GIS Combined with Multivariate Analysis in Supporting Digitalization Supply Chain Management of Halal Products: The Case Study of MSMEs in West Java Indonesia

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ABSTRACT

Micro, Small, and Medium Enterprises (MSMEs) struggle to compete in the global market, especially those producing halal products. Information system support is one solution that can solve the complex supply chain problem from producers to consumers. The objective of this study is to develop a Geographic Information System (GIS) supported by multivariate analysis for the digitalization of Supply Chain Management (SCM) of halal products in MSMEs located in West Java, Indonesia. Six attributes were evaluated: information technology, human resources, collaborative relationship, halal certificate, and SCM implementation as independent variables, and halal products as dependent. The results of the ANOVA test show that the six attributes are significantly different (p<5%). In addition, based on the Pearson correlation, only the collaborative relationship, human resources, and halal certificate attributes correlate more than 80%. The SCM analysis shows that supplier, manufacturing, and raw materials factors are the main levers in the halal product supply chain. A GIS-based information system was successfully developed, with satisfactory user acceptance results for usability, efficiency, reliability, and functionality. The results of this study indicate that this GIS-based system can help distribute halal products in MSMEs, especially those in the West Java area, Indonesia.

Keywords-case study; GIS; halal product; MSMEs; SCM

I. INTRODUCTION

The growth of halal products worldwide has intensified due to the increasing consumer demand and the global expansion of halal markets. This trend is particularly prominent in Indonesia, where halal certification is essential for many goods, and Micro, Small, and Medium Enterprises (MSMEs) play a crucial role in meeting this demand. However, MSMEs often struggle to compete in broader markets, especially in managing supply chains from production to final distribution [1]. Limited resources and technology adoption hinder their ability to efficiently coordinate the supply chain, leading to gaps in production, logistics, and market reach [2]. These challenges emphasize the importance of strengthening digital solutions to enhance the competitiveness of MSMEs and meet the complex requirements of the halal product industry.

Figure 1 shows the distribution of MSMEs in regions such as West Java, East Java, and Central Java. Despite their numbers, many MSMEs lack structured Supply Chain Management (SCM) frameworks to support their operations. According to [3, 4], the absence of systematic digital tools hinders these companies from optimizing their resources and fully participating in the competitive halal market. This gap presents a unique research opportunity to explore and implement digitalization strategies that could bridge this divide, empowering MSMEs in prominent regions to become significant players in the halal product supply chain.

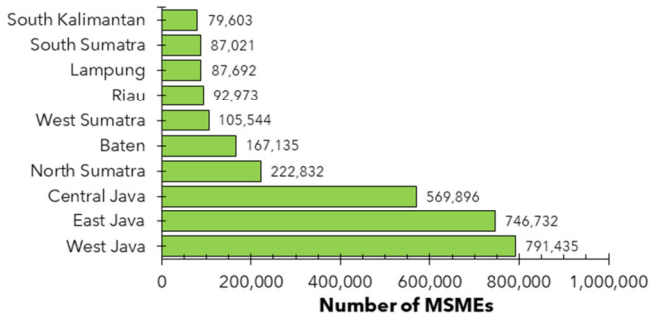

Fig. 1. Top ten provinces with the largest number of MSMEs in Indonesia in 2019 [5, 6].

Integrating Geographic Information Systems (GIS) into SCM can provide significant advantages, particularly for halal products that require traceability and authenticity. GIS allows for geographical data analysis and real-time monitoring [7], which can improve transparency [8], resource management [9], and decision-making processes [10]. However, there is a scarcity of research exploring the integration of GIS and multivariate analysis to address SCM challenges in the halal industry. There is a research gap in developing and implementing GIS-based solutions specifically tailored to the unique SCM requirements of halal products, particularly for MSMEs in regions such as West Java.

Moreover, implementing multivariate analysis in SCM allows businesses to recognize intricate relationships among various SCM factors, thus enhancing their analytical capabilities. This method can facilitate a deeper understanding of how the efficacy of SCM in the halal industry is influenced by independent attributes, including human resources and information technology [11, 12]. However, there is a lack of research on integrating multivariate analysis with GIS to enhance SCM in halal product MSMEs. By addressing this research gap, it is possible to improve SCM strategies, improve coordination among supply chain actors, and ultimately support the digital transformation of the halal product supply chain.

