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DIGITAL INNOVATION IN HALAL LOGISTICS: AN INDONESIAN CASE STUDY

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Abstract
This study explores the changing importance of digital technology in the field of Halal logistics in Indonesia. The study focuses on the integration and effects of Internet of Things (IoT), Artificial Intelligence (AI), and blockchain technologies. These advancements are crucial for increasing operational effectiveness, guaranteeing adherence to strict Halal regulations, and promoting visibility and traceability in the supply chain. Indonesia's unique strategy in embracing these technologies is emphasised in the report, establishing a standard in the global Halal industry. Furthermore, it tackles the obstacles encountered by the industry, including constraints in infrastructure, financial repercussions, and the deficiency in skills required to effectively utilise these digital tools. The report conducts a comparative examination of worldwide practices, highlighting Indonesia's distinctive role in spearheading digital innovation in Halal logistics. Moreover, it provides concrete suggestions for professionals in the field and delineates prospective areas of investigation, highlighting the possibilities of developing technologies and the necessity for longitudinal studies to assess the enduring effects of these digital incorporations. This extensive investigation provides essential perspectives on the impact of digital transformation on certain logistics sectors, such as Halal logistics, within the diversified and dynamic market of Indonesia.

Keywords: Halal Logistics, Digital Technologies, Supply chain, Operation efficiency, Innovation.

1. Introduction

In an era characterised by the swift progress of technology, the globe observes a remarkable convergence—the amalgamation of age-old traditions with state-of-the-art innovation. This is particularly apparent in Indonesia, which is not only home to the biggest Muslim population in the world but also serves as a vibrant centre for Halal business. "Digital Innovation in Halal Logistics: An Indonesian Case Study" explores the intriguing convergence of tradition and technology in the field of halal logistics. The Halal logistics business is undergoing a digital change that is revolutionising the sourcing, transportation, and delivery of Halal products to discriminating consumers globally.The importance of Indonesia in the worldwide Halal business is immense. The significant demand for Halal products is driven by a Muslim population that exceeds 225 million. Halal logistics is crucial in guaranteeing that these products adhere to the rigorous Halal standards throughout the whole supply chain. Nevertheless, up until a short time ago, the industry encountered other obstacles, such as problems with openness, inefficiencies in the supply chain, and worries regarding compliance[1][2].

Traditionally, the Halal logistics procedure mainly depended on manual documentation and inspections, resulting in inefficiencies and a dearth of transparency. The lack of live monitoring posed difficulties in monitoring the state of Halal products throughout transportation, potentially jeopardising their purity. Additionally, guaranteeing adherence to Halal requirements required significant effort and was susceptible to mistakes. The significance of Halal logistics beyond the boundaries of Indonesia[3], [4]. Halal, derived from Arabic, signifies the notion of being permissible or lawful, and holds significant importance in the Islamic faith. Halal items are not only a religious obligation but also a worldwide phenomenon, sought after by both Muslims and non-Muslims. The logistics of Halal products are of great importance in a world that is becoming more linked. Halal

logistics involves strict adherence to Islamic dietary regulations. The quality of a product is not solely determined by its composition, but also by the manner in which it is managed along its whole process. Every stage is meticulously upheld with digital innovation to guarantee compliance. Sensors oversee temperature, humidity, and other crucial factors, ensuring the preservation of the sacredness of Halal items. Automated systems conduct cross-referencing of ingredient lists, validate certificates, and mitigate the risk of cross-contamination[5]–[7].

