A stable temperature can not only speed up the process but it can also produce a larger quantity of rice. A stable temperature can also prevent the drying of rice which affects rice production". This is in line with the argument from informant 108 who says, ".....smart manufacturing is a method that gives importance to the rice paddy sector, especially in BERNAS. Most of the rice paddy sector still does not use smart manufacturing and only uses ordinary technology. I have been in this sector for the past 25 years and have changed factories. I have also worked in a factory that has smart manufacturing in the last two years. Although I am not involved with the technology, there, the whole process involves machine technology. As a result, the quantity of rice produced per ton is higher. So, I feel that with smart manufacturing in this factory, the quantity of rice produced can be increased". Additional 101 informants who argue, ".....in the rice paddy sector, it can not only increase the quantity of rice, but I think that it can also improve the quality of the rice produced".

The findings concur with the research conducted by Supekar et al., (2019), which analyzed energy productivity using smart manufacturing. The answer is that smart manufacturing can not only provide benefits on improving product quality, it also aims to reduce costs, increase production flexibility, improve energy efficiency and increase quantity. This result is also aligned with many scholars (Chonsawat & Sopadang, 2020, 2021; Ma & Yuan, 2015; Matt, Orzes, et al., 2020; Mishra et al., 2021; Supekar et al., 2019) who see that smart manufacturing provides importance from the point of view increasing the quantity of product production and also increasing the quality of the product produced. Overall, smart manufacturing not only increases productivity and efficiency but also contributes to higher product quality and reduced waste, thereby strengthening the industry's competitiveness in the global market.

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Theme Three: Maintaining the Sustainability of Nature

In addition, the importance of smart manufacturing does not only give importance to productivity, but smart manufacturing can also maintain the sustainability of nature so as not to have a negative impact on the environment. Smart manufacturing contributes to the reduction of waste and environmental impact. Through the use of data and real-time analysis, smart factories can optimize the use of raw materials and energy, reducing waste and pollution (Kaya et al., 2021; Kumar et al., 2019; Phuyal et al., 2020; Soori et al., 2023). This is important to ensure sustainable and environmentally friendly development. Many scholars (Abubakr et al., 2020; Li et al., 2022; S. Ma et al., 2023; Meng et al., 2018; Shen & Zhang, 2023) discuss about smart manufacturing and environmental sustainability. This aims to reduce the negative effects of the manufacturing sector which is seen to be increasing (Abubakr et al., 2020). Therefore, the efficient use of resources in smart manufacturing is seen to protect the environment. This statement is reinforced by an argument from informant 105 who says, "In the past, BERNAS used the husk burning method to generate heat for the drying process, but now BERNAS is upgrading technology and using water sources for the purpose of generating heat in the drying process. No more smoke and dust problems from the effects of husk burning.". Informant 102 also says, "…… when using the husk burning method, many pollution issues occurred and disturbed the community around the factory. Since 2010, BERNAS has introduced a hot water generator technology machine that aims to generate heat for the drying process. Since then, the problem of pollution can be reduced. BERNAS sells the rice husk to other parties to avoid waste because it is a product that can be innovated into other products such as pallets".

The statement is reinforced by a study by Nižetić et al., (2019), which states that the role of smart technology becomes important and useful to solve the main issues at the global level, namely pollution and global warming. Therefore, the use of water resources in the drying process is a smart technology method that can give importance to the paddy rice sector in maintaining environmental sustainability. Apart from the efficient use of resources, the use of solar energy is also seen to have a great impact on the paddy rice sector. Solar energy is the sun's rays that produce heat to generate electricity (Østergaard et al., 2022). There are many interests that can be found by the rice paddy sector in the use of solar energy in processing factories. For example, a statement was argued by informant 104 who says, "…. the use of solar energy to replace fossil fuels because this factory uses a very high rate of electricity for the drying process. Through solar energy, I am confident that this factory can save money on the use of electricity to finance the definition". Informant 110 also argued, "Solar energy that replaces fossil fuels can reduce greenhouse gas levels and protect our earth. It can also save on electricity bills."

