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Analysis and Application of the Internet of Things (IoT) in Cyber Business Actors Pottery MSME Group



Abstract: - The development of Internet technology in the business and industrial world is taking place very quickly in the modern era and the post-millennial era, Post Gen Z is also known as the Alpha generation. This generation grew up amidst continued technological developments, including the presence of artificial intelligence, virtual reality, and the Internet of Things. The development of existing technology in general makes our lives simpler and more practical, in other words the world is within our grasp just by mastering technology and the internet. Several technological model innovations such as the Technology Acceptance Model (TAM) and technology readiness index (TRI), especially social development media technology for users, can help business development. The aim of this research is to Analysis and Application of the Internet of Things (IoT) in Cyber Business Actors Melikan Pottery MSME Group. The output of this research is the implementation of IoTbased technology in Micro, Small and Medium Enterprises Company in Klaten Regency. Analysis and Application of the Internet of Things (IoT) in Cyber Business Actors Melikan Pottery MSME Group can provide convenience and usefulness when running a business in the era of globalization and modernization. To be a sustainable solution, this IoT-based technology model will be patented to make it easier for users to adopt this technology, thereby changing and increasing the socio-economic improvement of the Pottery MSME community in Melikan.

Keywords: IoT, MSMEs, Generation Alpha, Generation Z

INTRODUCTION

Digital transformation has changed the business landscape globally, forcing business actors to continue to adapt to rapid technological developments. One of the prominent technological innovations in the last decade is the Internet of Things (IoT). IoT refers to a network of physical devices connected to the internet, enabling real-time data exchange between devices that support automation and increased operational efficiency. The application of IoT is not limited to large industries, but has also penetrated the Micro, Small, and Medium Enterprises (MSMEs) sector, which is the backbone of the economy in many countries, including Indonesia.

MSMEs play an important role in supporting the Indonesian economy, contributing more than 60% to Gross Domestic Product (GDP) and absorbing around 97% of the workforce. However, MSMEs also face various challenges that limit their competitiveness in the global market, including limited access to technology, funding, and markets. Amid these challenges, the adoption of digital technology such as IoT can be a strategic solution to increase the competitiveness of MSMEs. IoT technology can help MSMEs improve production efficiency, optimize supply chains, and open access to wider markets through integration with e-commerce platforms.

Melikan Pottery, a group of MSMEs focused on the production and sale of pottery crafts, is a relevant example in this context. Melikan Pottery has begun exploring the potential of IoT to improve their operational efficiency and expand their market reach. However, the implementation of IoT in the MSME sector such as Melikan Pottery is not without challenges, including limited technological infrastructure, lack of technical knowledge, and high initial investment costs. (1). Context and Relevance of the Research. In the last decade, various studies have been conducted to explore the impact of digital technology adoption on the MSME sector. These studies show that the use of digital technology, including IoT, can provide various benefits for MSMEs, such as increased operational efficiency, reduced costs, and increased access to global markets. However, most of the existing research is still focused on MSMEs in developed countries, while studies exploring the implementation of IoT in MSMEs in developing countries, especially in Indonesia, are still limited. Melikan Pottery is an interesting example of an MSME in Indonesia that has begun to adopt IoT technology in its operations.

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Melikan Pottery, a group of MSMEs focused on the production and sale of pottery crafts, is a relevant example in this context. Melikan Pottery has begun exploring the potential of IoT to improve their operational efficiency and expand their market reach. However, the implementation of IoT in the MSME sector such as Melikan Pottery is not without challenges, including limited technological infrastructure, lack of technical knowledge, and high initial investment costs. (1). Context and Relevance of the Research. In the last decade, various studies have been conducted to explore the impact of digital technology adoption on the MSME sector. These studies show that the use of digital technology, including IoT, can provide various benefits for MSMEs, such as increased operational efficiency, reduced costs, and increased access to global markets. However, most of the existing research is still focused on MSMEs in developed countries, while studies exploring the implementation of IoT in MSMEs in developing countries, especially in Indonesia, are still limited. Melikan Pottery is an interesting example of an MSME in Indonesia that has begun to adopt IoT technology in its operations. However, there has not been much research that analyzes in depth how IoT is applied in the context of MSMEs in Indonesia, as well as the impacts and challenges faced.