MSMEs play a pivotal role in the global economy, especially in developing countries, by significantly contributing to economic growth and employment [13]. Despite their importance, MSMEs face numerous challenges, such as limited resources, inadequate access to advanced technology, and difficulties in securing financing, which hinder their competitiveness [14]. Adopting SCM strategies and digital tools is crucial to overcome these obstacles. Digital SCM methods, including GIS, offer promising solutions to optimize logistics and resource allocation. However, financial and technical constraints result in low adoption rates among MSMEs [15]. GIS technology, widely used in various fields, enhances operational efficiency by facilitating data-driven decision-making and optimizing routing, which can significantly benefit MSMEs, particularly in the halal product sector [16, 17].

Furthermore, integrating SCM and halal standards is vital for MSMEs to ensure compliance and competitiveness in the growing halal market [18]. Web-based information systems offer substantial advantages to MSMEs by improving cost-effectiveness, efficiency, and accessibility, enabling real-time operations management and stakeholder communication [19]. Performance measurement through Key Performance Indicators (KPIs) is essential to ensure these systems align with business objectives and user expectations [20]. High user satisfaction, a critical metric for system effectiveness, promotes system adoption and operational efficiency, thus supporting the sustainable growth of MSMEs [21]. By leveraging these digital tools and strategies, MSMEs can improve their resilience and access to larger markets, ultimately contributing more significantly to local and global economies.

This study aimed to develop a GIS-based system, coupled with multivariate analysis, to enhance SCM for halal products in West Java's MSMEs. The goal was to create a comprehensive digital solution that integrates tracking, analysis, and SCM optimization tailored to the standards of halal products. This research could significantly affect MSMEs, allowing them to overcome resource limitations and improve competitiveness in local and international halal markets. The resulting system could be a model for similar initiatives, encouraging digitalization and SCM improvements in halal product sectors beyond Indonesia.

II. METHODOLOGY

A. Research Design and Data Acquisition

Figure 2 illustrates the sequential stages involved in the data acquisition and analysis process, describing the research design in this investigation. The flowchart starts with a feasibility assessment to ensure the practicality of the available resources and methods. The data collection process was initiated after determining that the approach was viable, and an initial evaluation was performed to verify that the results were consistent with the anticipated outcomes. The procedure advanced to a quality evaluation stage where the results met the expected criteria. Data that successfully passed the quality assessment were subjected to additional analysis, while errors or issues required a review and correction phase. This structured approach ensured that each stage was systematically validated, enhancing the accuracy and reliability of analyzing the factors influencing halal product SCM in MSMEs.

This research was carried out in Bogor (West Java, Indonesia), a strategically located city close to the campus of the consortium team leader, which ensured that local MSMEs were engaged in a targeted and accessible way. Bogor's proximity facilitates the efficient accumulation of data and collaboration with approximately 15,000 certified MSMEs,

rendering it an optimal location for this investigation. Data were gathered on six critical attributes relevant to the digitalization of halal product SCM. The dependent variable was halal products, while the independent variables were information technology, human resources, collaborative relationships, halal certification, and SCM implementation. This targeted data acquisition facilitates a thorough examination of the factors influencing the effective distribution of halal-certified products in Bogor's MSMEs.

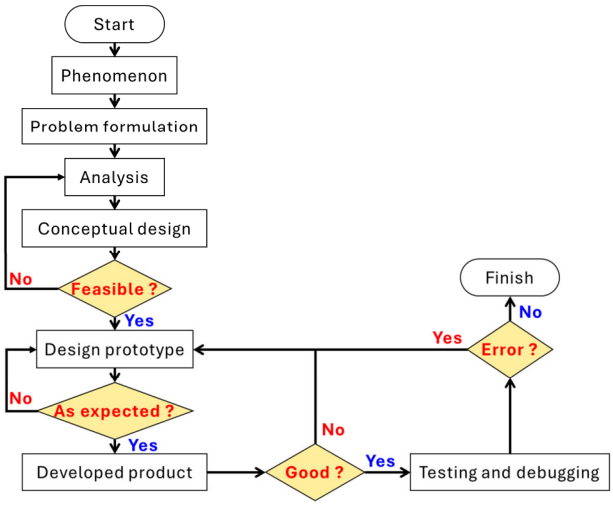

Fig. 2. Flowchart of research design in this investigation.