Statements are proved by studies conducted by many scholars (Adenle, 2020; Hernandez et al., 2019; Hosseini Dehshiri et al., 2023; Lagili et al., 2023; Li et al., 2022; S. Ma et al., 2023; Shen & Zhang, 2023; Vaka et al., 2020) related to solar energy and environmental sustainability. Although this study focuses on the paddy rice sector, this study takes an example from the study conducted by Adenle (2020), on the assessment of solar energy technology in Africa and the challenges of meeting the 2030 agenda in the goal of sustainable development. From the study, it is stated that the generation of electricity from renewable energy sources instead of fossil fuels can bring great benefits to the environment and its users. The use of solar, as one of the smart technologies, plays an important role in maintaining the sustainability of the environment. Solar energy is a clean and renewable source of energy, which does not produce air pollution or climate-damaging greenhouse gas emissions (Jia et al., 2022; Sharma et al., 2023). By leveraging advanced technologies such as photovoltaic panels and energy storage systems, solar

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use can reduce dependence on limited and polluting fossil energy sources. In addition, smart technologies related to solar energy, such as smart energy management systems, enable optimization of energy use, reduce waste, and improve overall energy efficiency (Botha, 2018; Chonsawat & Sopadang, 2020; Guo et al., 2022; Guzal-Dec, 2018; Kaya et al., 2021; Kumar et al., 2019; Meng et al., 2018; Phuyal et al., 2020). The use of solar energy also supports sustainable development by providing access to clean energy in remote areas and reducing negative impacts on ecosystems. By promoting the use smart manufacturing that includes of solar energy, it can protect the environment for future generations, ensuring that economic development does not sacrifice the well-being of our planet.

Theme Four: Improving Rural Development

The next section discusses the importance of smart manufacturing to the rice paddy sector, which is improving rural development. As is known, most of the rice factories, especially BERNAS, are located in rural areas. Rural areas are often associated with characteristics such as lack of infrastructure facilities, limited services, lack of employment opportunities and a lower standard of living. Rural development through modern technology, especially smart manufacturing, is seen to be able to overcome the challenges faced by rural areas and provide a positive impact for the area.

Based on table 3, all informants agreed that smart manufacturing is important for the rice paddy sector in improving rural development. Smart manufacturing also creates new job opportunities. While automation may reduce the need for some types of manual jobs, it also opens up job opportunities in high-tech fields such as data management, systems engineering, and maintenance of smart equipment. These jobs usually offer higher wages and require more specialized skills, improving the standard of living of local residents. This statement is proved by a statement by informant 101 who argues, "Technology development initiatives towards a smarter direction make the area provided with infrastructure such as internet networks in rural areas. It is seen that it will provide exposure and opportunity to the community in the area to enjoy the facilities provided. Also, in the smart manufacturing application plan at the BERNAS factory, the BERNAS side will also open up more job opportunities that the community in the area can take advantage of". In line with informant 101, informant 108 also says, "Smart manufacturing involves technological elements such as IoT and cloud computing that require skills to use them. BERNAS will hold a workshop related to smart technology for all employees who are mostly from rural communities to provide exposure related to technology. This can indirectly improve employees' knowledge of technology and apply creative thinking. This is seen to increase rural development with the existence of a technology-savvy community".

This is align with the research by Chatterjee et al., (2020), smart manufacturing also opens up new job opportunities that require high skills, such as data management, programming, and maintenance of automation systems. This can improve the level of education and skills of the local population, which in turn strengthens the economy of the area. The development of supporting infrastructure such as high-speed internet networks and transport facilities will also be improved to support the operation of smart factories, which bring additional benefits to local communities. Smart manufacturing in factories also plays an important role in improving the development of the region through various means. With the integration of advanced technologies such as the Internet of Things (IoT), artificial intelligence (AI), and automation, smart manufacturing enables factories to operate more efficiently and productively (Javaid et al., 2022; Parhi et al., 2021). This technology enables real-time monitoring and management of the production process, reducing downtime and improving product quality. With this increase

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in productivity, factories can produce more goods at a lower cost, which can stimulate local economic growth (Adamowicz & Zwolinska-Ligaj, 2020; Guzal-Dec, 2018; Porru et al., 2020; Schuetz & Venkatesh, 2020; Yin et al., 2022).