Therefore, this study has high relevance in filling the existing literature gap, as well as providing practical insights for other MSMEs planning to adopt IoT technology. (2). Research Objectives. This study aims to analyze the implementation of IoT in the Melikan Pottery MSME group, focusing on three main aspects: (1) how IoT is implemented in various operational processes at Melikan Pottery, (2) the impact of IoT implementation on Melikan Pottery's operational efficiency and competitiveness, and (3) the challenges faced by Melikan Pottery in adopting this technology. Thus, this study is expected to provide a significant contribution to the development of literature on the implementation of IoT in the MSME sector, as well as provide strategic recommendations that can be implemented by other MSMEs in Indonesia. (3). Significance of the Study. This study has high significance both from a theoretical and practical perspective. From a theoretical perspective, this study contributes to the development of literature on the implementation of IoT in the MSME sector, especially in developing countries such as Indonesia. This study can also be a basis for further studies that focus on the implementation of digital technology in the context of MSMEs in developing countries. From a practical perspective, the results of this study can provide valuable insights for MSMEs, policy makers, and other stakeholders who are trying to encourage the adoption of digital technology in the MSME sector. The findings of this study can also be a reference for Melikan Pottery and other MSMEs in developing effective IoT adoption strategies. (4). Research Structure. This study consists of five main sections.

The first section is the introduction, which provides the background, context, relevance, objectives, and significance of the study. The second section is the literature review, which discusses theories and previous studies relevant to the topic of this study. The third section is the research methodology, which explains the research design, data collection techniques, and analysis methods used. The fourth section is the results and discussion, which presents the research findings and their analysis. The fifth section is the conclusion and recommendations, which summarizes the main findings of the study and provides recommendations for further research and practical implementation. This introduction covers the various elements needed for a comprehensive research article. If necessary, it can expand each section in more detail, adding empirical data, case studies, a broader literature review, and in-depth analysis. It can also develop more specific subsections, such as the history of IoT technology, an analysis of the MSME market, or a comparative study between MSMEs in developing and developed countries in adopting IoT.

LITERATURE REVIEW

In this article, the discussion of the application of the Internet of Things (IoT) in the Melikan Pottery Micro, Small, and Medium Enterprises (UMKM) group focuses on how this technology can optimize business processes in the cyber realm. The following literature review outlines various important aspects underlying this research, including the basic concept of IoT, its application in business, and its implications for the development of UMKM. (1). Internet of Things (IoT). IoT is a concept that connects physical devices via the internet, enabling the collection and exchange of data in real time. According to [reference], IoT has great potential in improving operational efficiency, reducing costs, and creating new business opportunities. IoT includes various technologies such as sensors, RFID, and smart devices that are integrated with network systems to support automation and data analysis. (2). Application of IoT in Business. The application of IoT in business has been widely discussed in the literature [reference]. IoT allows businesses to monitor operational conditions, track products, and optimize supply chains. In the context of UMKM, IoT can help improve production efficiency, reduce waste, and enable faster and more accurate decision making based on available data. (3). IoT in MSME Development. MSMEs face unique challenges in adopting advanced technologies such as IoT, especially related to limited resources and technological knowledge [reference]. However, research shows that MSMEs that successfully implement IoT can gain a competitive advantage through increased productivity and product innovation. IoT can also help MSMEs expand

their markets and improve the quality of service to customers. (4). Case Study: Melikan Pottery MSME Group. Melikan Pottery is one of the MSME groups engaged in clay-based handicrafts. The application of IoT in this group can include monitoring the production process, inventory management, and sales data analysis. Case studies related to the implementation of IoT in this sector show that this technology can help reduce production costs, improve product quality, and expand market reach [reference]. (5). Implications of IoT on Cyber Business. Cyber business refers to a business model that utilizes digital technology to support operations and interactions with customers [reference]. The application of IoT in the context of cyber business allows MSMEs such as Melikan Pottery to integrate physical operations with digital platforms, enabling more effective business monitoring and management. This can improve the ability of MSMEs to compete in the global market. (6). Challenges and Opportunities for Implementing IoT in MSMEs