B. Multivariate Analysis

This study used multivariate analysis to examine the intricate relationships between various attributes that influence the management of halal products in the supply chain of MSMEs. Among the methods implemented, the Pearson correlation coefficient was indispensable to assess the intensity and direction of linear relationships between variables [22]. This statistical measure offered perspective on the correlation between the dependent variable, halal products, and independent variables, including information technology, human resources, collaborative relationships, halal certification, and SCM implementation. This analysis emphasized the critical attributes that substantially influence the efficacy of SCM by identifying correlations that exceed a threshold. Pearson's correlation facilitated the development of a more targeted and efficient GIS-based system for MSMEs by facilitating a nuanced understanding of attribute interdependencies.

C. Statistical Test Analysis

The objective of the statistical test analysis was to assess the impact of independent attributes on the dependent variable, halal products, by applying Analysis Of Variance (ANOVA). This analysis evaluates statistically significant variations in the mean values of the performance of halal products at various levels of independent attributes. Information technology, human resources, collaborative relationships, halal certification, and SCM implementation are among the attributes assessed. ANOVA assists in identifying the factors that produce substantial variations in the outcomes of halal products by computing F-values and comparing them with critical thresholds [23]. This statistical method establishes a strong foundation for identifying priority areas in the SCM of MSMEs, facilitating targeted enhancements, and increasing overall effectiveness.

III. RESULTS AND DISCUSSION

A. Data Description

Table I presents the data used in this study, including a detailed ANOVA to evaluate the impact of independent attributes on the halal product supply chain. The performance of halal products was substantially influenced by information technology, human resources, collaborative relationships, halal certification, and SCM implementation, as evidenced by the ANOVA results, which have a high F-value of 11.55 for regression. These results are consistent with prior research that underscored the importance of competent human resources and technological integration in improving supply chain efficiency [24]. The observed variance in attributes underscores the necessity of customized SCM strategies in MSMEs, consistent with prior research that advocates personalized approaches to address specific supply chain challenges in halal-certified products.

TABLE I. ANOVA FROM INDEPENDENT ATTRIBUTES.

Source of variation	Degree of freedom	Sum of squares	Mean squares	F-value
Regression	5	19.84	3.97	11.55
Residual	48	16.49	0.34	
Total	53	36.34		

The relationships among information technology, human resources, collaborative relationships, halal certification, SCM implementation, and halal products are illuminated by the multiple pairwise bivariate distributions between the evaluated attributes in Figure 3. The distribution diagrams demonstrate discrete aggregation patterns and varying degrees of association between attributes. For instance, there is a discernible correlation between collaborative relationships and human resources, which, according to prior research, suggests that competent human capital is essential for developing effective partnerships within supply chains [25]. Furthermore, previous research substantiates the interdependence of attributes such as halal certification and SCM implementation and underscores the importance of structured SCM practices in ensuring halal compliance [26]. The significance of a comprehensive approach in SCM strategies for MSMEs is highlighted by these bivariate analyses, which emphasize the complex relationships that influence the performance of halal products.

Figure 4 shows a heatmap of the Pearson correlation coefficients for all attribute pairings, illustrating the intensity and direction of the relationships among the variables. Notably, there is a strong correlation of 0.87 between SCM implementation and collaborative relationships and a high positive correlation of 0.82 between human resources and cooperative relationships. These correlations are consistent with prior research that indicated that competent human

resources and effective collaboration are essential to improve SCM efficiency [27]. Additionally, the findings that structured SCM processes are essential to maintain halal compliance are substantiated by the strong relationship of 0.83 between SCM implementation and halal certification. The heatmap underscores the critical interdependencies within the MSMEs' supply chains, emphasizing the attributes that substantially affect the reliability and efficacy of halal product management.