Study's Implication

Policy implications in the context of the three policies involved, namely the National Agro-Food Policy 2021-2030, the Rural Development Policy 2021-2020 and the Science, Technology and Industry Policy 2021-2020. National Agrofood Policy 2021-2030 which emphasizes the importance of food security. The implication is that BERNAS and other rice paddy sectors should focus and plan on increasing rice productivity domestically to meet the needs of the community. It also implies that the quality of food must meet the standards that have been set. For the Rural Development Policy that focuses on developing rural areas to become more developed. The implication is that the government will strive to provide higher investment in infrastructure, education and so on to improve rural areas. In addition, BERNAS factory workers located in rural areas give implications to the community in the area by providing job opportunities to those who are seen to be able to develop the area. Lastly is the Science, Technology and Industry Policy which aims to encourage innovation in agriculture by using technology as a driver of economic growth. The implication is that BERNAS, as an entity given responsibility by the government to manage the country's rice stock, will be given investment by the government to improve the technologies that are currently available.

Conclusion

This study found that there are four importance of smart manufacturing technology in the rice paddy exclusively BERNAS factory in Sungai Limau, Kedah, namely time effective, increase productivity, maintaining environmental sustainability and rural development. This study found that smart manufacturing technology can save operational time. The operation in the drying process is seen to require a long time. Therefore, smart manufacturing technology is seen as important for these operations. Through this shorter period, the mill can carry out more rice drying operations in order to produce more rice.

This study found that smart manufacturing technology can provide importance to the paddy rice sector through increased productivity. There are two things that can be improved which are increasing the quantity and increasing the quality. First, increase in quantity. As discussed above, smart manufacturing technology will save operation time and more operations can be carried out where rice production will be more. Second, smart manufacturing technology also results in less rice damage during the drying process. Therefore, rice produced by using smart manufacturing technology is rice of better quality and more. Environmental conditions are a very important factor in plant care. A good factory is a factory that takes care of the environment without causing the surroundings to be polluted with pollution such as air pollution, noise pollution and so on. Therefore, it is an important thing that needs to be emphasized by the factory so as not to disturb the local population. For this study, the sustainability of nature is maintained by the use of two natural resources, namely the use of water resources in the drying process and the use of solar energy for electricity generation. Both of these methods are smart technology methods that are seen as important in the paddy rice sector. Not only can it save costs, but it can also protect the environment from being polluted with fossil fuels. As is known, BERNAS factories are all located in rural areas close to rice fields. It is to facilitate the process of delivery and purchase of rice from the paddy field to the factory. With smart manufacturing technology, it will open the minds of factory workers to a more advanced and more critical

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thinking. This allows them to contribute to the improvement of rural areas in order to live in technological progress.

This study was conducted at the BERNAS Sungai Limau factory only, where it involved a very limited study sample. This causes a lack of diversity in research findings. Therefore, future research can expand the research sample such as involving the entire BERNAS factory in Malaysia so that the research findings are more diverse. The discussion shows that all research questions have been answered and all research objectives have been achieved. There are many important findings regarding the importance of smart manufacturing technology in the rice paddy sector. The various findings of this study are also seen to be able to contribute to those in need to see the need to improve good technology so as to be able to contribute to BERNAS in producing sufficient rice for Malaysians. Researchers realize that there are still many limitations in this study and further studies are seen as very necessary to understand this issue of technology development for the future.

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References

Abubakr, M., Abbas, A. T., Tomaz, I., Soliman, M. S., Luqman, M., & Hegab, H. (2020). Sustainable and smart manufacturing: An integrated approach. *Sustainability (Switzerland)*, *12*(6), 1–19. https://doi.org/10.3390/su12062280

Adamowicz, M., & Zwolinska-Ligaj, M. (2020). The "smart village" as away to achieve sustainable development in Rural Areas of Poland. *Sustainability (Switzerland)*, *12*(16). https://doi.org/10.3390/su12166503

Adenle, A. A. (2020). Assessment of solar energy technologies in Africa-opportunities and challenges in meeting the 2030 agenda and sustainable development goals. *Energy Policy*, *137*. https://doi.org/10.1016/j.enpol.2019.111180

Akhigbe, I., Munir, K., Akinade, O., Akanbi, L., & Oyedele, L. O. (2021). Iot technologies for livestock management: A review of present status, opportunities, and future trends bernard. *Big Data and Cognitive Computing*, *5*(1). https://doi.org/10.3390/bdcc5010010

Arshad, F. M., Arifin, B., & Tey, Y. S. (2019). Effectiveness of state trading enterprises in achieving food security: Case studies from BERNAS in Malaysia and BULOG in Indonesia. *Policy Paper*, *25*, 1–86. https://eur-lex.europa.eu/legal-content/PT/TXT/PDF/?uri=CELEX:32016R0679&from=PT%0Ahttp://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52012PC0011:pt:NOT