Although IoT offers many advantages, its adoption in MSMEs still faces various challenges such as high investment costs, limited infrastructure, and the need for deeper technological knowledge [reference]. However, the opportunities offered by IoT, such as increased operational efficiency and new product development, make it an important area for MSMEs to explore further. (7). Conclusion. This literature review shows that IoT has great potential in supporting the development of MSMEs, especially in the context of cyber business. Its implementation in MSME groups such as Melikan Pottery can provide various benefits ranging from increased efficiency to market expansion. However, further research is needed to fully understand the challenges faced and the best way to overcome barriers to the adoption of this technology.

1. Concept and History of the Internet of Things (IoT)

Basic understanding of IoT, history of development, and supporting technologies for IoT such as sensors, wireless networks, and cloud computing. Focus on the definition of IoT according to several technology experts, for example according to Atzori, Iera, and Morabito (2010), who define IoT as a technology paradigm that allows physical objects to communicate over a network without human intervention. Discusses the milestones in the development of IoT, from simple connected devices to a more complex global network stage. Stages of IoT progress, from the initial concept starting from RFID to the era of cloud and edge computing (Gubbi et al., 2013). Describes the main components of IoT such as sensors, actuators, communication devices, and how each of these components works together to create an IoT ecosystem (Xu et al., 2014).

2. Application of IoT in Various Business Sectors

Utilization of IoT in industrial automation, machine condition monitoring, and predictive maintenance.

Case studies of IoT implementation in smart factories (Khan et al., 2012). Use of IoT for agricultural land monitoring, smart irrigation, and automatic fertilization systems. Case studies of IoT implementation in precision agriculture and how it improves crop yields (Wolfert et al., 2017). IoT implementation in healthcare, remote patient health monitoring, and telemedicine. Examples of IoT applications in patient vital sign monitoring systems and wearable devices (Islam et al., 2015). How IoT is implemented in supply chain systems, logistics, and shipping. Case studies on tracking shipments using RFID technology and IoT sensors (Rüßmann et al., 2015).

3. Cyber Business: Definition and Digital Transformation

Exploring the meaning of cyber business and the differences between cyber business and traditional e-commerce. Discussion of digital transformation, its impact on traditional business models, and how new technologies such as IoT are accelerating change (Verhoef et al., 2021). IoT's impact on customer experience, personalization, and data-driven service enhancement. Case studies on Amazon, Alibaba, or other e-commerce companies implementing IoT (Lee et al., 2017).

4. MSMEs: Definition, Characteristics, and Challenges in Implementing IoT

Definition of MSMEs according to various authorities, such as the World Bank, OECD, and the Indonesian government. Analysis of the contribution of MSMEs to the global economy and how technology plays a role in driving the growth of the MSME sector (OECD, 2020). Challenges faced by MSMEs in the process of digitalization and implementation of new technologies such as IoT. Discussion of the lack of access to technology, limited resources, and security and privacy issues (Borgia, 2014).

5. Implementation of IoT in the Melikan Pottery Group MSMEs

Explanation of the history and characteristics of the Melikan Pottery group business, as well as the importance of handicrafts in local culture and economy. Use of IoT sensors to monitor temperature, humidity, and environmental conditions of pottery production. Automatic monitoring of raw materials with IoT to increase production efficiency (Iansiti & Lakhani, 2014). Utilization of IoT-based e-commerce platforms to connect products with

consumers directly. Example of IoT use in stock management and supply chains in MSMEs (Madakam et al., 2015).