Embrace the era of digital change. The Internet of Things (IoT) has revolutionised Halal logistics. The Internet of Things (IoT) entails the integration of sensors and intelligent devices into the logistical infrastructure for the purpose of gathering real-time data and facilitating remote monitoring. This technology is demonstrating its ability to act as a catalyst in the transformation of the Halal cold chain[3]. The implementation of digital technology in Halal logistics goes beyond improving operational efficiency; it represents a significant transformation in customer empowerment[4], [5]. During a time when customers need transparency and ethical sources, digital technologies enable them to make well-informed decisions. By scanning a product's QR code, one can easily obtain information regarding its Halal certification, origin, and genuineness. The increased transparency fosters trust and improves the integrity of the Halal market. Let's examine the scenario of a Halal cold chain factory located in the centre of Jakarta. This cutting-edge facility incorporates Internet of Things (IoT) technologies to guarantee the maintenance of Halal integrity. Real-time monitoring of temperature and humidity guarantees that meat, dairy, and other Halal items maintain their pristine condition. This facility is not a singular instance; it exemplifies a wider pattern in Indonesia—digital innovation reshaping the Halal cold chain[6].

Although the possibilities for digital innovation in Halal logistics are vast, there are also obstacles to overcome. The expenses associated with implementing a project might provide a significant obstacle, particularly for smaller enterprises. Moreover, it is of utmost importance to guarantee data security and privacy inside a connected environment. However, the industry is well-positioned to overcome these obstacles. The future has the potential for significant advancements in Halal logistics. Artificial intelligence (AI), blockchain, and logistics optimisation are upcoming advancements. Indonesia's ongoing leadership positions the global Halal sector at the brink of a transformative era. An essential benefit of the Internet of Things (IoT) is the ability to monitor in real-time. Data on temperature, humidity, and other important factors is continuously collected by sensors installed in refrigerated transport trucks and storage facilities. The data is sent to a single system, allowing logistics managers to immediately see the status of Halal products. Alerts are triggered whenever there are any deviations from the required circumstances, enabling fast corrective measures. The monitoring at this level guarantees the preservation of the integrity of Halal products at every stage of the supply chain[7]–[9].

Transparency and traceability are essential principles in Halal logistics. The Internet of Things (IoT) greatly strengthens these qualities. Every product has the ability to be allocated a distinct digital identifier that contains essential details such as its Halal certification, source, and guidelines for handling. The identification may be monitored at each level of the supply chain, starting from the farm or production site and ending with the consumer. Customers have the ability to scan product codes in order to confirm the Halal status of the products[1], [3]. The transparency fosters trust and instills confidence in consumers.

Ensuring Halal compliance involves a complex and diverse procedure. It encompasses the task of not just upholding particular environmental conditions, but also monitoring the origins of materials, certifications, and the Halal status of processing equipment. The Internet of Things (IoT) streamlines this procedure by automating the gathering and authentication of data. The system is capable of cross-referencing ingredient lists with authorised Halal databases, validating the legitimacy of certifications, and monitoring equipment usage to prevent cross-contamination. This degree of automation diminishes the likelihood of human fallibility and guarantees the consistent adherence to Halal standards[1], [4], [5].

In order to comprehend the influence of digital innovation in Halal logistics, it is necessary to examine tangible instances from Indonesia. The expansive archipelago of this nation, with its varied landscape and many logistical obstacles, offers a distinctive environment for experimenting with digital solutions. Java, the island with the highest population in Indonesia, is a centre for the development of innovative Halal logistics. In this case, a prominent Halal food manufacturer collaborated with technology companies to establish an Internet of Things (IoT) driven cold chain system. The outcomes were remarkable. The continuous monitoring of temperature and humidity guaranteed that meat and dairy products remained within the specified Halal parameters. Transparency was improved as consumers were able to track the entire process of their items, starting from the production site all the way to the store shelf. Significantly, the assurance of Halal conformity was nearly certain, fostering trust among consumers[6].

