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THE USE OF INDUSTRY 4.0 TECHNOLOGY IN THE TRANSFORMATION OF PRODUCTION PROCESSES TOWARDS SMART FACTORIES

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ABSTRACT

This research aims to explore the use of Industry 4.0 technology in the transformation of the production process towards a smart factory. The method used in this research is qualitative. The process of collecting data and information comes from literature studies obtained from various articles, books, and documents relevant to the topic of discussion. The results show that the implementation of industry 4.0 technology can improve efficiency, flexibility, and operational resilience in the production environment. Through better integration between equipment and systems, smart factories can monitor, forecast, and control production processes in real-time, allowing adaptation of production models that are responsive to market dynamics. However, there are also challenges and opportunities that arise in its application. As such, this research provides a contribution to understanding the implications of Industry 4.0 technologies on the future of production and industry as a whole.

KEYWORDS *Technology, Industry 4.0, Smart Factory*

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INTRODUCTION

The Industrial Revolution 4.0 is changing the industrial paradigm by introducing the integration of advanced technologies such as Internet of Things (IoT), artificial intelligence (AI), robotics, cloud computing, and data analytics (Triansyah et al., 2024). Through IoT, real-time data from multiple sources enables faster monitoring, while artificial intelligence improves efficiency with deep data analysis capabilities (Aulia et al., 2023). Increasingly sophisticated robotics enable automation of industrial tasks (Simamora, 2024), while cloud computing provides the infrastructure for faster innovation and greater scalability (Siska & Farizy, 2023). Data analytics provides the insights needed to improve operations and drive business strategy, creating fundamental changes in the way industries operate and innovate (Ghozali et al., 2024).

Smart factories bring a revolutionary vision of the future to the industrialised world, where advanced technologies such as high automation, widespread connectivity between equipment, real-time monitoring, and the ability for independent decision-making are key (Deni, 2023). Smart factories are designed to operate at maximum efficiency through the integration of connected systems, enabling adaptive production and responsiveness to market demands in real time (Fonna, 2019). The equipment in a smart factory is able to communicate with each other to optimise the production process, quickly identify and respond to changing conditions, and take corrective action or adjustments automatically. With real-time monitoring and advanced data analytics, a smart factory can generate deep insights into its operational performance, enabling more timely and effective decision-making. This forms a dynamic, adaptive, and efficient industrial environment, which is able to face the challenges and opportunities in the digital era to the fullest (Sugiana & Musty, 2023).

As global competition intensifies, industrial companies are required to increase efficiency and innovation in their production to remain competitive. In addition, rapidly changing consumer demands require manufacturers to be able to adjust their products and services quickly and appropriately (Kadim, 2017). In the face of these challenges, smart factories can be a solution to effectively address them as they can improve production efficiency, reduce lead times, and provide greater flexibility in meeting changing market demands (Lantemona et al., 2024). This transformation also provides an opportunity to integrate the latest technologies such as artificial intelligence, IoT, and data analytics to gain deeper insights into factory operations and enable smarter and more timely decision-making.

Research results by (Raza & Komala, 2020) show that the use of technology to automate logistics processes has a number of significant advantages for individuals and business entities. Another study by (Nugrowibowo & Muslimin, 2023) shows that the implementation of Industry 4.0 will bring operational excellence that reaches new standards unimaginable in conventional manufacturing organisations, thanks to the adoption of smart manufacturing. Businesses related to industrial engineering are expected to play a role in reducing environmental emissions as Industry 4.0 will actively monitor and regulate emission levels through cyber physical systems, thereby

reducing environmental impacts. Ergonomic hazards and unsafe activities will be automated, safeguarding workers' health. In addition, the implementation of Smart Manufacturing in industrial engineering has the potential to significantly change production output and processes, including aspects of time, cost and sustainability. The results of the analysis (Çınar et al., 2021) indicate that the overall maturity score of the company is 2.73 on a scale of 5.00, while the projected time to full implementation of Industry 4.0 is estimated to be in the range of 2031 to 2034, depending on the policies adopted.

This research aims to understand how the implementation of smart factory technologies and concepts can improve efficiency, productivity and flexibility in the production process. In addition, the research will also explore the challenges that may be faced during the journey towards smart factories, both from a technical and organisational perspective, and identify strategies and solutions to overcome these obstacles. With an in-depth understanding of how smart factories can change the industrial landscape, this research is expected to provide valuable guidance and insights for industry stakeholders to plan and execute a successful transformation towards a more adaptive and innovative future.

RESEARCH METHOD

This research method will utilise a literature study approach to collect relevant and in-depth data on the transformation towards smart factories. The first step will involve identifying literature sources including scientific journals, books, articles, research reports, and relevant industry documents that discuss the concepts, technologies, implementation, benefits, and challenges of smart factory development. Subsequently, data from the literature will be systematically analysed to extract key findings, trends and patterns relevant to the research objectives. This approach makes it possible to gain a comprehensive understanding of the smart factory concept, as well as evaluate its successful implementation and impact in the current industrial context. In addition, the literature study also made it possible to access various perspectives and recent research in this domain, which can provide valuable insights to formulate recommendations and practical implications for the industry and future research.