6. Analysis of the Benefits and Challenges of IoT Implementation in Pottery MSMEs

Analysis of the advantages in cost efficiency, improving product quality, and expanding the global market. Technical and financial challenges, and lack of workforce skills in dealing with new technologies (Weber, 2010). Analysis of strengths, weaknesses, opportunities, and threats in the implementation of IoT (Yerpude & Singhal, 2018). Discuss security threats such as hacking, malware, and data breaches in IoT. Examples of security breach cases on IoT devices and solutions to overcome them (Sicari et al., 2015). Risk mitigation measures, such as data encryption, firewalls, and cloud-based security monitoring.

7. Case Studies of MSMEs That Have Successfully Used IoT

Discussing successful examples of MSMEs in Indonesia that have successfully adopted IoT in their businesses. Comparative study with MSMEs in other countries that have also implemented IoT in production and distribution (Kim et al., 2019). Drawing conclusions from various literature studies regarding the positive and negative impacts of IoT in the MSME sector. Recommendations for the government, MSME actors, and technology developers in increasing the adoption of IoT in the MSME sector.

RESEARCH METHOD

The case study method is the most appropriate method for research entitled "Analysis and Application of the Internet of Things (IoT) in Cyber Business Actors: Melikan Pottery MSME Group". Here are the reasons: (1). Contextual and In-depth Approach. Rationale: Case studies are suitable for examining IoT applications in a specific context, namely the Melikan Pottery MSME group. This study can explore the application of IoT in depth and in a real environment, including the challenges and benefits for the MSME. Advantages: Case studies allow researchers to understand how IoT technology is integrated into the Melikan Pottery MSME business operations and its impact on efficiency, production, distribution, marketing, and customer interaction. (2). Use of Various Data Sources. Rationale: Case studies allow the use of various data collection techniques, such as in-depth interviews with MSME actors, direct observation of IoT implementation, analysis of business documents or reports, and surveys or questionnaires. Advantages: This combination of qualitative and quantitative data will provide a more comprehensive picture of how IoT is implemented in the MSME group and how the technology interacts with business processes. (3). Focus on the Adoption Process and Impact of IoT. Rationale: Case studies allow a strong focus on the IoT adoption process in Melikan Pottery MSMEs. Research can trace the stages of adoption, strategic decisions, and changes resulting in business models, stock management, and interactions with the market. Advantages: Can provide practical recommendations for other MSMEs who want to adopt IoT, based on Melikan Pottery's experience. (4). Richer Contextual Analysis. Rationale: With case studies, analysis can consider local conditions, such as limitations in technology infrastructure, HR readiness at Melikan Pottery, or local market responses to IoT implementation. Advantages: This approach provides flexibility to consider social, economic, and cultural factors that influence technology adoption in MSMEs. (5). Ability to Explain Long-Term Impacts. Rationale: Case studies allow researchers to evaluate the impact of IoT implementation in the long term, both in terms of finance, operations, and customer satisfaction. Advantages: Can produce relevant findings to understand the long-term benefits of IoT adoption by MSME groups. By using case studies, the research will provide rich contextual and empirical insights regarding IoT applications in the operations of Melikan Pottery MSMEs, while also generating recommendations for other MSMEs who wish to implement similar technologies. Preference Level The alternative preference value for each attribute is determined by the alternative decision-maker. A score of 100 is assigned to the i th alternative reference value on the j th largest attribute. Conversely, the j th lowest attribute's i th alternative reference value is assigned a score of 0.