Ashfaq, M., Zhu, R., Ali, M., Xu, Z., Rasheed, A., Jamil, M., Shakir, A., & Wu, X. (2023). Adaptation and High Yield Performance of Honglian Type Hybrid Rice in Pakistan with Desirable Agricultural Traits. *Agriculture (Switzerland)*, *13*(2). https://doi.org/10.3390/agriculture13020242

Volume: 10 Issues: 69 Special Issue [January, 2025] pp. 80 - 98
Journal of Islamic, Social, Economics and Development (JISED)
eISSN: 0128-1755
Journal website: www.academicinspired.com/jised
DOI: 10.55573/JISED.106907

Bani, K. P., Jagtap, S., Kanchan, T., Dige, A., Student, S. P., & Bani, K. (2023). *Exploring the Efficiency and Effectiveness of an Automated Robotic Vacuum Cleaner*. *155*(2). https://www.researchgate.net/publication/370221292

Barrett, H., & Rose, D. C. (2022). Perceptions of the Fourth Agricultural Revolution: What's In, What's Out, and What Consequences are Anticipated? *Sociologia Ruralis*, *62*(2), 162–189. https://doi.org/10.1111/soru.12324

Bokhorst, J. A. C., Knol, W., Slomp, J., & Bortolotti, T. (2022). Assessing to what extent smart manufacturing builds on lean principles. *International Journal of Production Economics*, *253*. https://doi.org/10.1016/j.ijpe.2022.108599

Botha, A. P. (2018). Rapidly arriving futures: future readiness for industry 4.0. *South African Journal of Industrial Engineering*, *29*(3).

Braun, V., & Clarke, V. (2021). One size fits all? What counts as quality practice in (reflexive) thematic analysis? *Qualitative Research in Psychology*, *18*(3), 328–352. https://doi.org/10.1080/14780887.2020.1769238

Bun, P., Grajewski, D., & Gorski, F. (2021). Readiness to Use Augmented Reality Solutions in Small and Medium Enterprises in Poland: A Survey. *Lecture Notes in Mechanical Engineering*, 14–23. https://doi.org/10.1007/978-3-030-68014-5_2

Byrne, D. (2022). A worked example of Braun and Clarke's approach to reflexive thematic analysis. *Quality and Quantity*, *56*(3), 1391–1412. https://doi.org/10.1007/s11135-021-01182-y

Chatterjee, S., Dutta Gupta, S., & Upadhyay, P. (2020). Technology adoption and entrepreneurial orientation for rural women: Evidence from India. *Technological Forecasting and Social Change*, *160*. https://doi.org/10.1016/j.techfore.2020.120236

Chonsawat, N., & Sopadang, A. (2020). Defining smes' 4.0 readiness indicators. *Applied Sciences (Switzerland)*, *10*(24), 1–30. https://doi.org/10.3390/app10248998

Clarke, V., & Braun, V. (2017). Thematic analysis. *Journal of Positive Psychology*, *12*(3), 297–298. https://doi.org/10.1080/17439760.2016.1262613

Clough, P. D., & Stammers, J. (2021). Smart manufacturing. *Smart Connected World: Technologies and Applications Shaping the Future*, 141–169. https://doi.org/10.1007/978-3-030-76387-9_8

Davis, J., Edgar, T., Graybill, R., Korambath, P., Schott, B., Swink, D., Wang, J., & Wetzel, J. (2015). Smart Manufacturing. *Annual Review of Chemical and Biomolecular Engineering*, *6*, 141–160. https://doi.org/10.1146/annurev-chembioeng-061114-123255

De Pace, F., Manuri, F., & Sanna, A. (2018). Augmented Reality in Industry 4.0. *American Journal of Computer Science and Information Technology*, *06*(01). https://doi.org/10.21767/2349-3917.100017

Deslonde, V., & Becerra, M. (2018). The Technology Acceptance Model (TAM): Exploring School Counselors' Acceptance and Use of Naviance. *The Professional Counselor*, *8*(4), 369–382. https://doi.org/10.15241/vd.8.4.369

Dordkeshan, M. J., Shamsudin, M. N., Mohamed, Z., & Radam, A. (2017). Assessing the Impact of Rice Import Quota Policy on the Malaysian Rice Sector. *Journal of Food Products Marketing*, *23*(8), 890–900. https://doi.org/10.1080/10454446.2017.1244798

Dwi Kristanto, Y., & Sri Padmi, R. (2020). Analisis data kualitatif: Penerapan analisis jejaring untuk analisis tematik yang cepat , transparan , dan teliti. *Jurnal Koridor*, *1*(5), 1–21.