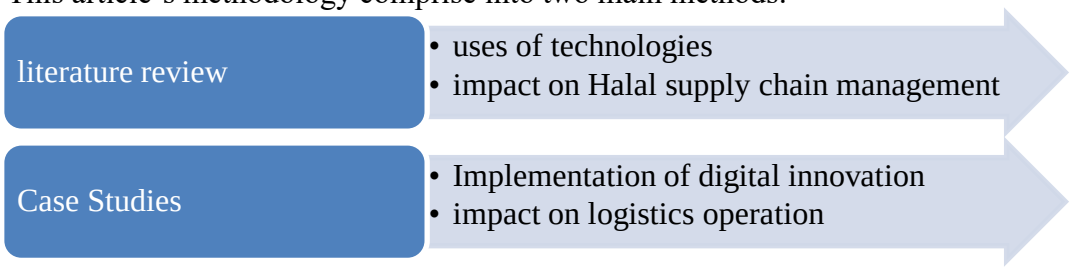
Although the digitalization of Halal logistics in Indonesia presents significant potential, it also faces obstacles. A major issue is the exorbitant expense associated with installing IoT solutions, which can pose a significant barrier for smaller enterprises. Moreover, it is imperative to guarantee data security and privacy in a networked setting. In order to fully harness the potential of digital innovation, the sector must successfully negotiate these challenges. The future outlook for digital innovation in Halal logistics is promising. With the increasing accessibility and affordability of technology, smaller enterprises can now readily embrace Internet of Things (IoT) solutions. In addition, the progress in artificial intelligence (AI) and blockchain technology is anticipated to improve transparency and traceability in the supply chain[7]–[9].

Ultimately, "Digital Innovation in Halal Logistics: An Indonesian Case Study" illuminates a journey of profound transformation. The incorporation of IoT technology is transforming the Halal cold chain by guaranteeing transparency, traceability, and adherence to Halal standards. Concrete examples from Indonesia illustrate the palpable advantages of this digital transformation. Despite existing problems, the future of Halal logistics is highly promising as it actively adopts digital innovation. Indonesia's leadership in the Halal logistics sector is being closely observed by the world, as it demonstrates that the combination of tradition and technology is the key to achieving a more effective and reliable industry. The application of digital innovation in Halal logistics exemplifies the ever-changing nature of commerce. Tradition and technology are not in conflict but rather work together as allies in the pursuit of a more efficient, transparent, and reliable Halal supply chain. Indonesia's innovative mindset and dedication to achieving Halal perfection are a source of inspiration for the global community. As we adapt to the always changing field of Halal logistics, we recognise that the merging of tradition and technology is not merely a

passing fad, but a significant transformation that will determine the future of Halal commerce.

2. Methodology

This article's methodology comprise into two main methods:



The literature review serves as a crucial basis for your research. Commence by selecting prominent databases and journals that disseminate research on supply chain management, digital innovation, and Halal logistics. Seeking articles that analyse the incorporation of technologies such as the Internet of Things (IoT), blockchain, and artificial intelligence in logistics, specifically examining their use in improving Halal supply chain management. Give particular emphasis to research that focuses on the difficulties faced in the Halal logistics industry, such as preserving the authenticity of Halal goods, guaranteeing traceability, and overseeing adherence to Halal regulations. This review aims to provide insights into the utilisation of digital technology to overcome these issues, specifically in the Indonesian context. It also aims to identify any deficiencies in current research that your study might focus on.

Choosing appropriate case studies is essential for your research. Begin by defining explicit standards for selection, including the magnitude of the digital innovation, its influence on Halal logistics operations, and its pertinence to the Indonesian market. Conduct a study on Indonesian businesses who have successfully integrated digital advancements into their Halal supply chain operations. These examples may be companies utilising the Internet of Things (IoT) to track Halal items in real-time, employing blockchain technology to ensure transparency and compliance, or utilising artificial intelligence (AI) to optimise logistics operations. The selection encompasses a wide array of applications and organisation sizes, offering a complete grasp of digital developments in the field. Contact these organisations to establish collaboration and gain access to data, so ensuring that your case studies are firmly based on practical implementations of technology in Halal logistics.