RESULT AND DISCUSSION

Criteria and Alternative Analysis

In analyzing the implementation and application of Internet of Things (IoT) within the Melikan Pottery MSME Group in a cyber business environment, it is essential to evaluate the criteria for successful IoT integration and assess the available alternatives for optimal implementation. The section discusses both the evaluation criteria and the alternatives considered to ensure effective and sustainable IoT adoption within the MSME group. (1). **Criteria for IoT Implementation.** The criteria for evaluating the success of IoT implementation in the Melikan Pottery MSME group are based on a set of key factors that directly impact business operations, productivity, and competitiveness. These factors can be broadly categorized as follows: (1.1). **Cost-Effectiveness.** One of the

primary criteria for evaluating the feasibility of IoT adoption is its cost-effectiveness. Implementing IoT requires investment in hardware (sensors, devices), software (platforms, analytics tools), and infrastructure (network connectivity, cloud storage). For small-scale businesses like Melikan Pottery, the cost of IoT deployment must justify the expected returns in terms of increased productivity, reduced operational costs, and enhanced market competitiveness. **Initial setup costs:** This includes the procurement of IoT devices, installation, and system integration. MSMEs often face budgetary constraints, making this a crucial evaluation factor. **Maintenance and operational costs:** IoT systems require regular maintenance to ensure data accuracy and device functionality. Maintenance costs and ongoing support are critical to consider for long-term sustainability. **(1.2). Efficiency Improvement.** IoT should contribute to improving the efficiency of production processes, inventory management, and overall business operations. Efficiency gains can be measured in terms of: **Production monitoring:** The ability of IoT systems to track environmental variables such as humidity and temperature, which affect the quality of pottery during the drying process. **Automation:** Reducing manual intervention in tasks such as inventory tracking, supply chain management, and product quality control can lead to time savings and error reduction. **Data-driven decision-making:** Access to real-time data can enable better decision-making in resource allocation, demand forecasting, and production scheduling. **(1.3). Scalability.** The scalability of IoT systems is essential for MSMEs like Melikan Pottery, which may have plans to grow and expand their market reach. The IoT infrastructure must be scalable enough to handle increased production capacity, additional devices, and a larger volume of data without significant modifications or additional costs. **Scalability of IoT platforms:** The cloudbased IoT platforms chosen should be capable of expanding alongside the business without requiring complete overhauls. **Integration with new technologies:** As IoT technology continues to evolve, the selected system must be able to integrate with new advancements, such as AI-based analytics or blockchain for supply chain transparency. **(1.4). Usability and Accessibility.** For effective implementation, the IoT system should be userfriendly and accessible to the workforce. Considering the varying levels of technical proficiency within the Melikan Pottery MSME group, the system must: **Ease of use:** Be designed with intuitive interfaces, minimal technical jargon, and easy-to-use mobile applications for real-time monitoring. **Training and support:** Providing proper training to the workers and managers on how to operate and troubleshoot IoT systems is crucial for longterm success. **Remote access:** Allow business owners or managers to monitor operations remotely, which can be beneficial when managing multiple production facilities or when away from the business site. **(1.5). Security and Data Privacy.** Security is a critical concern when adopting IoT in any business, especially MSMEs that may not have dedicated IT security teams. The selected IoT solution must address the following security aspects: **Data protection:** The system must ensure the confidentiality of business data, especially related to proprietary pottery-making techniques or sensitive customer information. **Device security:** Ensuring the security of IoT devices against tampering or hacking, as these devices can be vulnerable to cyberattacks. **Data ownership and privacy:**

Clearly defined policies on data ownership and usage should be established to protect the MSME's interests. **(2). Alternative IoT Solutions for MSME Group**

Given the criteria outlined above, the following alternatives for IoT implementation in the Melikan Pottery MSME group were evaluated: **(2.1). Off-the-Shelf IoT Solutions.** Off-the-shelf IoT solutions refer to pre-built, commercial IoT platforms and devices readily available in the market. These solutions are generally designed for small businesses and come with a range of functionalities, including sensors, cloud storage, and analytics tools. Some well-known providers include Amazon Web Services (AWS IoT), Google Cloud IoT, and Microsoft Azure IoT. **Advantages:** Ready-to-use: Pre-configured systems allow for quicker deployment; Comprehensive support: These platforms come with customer support, training resources, and troubleshooting assistance; Integration with existing tools: These solutions often integrate seamlessly with existing business tools such as accounting software, CRM, and supply chain management systems. **Disadvantages:** Cost: The subscription fees for cloud storage and analytics can add up over time; Limited customization: These solutions may not be tailored to the specific needs of pottery production, limiting their flexibility. **(2.2). Customized IoT Solutions**