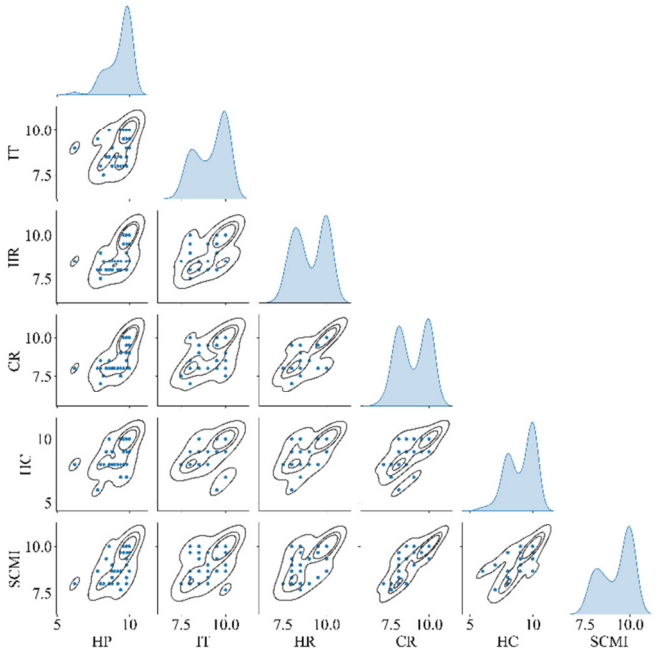

Fig. 3. Plot multiple pairwise bivariate distributions between attributes in the data (HP: Halal Products, IT: Information Technology, HR: Human Resources, CR: Collaborative Relationship, HC: Halal Certificate; SCMI: SCM Implementation).

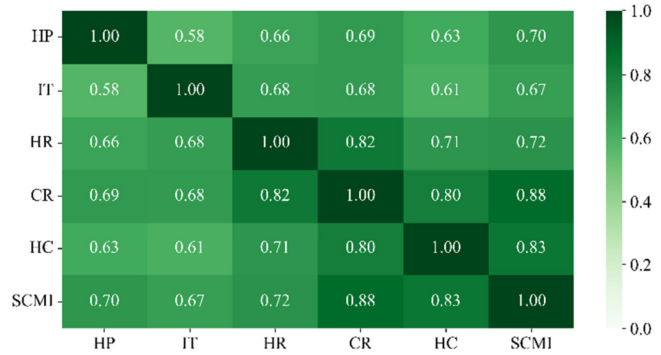

Fig. 4. Feature correlation matrix and heatmap of Pearson correlation coefficient for all attribute pairs.

B. Actors of MSMEs in SCM

Figure 5 presents the distribution of MSME actors across different supply chain stages, including raw materials, suppliers, manufacturers, distributors, retailers, and end users. The mapping reveals that suppliers and manufacturers are the most prominent actors, with 25 and 21 entities, respectively, highlighting their crucial roles in maintaining the flow of halal-certified products. These findings are consistent with previous studies, highlighting the importance of reliable suppliers and efficient manufacturing processes in ensuring product quality and compliance within halal supply chains [28]. The relatively large number of retailers and end users on the map reflects the niche market for halal products and the importance of streamlined distribution. This mapping underscores the need for coordination among supply chain actors to enhance overall SCM efficiency for halal products in MSMEs.

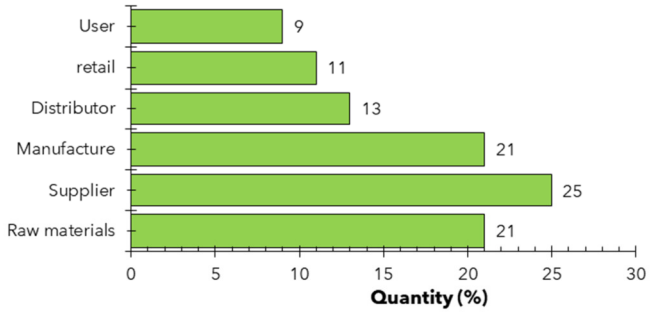

Fig. 5. Results of observations of mapping of MSME actors in SCM.