RESULT AND DISCUSSION

Industry 4.0 is the latest industrial revolution concept that incorporates advanced digital technologies in the production process to create smarter, more efficient, and more digitally connected factories (Savitri, 2019). The concept is based on the integration of elements such as the Internet of Things (IoT), big data analytics, artificial intelligence (AI), robotics, and additive manufacturing. With Industry 4.0, the production process undergoes a fundamental transformation.

Industry 4.0 technology has been a key driver in improving efficiency and automation in production processes. One of the key technologies in the Industry 4.0 framework is the Internet of Things (IoT), which connects physical devices to the

internet network for better monitoring and control. Through IoT, companies can collect real-time data from machines and sensors, enabling early detection of machine faults and failures, and optimisation of resource usage. In addition, big data analytics plays an important role in analysing data generated by production processes to gain deeper insights into production performance and market demand. Artificial Intelligence (AI) technology enables systems to make decisions without human intervention that can be used to optimise production processes and detect anomalies automatically. Robotics also plays a crucial role with intelligent robots able to take over repetitive and repetitive tasks, improving production efficiency and accuracy. Finally, additive manufacturing or 3D printing enables the creation of complex components at low cost and in short time, opening the door for further product innovation and customised production. With the integration of these technologies, companies can increase productivity, reduce production costs, and improve their competitiveness in the global market.

The impact of Industry 4.0 technology on the production process is significant, changing the traditional way of production and bringing a huge impact in various aspects. The use of Industry 4.0 technologies such as more advanced automation, robotics, and in-depth data analysis has led to an overall increase in productivity. More efficient and automated production processes allow companies to produce more goods in less time, significantly increasing production output (R. Saputra, 2023).

Better control over the production process and early detection of errors or defects, Industry 4.0 technology has led to improvements in product quality. Integrated monitoring and control systems enable companies to identify and address production issues quickly, reducing the number of defective products and increasing customer satisfaction.

The integration of technologies such as IoT and AI has significantly reduced production cycle times. More accurate monitoring and real-time data analysis enable companies to identify bottlenecks and optimise workflows, reduce the time taken to complete each stage of production, and speed up product delivery time to market.

Further automation makes for more efficient use of resources and better data management, Industry 4.0 technology has resulted in an overall increase in efficiency in the production process. Companies can reduce wastage, both in terms of raw materials and labour, and increase production output without adding much additional cost.

One of the important implications of Industry 4.0 technologies is the ability for innovation in product design and production. With additive manufacturing and the integration of AI in the design process, companies can create more complex products that are individually customisable and innovative, enabling them to compete in an increasingly competitive market.

The application of Technology in Smart Factories has become a new model in modern industry, and a case study can illustrate how the integration of various Industry 4.0 technologies has created an adaptive and responsive production ecosystem. For example, in research by (Ashar et al., 2018) which examines pipe manufacturers. KHI Pipe Industries is a company that produces high-quality steel pipes. In the production

process, the company adapts production to customer demand regarding pipe diameter, thickness, and length. Despite striving to produce high-quality pipes, the possibility of damaged pipes can disrupt the smooth fulfilment of customer demand. This forces the company to incur additional costs for raw materials to compensate for the damaged pipes. The production quantities for each specification are different, making it difficult to accurately predict the number of feasible pipes. Predicting the number of feasible pipes can help companies set production targets. This research uses the Extreme Learning Machine (ELM) method, to predict the feasible production quantity of pipes. The prediction process involves normalisation, training, testing, and denormalisation, and calculates the Mean Square Error (MSE) value to evaluate the prediction accuracy. Through experiments, it was found that the use of 7 hidden neurons, 5 features, and an 80:20 split of training and testing data resulted in the lowest error value, with an average of 0.00372 and a ±1% difference from the actual data.

Another research that has been attempted by (Wang et al., 2016) by planning vertical integration to implement a customisable and flexible smart factory. The initial step is to propose a brief framework that integrates wireless industrial networks, cloud computing, and mobile or fixed terminals with intelligent devices such as machines, products, and conveyors. Next, the operational mechanism from the perspective of engineering control, where intelligent devices form a self-organised system supported by feedback and coordination blocks implemented in the cloud, as well as based on big data analysis. Key technical features and useful results as well as detailed design schemes are presented. The conclusion is that the achievement of Industrie 4.0 smart factories can be made by widely adopting already existing supporting technologies by actively addressing existing technical challenges.

Research conducted by (Ryalat et al., 2023) through the design of intelligent cyber-physical systems in accordance with the innovative smart factory paradigm for Industry 4.0, as well as applying core technologies in industrial, computing, information, and communication smart factories. Through his research, he explains how to integrate the key elements (pillars) of a smart factory to form a smart manufacturing system. As an example of a simplified smart factory model, a case study is conducted on the drilling process in smart manufacturing, where the effectiveness of the proposed method is demonstrated and verified through a series of experiments.