Customized IoT solutions involve developing bespoke systems that are tailored to the unique needs of the MSME group. These systems are designed from the ground up to suit specific production processes, monitoring needs, and business requirements. **Advantages:** Flexibility: Customized systems can be designed specifically for the pottery production process, including monitoring of environmental variables such as kiln temperature and drying conditions; Full control: The MSME has greater control over the data generated and the system's overall functionality, allowing for specific adjustments and enhancements; Scalability: Customized systems can be scaled more efficiently based on the unique business needs of the MSME. **Disadvantages:** Higher initial costs: The development of a custom IoT system requires significant upfront investment in terms of both money and time; Maintenance complexity: The MSME group would need dedicated IT support to maintain the system and handle any operational issues. **(2.3) Hybrid Solutions.** A hybrid approach involves using a combination of off-the-shelf

IoT platforms and custom-developed modules for specific functions that are critical to the MSME’s operations. This provides the flexibility of customization where needed while taking advantage of existing, cost-effective solutions. **Advantages:** Best of both worlds: Combines the flexibility of customization with the affordability of off-the-shelf solutions; Cost-effectiveness: Reduces development costs by leveraging ready-made platforms for general purposes, such as data storage and basic analytics; Tailored functionality: Custom modules can be developed for critical operations such as monitoring kiln temperature or inventory tracking. **Disadvantages:** Integration challenges: The integration of custom and off-the-shelf solutions can sometimes result in compatibility issues; Complexity: Managing a hybrid system may require more advanced technical skills. **(3). Evaluation of Alternatives.** To determine the best alternative for the Melikan Pottery MSME group, the criteria mentioned earlier (cost-effectiveness, efficiency improvement, scalability, usability, and security) were applied to each of the proposed solutions. The following factors were evaluated: **(3.1). Cost Comparison. Off-the-Shelf Solutions:** While off-the-shelf solutions come with predictable subscription models, the long-term costs may be higher due to ongoing fees for cloud storage and additional services; **Customized Solutions:** These require a higher initial investment, but the long-term costs can be controlled, and the MSME owns the system outright; **Hybrid Solutions:** Provides a balance between upfront investment and ongoing costs, offering flexibility without requiring full customization from the start. **(3.2). Efficiency and Functionality: Off-the-Shelf Solutions:** These solutions are general-purpose and may not offer specific functionality needed for pottery production, such as environmental monitoring for kilns; **Customized Solutions:** Can be designed specifically for pottery production, ensuring that all operational needs are met; **Hybrid Solutions:** Custom modules can be developed for critical functions while relying on off-the-shelf components for general purposes. **(3.3). Scalability: Off-the-Shelf Solutions:** These platforms are highly scalable, with most cloud providers offering unlimited capacity for data and devices; **Customized Solutions:** Scalability depends on the architecture of the system, but it can be designed to grow with the business; **Hybrid Solutions:** Offers a scalable approach by leveraging cloud services for storage and custom solutions for specific operational needs. **(3.4). Usability and Accessibility: Off-the-Shelf Solutions:** These platforms are generally user-friendly, with intuitive interfaces and customer support; **Customized Solutions:** The usability depends on the design and user training, requiring more effort to set up but offering a tailored experience; **Hybrid Solutions:** A hybrid solution provides flexibility in usability, offering user-friendly interfaces for standard tasks and customized modules for specific needs. **(3.5). Security and Data Privacy : Off-the-Shelf Solutions:** These solutions typically come with robust security protocols but may limit control over data privacy; **Customized Solutions:** Custom solutions can provide enhanced security tailored to the business’s specific needs; **Hybrid Solutions:** By combining off-the-shelf security protocols with custom security measures, hybrid solutions can offer a balanced approach to data privacy. **(4). Discussion and Final Recommendations.** Based on the evaluation of the criteria and alternatives, the hybrid IoT solution appears to be the most suitable for the Melikan Pottery MSME group. This approach offers a balance between cost, functionality, scalability, and security, allowing the business to tailor specific modules to their unique production processes while leveraging the scalability and cost-effectiveness of off-the-shelf platforms. Moreover, the hybrid approach enables the MSME to scale as their operations grow, making it a future-proof investment in technology.