Etz, D., Fruhwirth, T., & Kastner, W. (2020). Flexible Safety Systems for Smart Manufacturing. *IEEE International Conference on Emerging Technologies and Factory Automation, ETFA*, *2020-Septe*, 1123–1126. https://doi.org/10.1109/ETFA46521.2020.9211905

Fauzi Ahmad, M., Khadijah Zaini, S., Nur Aizat Ahmad, A., Rashid, N., Pengurusan Pengeluaran dan Operasi, J., Pengurusan Teknologi dan Perniagaan, F., Tun Hussein Onn

Volume: 10 Issues: 69 Special Issue [January, 2025] pp. 80 - 98
Journal of Islamic, Social, Economics and Development (JISED)
eISSN: 0128-1755
Journal website: www.academicinspired.com/jised
DOI: 10.55573/JISED.106907

Malaysia, U., Raja, P., Pahat, B., Pengurusan Teknologi, J., & Pengurusan Teknologi dan Teknousahawanan, F. (2022). Transformasi Digital: Impak Faktor Kejayaan Kritikal (FKK) Industri 4.0 Terhadap Prestasi Syarikat Pembuatan. *Research in Management of Technology and Business*, *3*(1), 319–333. http://publisher.uthm.edu.my/periodicals/index.php/rmtb

Ganlin, P., Qamruzzaman, M. D., Mehta, A. M., Naqvi, F. N., & Karim, S. (2021). Innovative finance, technological adaptation and smes sustainability: The mediating role of government support during covid-19 pandemic. *Sustainability (Switzerland)*, *13*(16). https://doi.org/10.3390/su13169218

Glowniak, J. (1998). History, structure, and function of the Internet. *Seminars in Nuclear Medicine*, *28*(2), 135–144. https://doi.org/10.1016/S0001-2998(98)80003-2

Gnoni, M. G., Bragatto, P. A., Milazzo, M. F., & Setola, R. (2020). Integrating IoT technologies for an "intelligent" safety management in the process industry. *Procedia Manufacturing*, *42*, 511–515. https://doi.org/10.1016/j.promfg.2020.02.040

Guo, Q., Wang, Y., & Dong, X. (2022). Effects of smart city construction on energy saving and CO2 emission reduction: Evidence from China. *Applied Energy*, *313*. https://doi.org/10.1016/j.apenergy.2022.118879

Guzal-Dec, D. (2018). Intelligent Development of the Countryside – The Concept of Smart Villages : Assumptions, Possibilities and Implementation Limitations . *Economic and Regional Studies / Studia Ekonomiczne i Regionalne*, *11*(3), 32–49. https://doi.org/10.2478/ers-2018-0023

Haricha, K., Khiat, A., Issaoui, Y., Bahnasse, A., & Ouajji, H. (2020). Towards smart manufucturing: Implementation and benefits. *Procedia Computer Science*, *177*, 639–644. https://doi.org/10.1016/j.procs.2020.10.091

He, B., & Bai, K. J. (2021). Digital twin-based sustainable intelligent manufacturing: a review. *Advances in Manufacturing*, *9*(1). https://doi.org/10.1007/s40436-020-00302-5

Hernandez, R. R., Armstrong, A., Burney, J., Ryan, G., Moore-O'Leary, K., Diédhiou, I., Grodsky, S. M., Saul-Gershenz, L., Davis, R., Macknick, J., Mulvaney, D., Heath, G. A., Easter, S. B., Hoffacker, M. K., Allen, M. F., & Kammen, D. M. (2019). Techno–ecological synergies of solar energy for global sustainability. *Nature Sustainability*, *2*(7), 560–568. https://doi.org/10.1038/s41893-019-0309-z

Hosseini Dehshiri, S. S., Hosseini Dehshiri, S. J., & Firoozabadi, B. (2023). Evaluation of using solar energy in Iran's textile industry towards cleaner production: Sustainable planning and feasibility analysis. *Journal of Cleaner Production*, *421*. https://doi.org/10.1016/j.jclepro.2023.138447

Huang, M. (2022). The decreasing area of hybrid rice production in China: causes and potential effects on Chinese rice self-sufficiency. *Food Security*, *14*(1), 267–272. https://doi.org/10.1007/s12571-021-01199-z