C. Information System Design

Figure 6 illustrates the class diagram of the developed information system designed to support MSMEs in managing and sharing data relevant to the halal supply chain. Key components include User, Profile, News, Business Category, and Business Position, each with attributes such as User ID, Email, Name of MSME, and Business Category. This design enables streamlined data organization, where user profiles can be linked to business details, social media, and geographic data, improving accessibility and operational efficiency. Integrating location attributes, such as longitude and altitude, supports GIS capabilities, providing MSMEs with a robust platform to improve traceability and compliance in the halal product supply chain.

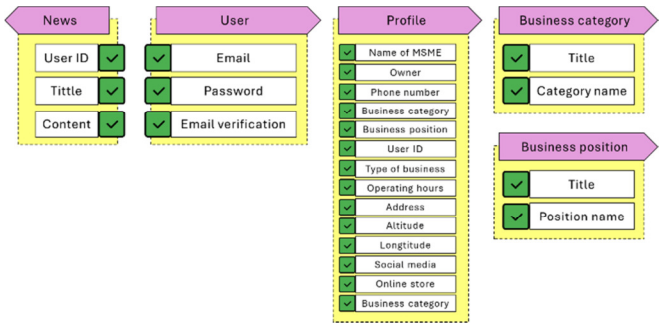

Fig. 6. Class diagram of the developed information system [29].

Figure 7 shows the main menu of the developed information system. This menu is accessible at [29] and offers MSMEs a user-friendly interface to manage their profiles, business categories, and news updates. The primary menu is designed to assist MSMEs in the halal supply chain by

providing access to updated halal-related information, business registration, and account management. This user-friendly interface allows users to effectively manage business data and monitor their adherence to halal standards, thus improving transparency and communication. User-centered design and intuitive navigation are essential to improving the adoption rates of digital platforms among MSMEs [30]. This system effectively enables MSMEs to meet halal certification requirements and facilitates digital transformation by providing an intuitive and accessible platform.

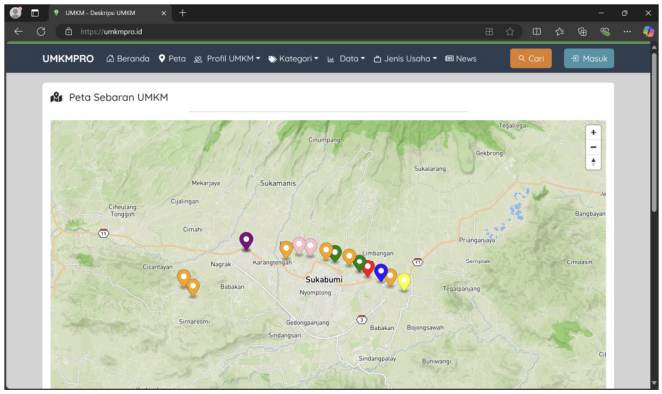

Fig. 7. The main menu of the developed information system [29].

D. Trial of information system

Figure 8 presents the results of user trials to evaluate the performance of the developed information system. The system was assessed on four key attributes: functionality (70%), reliability (78%), efficiency (84%), and usability (94%). The high usability score indicates that users found the platform easy to navigate, which aligns with previous studies that emphasized the importance of intuitive design for MSMEs' digital tools [30]. Efficiency and reliability also scored well, reflecting the system's robustness in handling MSMEs' data needs and ensuring consistent performance. However, functionality scored slightly lower, suggesting areas for potential enhancements in feature depth. These results highlight that although the system was well-received, further improvements could fully increase its capacity to support MSMEs in halal products SCM.

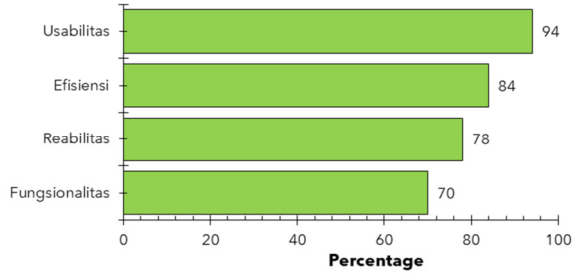

Fig. 8. Results of user trials on the developed information system.