Application of the MACBETH Method

The MACBETH (Measuring Attractiveness by a Categorical Based Evaluation Technique) method involves transforming qualitative judgments into quantitative scores to evaluate alternatives against a set of criteria. In the context of evaluating the best IoT solution for the Melikan Pottery MSME Group, we will apply this method in six steps:

A. Decision Matrix

The first step is to create a decision matrix that presents the alternatives and their performance against each criterion. For this analysis, the three alternatives considered are: (1). Off-the-Shelf IoT Solution; (2). Customized IoT Solution; (3). Hybrid IoT Solution. The criteria being considered are: Cost-Effectiveness (C1); Efficiency Improvement (C2); Scalability (C3); Usability (C4); Security (C5). Each alternative will be evaluated using a qualitative scale (e.g., Poor, Fair, Good, Very Good, Excellent) in the matrix:

Criteria	Off-the-Shelf IoT Solution	Customized IoT Solution	Hybrid IoT Solution
Cost-Effectiveness (C1)	Very Good	Good	Very Good
Efficiency Improvement (C2)	Good	Excellent	Very Good
Scalability (C3)	Excellent	Good	Excellent
Usability (C4)	Very Good	Good	Very Good
Security (C5)	Good	Excellent	Very Good

B. Weigh Attributes

The next step is to assign weights to each criterion based on its relative importance. For this example, the assumed weights are: Cost-Effectiveness (C1): 25%; Efficiency Improvement (C2): 20%; Scalability (C3): 20%; Usability (C4): 15%; Security (C5): 20%. These weights reflect the priorities of the MSME group in terms of balancing costs, efficiency, scalability, ease of use, and security.

C. Converting Semantic Scale into Numerical Scale

To convert qualitative judgments (e.g., Very Good, Good, etc.) into numerical values, the following semantic scale can be used: Excellent = 5; Very Good = 4; Good = 3; Fair = 2; Poor = 1. Now, we convert the decision matrix into a numerical format:

Criteria	Off-the-Shelf IoT Solution	Customized IoT Solution	Hybrid IoT Solution
Cost-Effectiveness (C1)	4	3	4
Efficiency Improvement (C2)	3	5	4
Scalability (C3)	5	3	5
Usability (C4)	4	3	4
Security (C5)	3	5	4

D. Value of Reference Level

In MACBETH, the reference level is used to determine the "value" associated with each alternative relative to the criteria. The reference level is typically the lowest performance score in each criterion, and it serves as a baseline for comparisons. In this case, for each criterion: Cost-Effectiveness: The lowest value is 3 (Good); Efficiency Improvement: The lowest value is 3 (Good); Scalability: The lowest value is 3 (Good); Usability: The lowest value is 3 (Good); Security: The lowest value is 3 (Good); Thus, for each criterion, we use 3 (Good) as the reference level.

E. The MACBETH Score (V)

The MACBETH scores (V) are derived by comparing the performance of each alternative to the reference level. For each criterion, the relative attractiveness of an alternative over the reference level is calculated by subtracting the reference score from the alternative's score. For example: Off-the-Shelf IoT Solution for Cost-Effectiveness (C1): $V=4-3=1$; Repeat this process for all criteria and alternatives:

Criteria	Off-the-Shelf IoT Solution	Customized IoT Solution	Hybrid IoT Solution
Cost-Effectiveness (C1)	1	0	1
Efficiency Improvement (C2)	0	2	1
Scalability (C3)	2	0	2
Usability (C4)	1	0	1
Security (C5)	0	2	1

F. Calculation of Final Ranking Score

The final ranking score is calculated by multiplying the MACBETH scores (V) by the weight of each criterion and summing them for each alternative.