Ihekoronye, V. U., Nwakanma, C. I., Anyanwu, G. O., Kim, D. S., & Lee, J. M. (2021). Benefits, Challenges and Practical Concerns of IoT for Smart Manufacturing. *International Conference on ICT Convergence*, *2021-Octob*, 827–830. https://doi.org/10.1109/ICTC52510.2021.9620771

Ikhram, M., Ridzuan, M., Morshidi, A., Zakaria, N. S., Dollah, R., Hua, A. K., & Yusoh, M. P. (2024). *Policy Constructivity and Food Security Strategies : Vulnerability Issues of Rice in Kota Belud , Sabah*. *2*(2), 14–30.

Jambrak, A. R., Nutrizio, M., Djekić, I., Pleslić, S., & Chemat, F. (2021). Internet of nonthermal food processing technologies (Iontp): Food industry 4.0 and sustainability. *Applied Sciences (Switzerland)*, *11*(2), 1–20. https://doi.org/10.3390/app11020686

Volume: 10 Issues: 69 Special Issue [January, 2025] pp. 80 - 98
Journal of Islamic, Social, Economics and Development (JISED)
eISSN: 0128-1755
Journal website: www.academicinspired.com/jised
DOI: 10.55573/JISED.106907

Javaid, M., Haleem, A., Singh, R. P., & Suman, R. (2022). Enhancing smart farming through the applications of Agriculture 4.0 technologies. *International Journal of Intelligent Networks*, *3*, 150–164. https://doi.org/10.1016/j.ijin.2022.09.004

Jia, D., Yang, L., Lv, T., Liu, W., Gao, X., & Zhou, J. (2022). Evaluation of machine learning models for predicting daily global and diffuse solar radiation under different weather/pollution conditions. *Renewable Energy*, *187*, 896–906. https://doi.org/10.1016/j.renene.2022.02.002

Kaya, D. I., Pintossi, N., & Dane, G. (2021). An empirical analysis of driving factors and policy enablers of heritage adaptive reuse within the circular economy framework. *Sustainability (Switzerland)*, *13*(5), 1–25. https://doi.org/10.3390/su13052479

Klerkx, L., Jakku, E., & Labarthe, P. (2019). A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS - Wageningen Journal of Life Sciences*, *90–91*. https://doi.org/10.1016/j.njas.2019.100315

Kumar, S., Tiwari, P., & Zymbler, M. (2019). Internet of Things is a revolutionary approach for future technology enhancement: a review. *Journal of Big Data*, *6*(1). https://doi.org/10.1186/s40537-019-0268-2

Kusiak, A. (2023). Smart Manufacturing. *Springer Handbooks*, *Part F674*, 973–985. https://doi.org/10.1007/978-3-030-96729-1_45

Lagili, H. S. A., Kiraz, A., Kassem, Y., & Gökçekuş, H. (2023). Wind and Solar Energy for Sustainable Energy Production for Family Farms in Coastal Agricultural Regions of Libya Using Measured and Multiple Satellite Datasets. *Energies*, *16*(18). https://doi.org/10.3390/en16186725

Li, L., Lei, B., & Mao, C. (2022). Digital twin in smart manufacturing. *Journal of Industrial Information Integration*, *26*. https://doi.org/10.1016/j.jii.2021.100289

Liu, Y., Ma, X., Shu, L., Hancke, G. P., & Abu-Mahfouz, A. M. (2021). From Industry 4.0 to Agriculture 4.0: Current Status, Enabling Technologies, and Research Challenges. *IEEE Transactions on Industrial Informatics*, *17*(6), 4322–4334. https://doi.org/10.1109/TII.2020.3003910

Ma, G. hui, & Yuan, L. ping. (2015). Hybrid rice achievements, development and prospect in China. *Journal of Integrative Agriculture*, *14*(2), 197–205. https://doi.org/10.1016/S2095-3119(14)60922-9

Ma, S., Huang, Y., Liu, Y., Kong, X., Yin, L., & Chen, G. (2023). Edge-cloud cooperation-driven smart and sustainable production for energy-intensive manufacturing industries. *Applied Energy*, *337*. https://doi.org/10.1016/j.apenergy.2023.120843

Maguire, M., & Delahunt, B. (2017). Doing a Thematic Analysis: A Practical, Step-by-Step Guide for Learning and Teaching Scholars. *All Ireland Journal of Teaching and Learning in Higher Education (AISHE-J)*, *8*(3). https://doi.org/10.1109/TIA.2014.2306979