E. Discussion

The data description analysis provided significant insights into the relationships among critical attributes that influence the halal supply chain in MSMEs. This study identified robust connections between attributes such as collaborative relationships, human resources, and SCM implementation by analyzing numerous pairwise distributions and correlations. These results emphasize the importance of a well-coordinated supply chain characterized by collaborative efforts and the utilization of human resources to increase efficiency. The notion that resource allocation and collaboration are indispensable for optimizing the supply chain has been previously substantiated [31]. This analysis indicates that MSMEs should prioritize investments in these areas to optimize their operational capabilities, particularly in managing halal-certified products that require compliance and quality control.

The role of MSME actors within the supply chain, as mapped in this study, reveals distinct participation patterns that emphasize suppliers and manufacturers as key components. This finding reflects the broader structure of halal supply chains, where upstream actors play a significant role in ensuring the integrity of halal standards from sourcing to production. Studies on halal SCM highlight that supplier reliability and manufacturing standards are crucial for maintaining halal compliance [32]. By focusing on these actors, MSMEs can strengthen their supply chains and ensure a seamless flow of halal products. Effective collaboration among actors can also mitigate challenges related to traceability, which is essential for consumer trust and product authenticity.

The design of the information system, as demonstrated by the class diagram and primary menu, shows a structured approach designed to meet the requirements of MSMEs in halal SCM. The incorporation of GIS elements to improve traceability and conformance is demonstrated by including comprehensive user and business profiles and location-based attributes. This is consistent with prior research that indicates that data-centric and user-friendly design is indispensable for the successful digital transformation of MSMEs [33]. The proposed system facilitates business information management, establishing connections with other supply chain actors, and the preservation of halal certification records for MSMEs, thus promoting a more transparent and coordinated supply chain environment.

The evaluation of the information system provided valuable feedback on its functionality, reliability, efficiency, and usability. The system's success in meeting user requirements and ensuring seamless operations is reflected in its high scores in efficiency (84%) and usability (94%), which are critical factors in its adoption among MSMEs. However, the functionality score of 70% suggests that there are areas in which additional features or refinements could improve the user experience. These results are consistent with prior research that underscores the importance of ongoing development in digital platforms for MSMEs [34]. Enhancing functionality could assist MSMEs in halal SCM, strengthening the platform's potential to facilitate business development and manage compliance.

IV. CONCLUSIONS

The primary goal of this study was to create a GIS-based information system that would facilitate the digitalization of SCM for halal products in MSMEs in West Java. This system was accompanied by multivariate analysis. The results indicate that the six attributes evaluated substantially affect SCM performance, with high correlations identified among halal certification, human resources, and collaborative relationships. The developed system [29] obtained positive user acceptability scores in the areas of usability (94%), efficiency (84%), reliability (78%), and functionality (70%), showing its potential to effectively assist MSMEs in administering halal product distribution. These results emphasize the system's ability to enhance traceability, expedite SCM, and bolster compliance in halal-certified MSMEs.

The novelty of this study lies in the development of a GIS-based system specifically tailored for halal product SCM in MSMEs, which has not been extensively explored in the existing literature. Unlike previous works that focused primarily on generic supply chain solutions, this research emphasizes the unique requirements of halal certification and the specific challenges faced by MSMEs in West Java. By integrating multivariate analysis, this study provides a comprehensive understanding of the critical attributes that influence SCM performance, offering a targeted approach to enhance operational efficiency. Furthermore, this work aligns with recent trends in digital transformation within supply chains, highlighting the importance of technology in improving traceability and compliance in halal industries. The findings contribute to the academic discourse on halal supply chains and serve as a practical framework for MSMEs looking to optimize their operations in a competitive market.

Future research could improve the system's functionality by integrating more sophisticated features, such as real-time surveillance of supply chain activities or predictive analytics for demand forecasting. Furthermore, the transparency and traceability of halal supply chains could be improved by extending the system to other regions and investigating the potential for integration with blockchain technology. Additional research could also refine the model and ensure its adaptability across various halal industries by examining the influence of external factors, such as market dynamics and regulatory changes or additional SCM attributes.

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