Off-the-Shelf IoT Solution:

$$(1 \times 0.25) + (0 \times 0.20) + (2 \times 0.20) + (1 \times 0.15) + (0 \times 0.20) = 0.25 + 0 + 0.40 + 0.15 + 0 = 0.80$$

$$(1 \times 0.25) + (0 \times 0.20) + (2 \times 0.20) + (1 \times 0.15) + (0 \times 0.20) = 0.25 + 0 + 0.40 + 0.15 + 0 = 0.80$$

Customized

IoT Solution:

$$(0 \times 0.25) + (2 \times 0.20) + (0 \times 0.20) + (0 \times 0.15) + (2 \times 0.20) = 0 + 0.40 + 0 + 0 + 0.40 = 0.80$$

$$(0 \times 0.25) + (2 \times 0.20) + (0 \times 0.20) + (0 \times 0.15) + (2 \times 0.20) = 0 + 0.40 + 0 + 0 + 0.40 = 0.80$$

Hybrid IoT

Solution:

$$(1 \times 0.25) + (1 \times 0.20) + (2 \times 0.20) + (1 \times 0.15) + (1 \times 0.20) = 0.25 + 0.20 + 0.40 + 0.15 + 0.20 = 1.20$$

$$(1 \times 0.25) + (1 \times 0.20) + (2 \times 0.20) + (1 \times 0.15) + (1 \times 0.20) = 0.25 + 0.20 + 0.40 + 0.15 + 0.20 = 1.20$$

G. Result Interpretation

Based on the weighted total scores, the Hybrid IoT Solution achieves the highest score (4.20), followed by both the Off-the-Shelf IoT Solution (3.80) and the Customized IoT Solution (3.80). The hybrid solution balances cost-effectiveness, scalability, and security while also offering the benefits of customization for specific operational needs. This makes it the most suitable alternative for the Melikan Pottery MSME group. Key Insights: Cost Effectiveness: The Off-the-Shelf and Hybrid IoT solutions scored well in cost-effectiveness due to their lower initial setup costs compared to the fully customized solution; Efficiency Improvement: The customized solution performs the best here, as it can be tailored specifically to the pottery production process; Scalability: Both Off-the-Shelf and Hybrid IoT solutions score high in scalability, as these systems typically rely on cloud infrastructure that easily scales with business needs; Usability: Off-the-shelf and hybrid solutions score higher in usability because they generally offer more user-friendly interfaces compared to custom-built systems that may require more technical knowledge; Security: The customized IoT solution scored highest in security, as it can be designed with specific security features tailored to the MSME's needs.

CONCLUSION

Based on the MACBETH method and the calculated final ranking scores, the Hybrid IoT Solution achieves the highest score (1.20), followed by both the Off-the-Shelf IoT Solution (0.80) and the Customized IoT Solution (0.80). Key Insights: The Hybrid IoT Solution provides a balanced approach that leverages the strengths of both off-the-shelf and customized solutions; The Off-the-Shelf IoT Solution and the Customized IoT Solution are tied in performance, with the off-the-shelf solution excelling in scalability, while the customized solution excels in efficiency improvement and security. Thus, the Hybrid IoT Solution is the most suitable alternative for the Melikan Pottery MSME group, as it offers the best combination of cost, efficiency, scalability, and security. The **Hybrid IoT Solution** emerges as the most balanced and effective option for the Melikan Pottery MSME group. It provides a good combination of cost-effectiveness, scalability, and ease of use, while still allowing for customization to meet specific production requirements. This approach ensures that the MSME can benefit from IoT technologies without facing the higher costs and complexities associated with fully customized solutions.

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