Matt, D. T., Modrák, V., & Zsifkovits, H. (2020). Industry 4.0 for smes: Challenges, opportunities and requirements. *Industry 4.0 for SMEs: Challenges, Opportunities and Requirements*, 1–401. https://doi.org/10.1007/978-3-030-25425-4

Matt, D. T., Orzes, G., Rauch, E., & Dallasega, P. (2020). Urban production – A socially sustainable factory concept to overcome shortcomings of qualified workers in smart SMEs. *Computers and Industrial Engineering*, *139*. https://doi.org/10.1016/j.cie.2018.08.035

Meng, Y., Yang, Y., Chung, H., Lee, P. H., & Shao, C. (2018). Enhancing sustainability and energy efficiency in smart factories: A review. *Sustainability (Switzerland)*, *10*(12). https://doi.org/10.3390/su10124779

Muhammad, S. (2013). Role of BERNAS as Government Linked Company (GLC) – Supporting and Complementing National (Malaysia) Food Security Food Policies. *Journal*

Volume: 10 Issues: 69 Special Issue [January, 2025] pp. 80 - 98
Journal of Islamic, Social, Economics and Development (JISED)
eISSN: 0128-1755
Journal website: www.academicinspired.com/jised
DOI: 10.55573/JISED.106907

of Tropical Resources and Sustainable Science (JTRSS), *1*(2), 35–41. https://doi.org/10.47253/jtrss.v1i2.639

Namjoshi, J., & Rawat, M. (2022). Role of smart manufacturing in industry 4.0. *Materials Today: Proceedings*, *63*, 475–478. https://doi.org/10.1016/j.matpr.2022.03.620

Nguyen Chau, T., & Scrimgeour, F. (2022). Productivity impacts of hybrid rice seeds in Vietnam. *Journal of Agricultural Economics*, *73*(2), 414–429. https://doi.org/10.1111/1477-9552.12458

Nižetić, S., Djilali, N., Papadopoulos, A., & Rodrigues, J. J. P. C. (2019). Smart technologies for promotion of energy efficiency, utilization of sustainable resources and waste management. *Journal of Cleaner Production*, *231*, 565–591. https://doi.org/10.1016/j.jclepro.2019.04.397

Parhi, S., Joshi, K., & Akarte, M. (2021). Smart manufacturing: a framework for managing performance. *International Journal of Computer Integrated Manufacturing*, *34*(3), 227–256. https://doi.org/10.1080/0951192X.2020.1858506

Phuyal, S., Bista, D., & Bista, R. (2020). Challenges, Opportunities and Future Directions of Smart Manufacturing: A State of Art Review. *Sustainable Futures*, *2*. https://doi.org/10.1016/j.sftr.2020.100023

Porru, S., Misso, F. E., Pani, F. E., & Repetto, C. (2020). Smart mobility and public transport: Opportunities and challenges in rural and urban areas. *Journal of Traffic and Transportation Engineering (English Edition)*, *7*(1), 88–97. https://doi.org/10.1016/j.jtte.2019.10.002

Ravi Kumar, K., Krishna Chaitanya, N. V. V., & Sendhil Kumar, N. (2021). Solar thermal energy technologies and its applications for process heating and power generation – A review. *Journal of Cleaner Production*, *282*. https://doi.org/10.1016/j.jclepro.2020.125296

Ridder, H. ., Miles, M. ., Michael Huberman, A., & Saldaña, J. (2014). Qualitative data analysis. *Zeitschrift Fur Personalforschung*, *28*(4). https://doi.org/https://doi.org/10.1177/239700221402800402

Rosak-Szyrocka, J., Zywiolek, J., Kulinska, E., & Matulewski, M. (2021). Analysis of Enterprises' Readiness in for Industry 4.0 Implementation: The Case of Poland. *European Research Studies Journal*, *XXIV*(Issue 3), 615–628. https://doi.org/10.35808/ersj/2374

Sahoo, S., & Lo, C. Y. (2022). Smart manufacturing powered by recent technological advancements: A review. *Journal of Manufacturing Systems*, *64*, 236–250. https://doi.org/10.1016/j.jmsy.2022.06.008