The implementation of Industry 4.0 technology in the transformation to smart factories brings a number of challenges that need to be overcome (Anggraini, 2023). One of the main challenges is the issue of data security, especially due to the large amount of sensitive data generated and used in factory operations (Munawar & Putri, 2020). Data security breaches can result in the theft of confidential company information or disruptions in production operations. In addition, the cost of implementation is another significant barrier, especially since large investments are required to adopt new technologies and change existing infrastructure and processes.

Employee training is also a key factor in successful implementation, as Industry 4.0 technologies require new skills that most of the workforce may not yet possess (Tahar et al., 2022). Companies need to invest time and resources to provide adequate

training to employees so that they can understand and use these new technologies effectively.

System integration is also a challenge that is often faced, especially in integrating different technology platforms in order to operate synergistically and efficiently. It requires a deep understanding of the existing IT infrastructure and how new technologies can be integrated into it without disrupting ongoing operations (Fahad et al., 2024). Therefore, overcoming these challenges and barriers requires careful planning, appropriate investment, and a strong commitment from all parties involved in the transformation to a smart factory.

The transformation to smart factories brings a number of significant benefits and advantages to companies. One of the main benefits is increased efficiency in the production process (Subekti et al., 2024). By adopting Industry 4.0 technologies, such as automation, robotics, and in-depth data analysis, companies can optimise resource usage, reduce production downtime, and increase overall output (D. Saputra et al., 2023). In addition, smart factories also offer a higher degree of production flexibility. The ability to quickly adapt production operations to changes in market demand or product specifications allows companies to be more responsive to customer needs and increasingly fierce market competition (Setiawan et al., 2023). Furthermore, the transformation to smart factories can also result in the reduction of waste in the production process. By using more advanced technologies and more controlled processes, companies can reduce material and energy wastage, and minimise the number of defective or unfit products (Arifin et al., 2023). This not only reduces production costs, but also creates significant environmental benefits. Overall, increased efficiency, production flexibility, and reduced waste bring added value to companies in the form of improved productivity, competitiveness, and sustainability. By taking steps towards smart factories, companies can strengthen their position in the market and prepare themselves for an increasingly connected and automated industrial future.

The use of Industry 4.0 technologies has a significant impact on the workforce, changing the whole way of working. One of the main impacts is the change in skill requirements (Adha, 2020). As production processes are automated and digitalised, workers need to acquire new skills that are more focused on managing and using technology. Skills such as computer programming, data analysis, and automated equipment maintenance are more important than ever. Changes in workers' tasks are also occurring, with more and more tasks being performed by automated systems and robots. Workers tend to shift from routine and repetitive tasks to those that require creativity, problem-solving and human interaction. In addition, automation and digitalisation also have complex socioeconomic implications. While it can improve production efficiency and corporate competitiveness, it can also result in labour shedding in some of the more automated sectors. This fuels concerns about increased structural unemployment and income inequality between skilled and unskilled workers. Therefore, while Industry 4.0 technologies bring a range of benefits in terms of efficiency and productivity, there is a need for thoughtful strategies to manage their

impact on labour, including investment in new skills training and policies that support worker mobility.

A successful implementation strategy in applying Industry 4.0 technologies and transforming production processes towards smart factories requires a holistic and planned approach. One of the key factors supporting successful implementation is the commitment of the company's top leadership to digital transformation. Strong leadership and support from the executive level ensure the allocation of sufficient resources, including budget and personnel to implement new technologies and design the necessary infrastructure. In addition, integration between the various departments and functions of the company is also an important thing to consider. Collaboration between IT, production, supply chain management and human resources departments enables a thorough understanding of implementation needs and challenges. Furthermore, investment in employee training is another important factor. Providing adequate training to employees on the use of new technologies and the skills required to operate in a smart factory environment is an important step in ensuring successful adoption. In addition, flexibility in the face of change and willingness to learn and adapt quickly are also important factors. Companies that are successful in implementing Industry 4.0 technologies typically have a culture that encourages innovation, experimentation and collaborative problem-solving. By implementing an implementation strategy that focuses on leadership commitment, inter-departmental integration, investment in employee training, and an organisational culture that supports innovation, companies can achieve success in transforming production processes towards smart factories.

CONCLUSION

This study illustrates the importance of using Industry 4.0 technologies in transforming production processes towards the concept of smart factories. By analysing various aspects of technologies such as the Internet of Things (IoT), artificial intelligence (AI), robotics, and big data processing, the study presents findings on how the implementation of these technologies can improve operational efficiency, flexibility, and resilience in production environments. By utilising better connectivity between equipment and systems, smart factories can improve real-time monitoring, prediction and control over production processes. This not only results in increased productivity and product quality, but also enables the adoption of a more adaptive and responsive production model to market changes. In conclusion, the use of Industry 4.0 technologies is an important step in advancing industrial transformation towards smart factories that have the potential to bring positive impacts to various industrial sectors in the future.

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