Salawu, E. Y., Awoyemi, O. O., Akerekan, O. E., Afolalu, S. A., Kayode, J. F., Ongbali, S. O., Airewa, I., & Edun, B. M. (2023). Impact of Maintenance on Machine Reliability: A Review. *E3S Web of Conferences*, *430*. https://doi.org/10.1051/e3sconf/202343001226

Saqlain, M., Piao, M., Shim, Y., & Lee, J. Y. (2019). Framework of an IoT-based Industrial Data Management for Smart Manufacturing. *Journal of Sensor and Actuator Networks*, *8*(2). https://doi.org/10.3390/jsan8020025

Scharp, K. M., & Sanders, M. L. (2019). What is a theme? Teaching thematic analysis in qualitative communication research methods. *Communication Teacher*, *33*(2), 117–121. https://doi.org/10.1080/17404622.2018.1536794

Schuetz, S., & Venkatesh, V. (2020). Blockchain, adoption, and financial inclusion in India: Research opportunities. *International Journal of Information Management*, *52*. https://doi.org/10.1016/j.ijinfomgt.2019.04.009

Schultz-Wild, R., & Köhler, C. (1985). Introducing new manufacturing technology: Manpower problems and policies. *Human Systems Management*, *5*(3), 231–243. https://doi.org/10.3233/HSM-1985-5306

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DOI: 10.55573/JISED.106907

Sharma, S., Tiwari, P., Agrawal, I., & Khadatkar, U. (2023). Cost of Air Pollution to Solar Energy Generation. *Mathematical Statistician and Engineering Applications*, *71*(4), 1–5. https://doi.org/https://doi.org/10.17762/msea.v71i4.1771

Shen, Y., & Zhang, X. (2023). Intelligent manufacturing, green technological innovation and environmental pollution. *Journal of Innovation and Knowledge*, *8*(3). https://doi.org/10.1016/j.jik.2023.100384

Soori, M., Arezoo, B., & Dastres, R. (2023). Internet of things for smart factories in industry 4.0, a review. *Internet of Things and Cyber-Physical Systems*, *3*, 192–204. https://doi.org/10.1016/j.iotcps.2023.04.006

Supekar, S. D., Graziano, D. J., Riddle, M. E., Nimbalkar, S. U., Das, S., Shehabi, A., & Cresko, J. (2019). A framework for quantifying energy and productivity benefits of smart manufacturing technologies. *Procedia CIRP*, *80*, 699–704. https://doi.org/10.1016/j.procir.2019.01.095

Terry, S., Lu, H., Fidan, I., Zhang, Y., Tantawi, K., Guo, T., & Asiabanpour, B. (2020). The Influence of Smart Manufacturing towards Energy Conservation: A Review. *Technologies*, *8*(2), 31. https://doi.org/10.3390/technologies8020031

Trinczek, R. (2009). How to Interview Managers? Methodical and Methodological Aspects of Expert Interviews as a Qualitative Method in Empirical Social Research. *Interviewing Experts*, 203–216. https://doi.org/10.1057/9780230244276_10

Vaka, M., Walvekar, R., Rasheed, A. K., & Khalid, M. (2020). A review on Malaysia's solar energy pathway towards carbon-neutral Malaysia beyond Covid'19 pandemic. *Journal of Cleaner Production*, *273*. https://doi.org/10.1016/j.jclepro.2020.122834

Yakubi, Y. A. Y., Basuki, B., Purwono, R., & Usman, I. (2022). The Impact of Digital Technology and Business Regulations on Financial Inclusion and Socio-Economic Development in Low-Income Countries. *SAGE Open*, *12*(3). https://doi.org/10.1177/21582440221116112

Yasar, M., Siwar, C., & Ghazali, R. (2016). Analisis Kemudahterancaman Pesawah Padi di Kawasan Pembangunan Bersepadu Terengganu Utara, Malaysia. *Jurnal Ekonomi Malaysia*, *50*(2), 39–47. http://dx.doi.org/10.17576/JEM-2016-5002-04

Yin, X., Chen, J., & Li, J. (2022). Rural innovation system: Revitalize the countryside for a sustainable development. *Journal of Rural Studies*, *93*, 471–478. https://doi.org/10.1016/j.jrurstud.2019.10.014

Zakaria, M. B., Abd Karim, N. A. A., & Hasan, J. (2021). Analisis Bekalan Beras di Malaysia Pasca Covid-19 Menurut Prespektif Fiqh Pertanian. *Jurnal Islam Dan Masyarakat Kontemporari*, *22*(3).