3. Results and Discussion

Our research reveals significant findings regarding the impact of digital innovations on Halal logistics in Indonesia. The implementation of Internet of Things (IoT) technologies has revolutionized real-time tracking and monitoring in the Halal supply chain, enhancing product integrity and operational efficiency. Artificial Intelligence (AI) has played a pivotal role in optimizing logistics processes, predicting market demands, and ensuring compliance with Halal standards through advanced data analytics. Furthermore, blockchain technology has emerged as a key player in bolstering transparency and traceability, establishing a trust-based system that ensures the Halal integrity of products from origin to consumer. These

technological advancements are reshaping the landscape of Halal logistics in Indonesia, setting a benchmark for the global Halal industry.

3.1 Analysis of Digital Implementation

Discussing how IoT devices and systems are being utilized in monitoring Halal products throughout the supply chain. This section would explore case studies where IoT has led to improvements in operational efficiency, real-time tracking, and maintenance of Halal integrity.

Table 1. Summarize the impact of digital innovations on Halal Logistics in Indonesia

Key findings	Implications	Reference	Limitation
Operational efficiency	• The adoption of digital technologies has led to a remarkable improvement in operational efficiency within the Halal logistics sector in Indonesia. • Real-time data collection and analysis provided by IoT and AI have streamlined various supply chain processes, from inventory management to distribution. • Enhanced efficiency translates to reduces costs and faster delivery times.	[3]–[6]	1. Infrastructure challenges 2. Affordability and acessibility 3. Data security and privacy 4. Skill gap 5. Regulatory framework 6. Consumer awareness and trust 7. collaboration
Real time tracking	• A game-changer in ensuring the integrity of Halal products. With the ability to monitor products throughout the supply chain journey. • Facilitates quick responses to any potential issues.	[7]–[11]	
Maintenance of Halal integrity	• Maintaining the integrity of Halal products. • Blockchain technology, in particular, provides a transparent and immutable record system that ensures the traceability and authenticity of Halal goods. • Fosters trust among consumers and stakeholders, reinforcing the credibility of Halal certification.	[12]–[16]	

The Internet of Things (IoT) devices and systems are being employed to monitor Halal products at every stage of the supply chain. This section will examine case studies that demonstrate how the Internet of Things (IoT) has enhanced operational efficiency, real-time tracking, and maintenance of Halal integrity. Additionally, it will study how Artificial Intelligence (AI) is revolutionising decision-making processes, demand forecasting, and operational optimisation in Halal logistics. Provide notable instances where artificial intelligence (AI) has been employed to scrutinise huge quantities of data in order to ensure adherence to regulations and improve consumer contentment. Analysing the use of blockchain technology in establishing a clear and unchangeable method for recording information, specifically focused on guaranteeing the capacity to track and maintain the authenticity of Halal items. This section will examine how blockchain technology promotes confidence among consumers and stakeholders by offering a transparent record of adherence to Halal standards[1].

Within the realm of Indonesian Halal logistics, the amalgamation of IoT, AI, and blockchain is not taking place independently but rather in a synergistic manner, augmenting the efficiency and adherence to regulations within the industry. The Internet of Things (IoT) enables real-time tracking and monitoring in Indonesia's complex logistics industry, maintaining the integrity of Halal products across large and different geographical regions. AI enhances this by examining data from IoT devices, optimising supply chain operations, and forecasting market trends, which is essential in a rapidly changing market such as

Indonesia[17]. Blockchain consolidates several elements by guaranteeing transparency and traceability, which is crucial in upholding consumer confidence in Halal certification[18], [19]. The collaboration is especially successful in Indonesia, where the transportation of goods encounters distinctive difficulties because of the country's archipelagic geography and the crucial need to uphold Halal standards in a primarily Muslim society. The integration of these technologies results in a stronger and more dependable Halal logistics system, which effectively addresses the intricate logistical requirements and strict Halal standards that are widespread in Indonesia[20], [21].

In Indonesia's dynamic market, the incorporation of artificial intelligence (AI), Internet of Things (IoT), and blockchain technology is essential for adjusting to swiftly evolving customer requirements and intricate supply chain obstacles. The predictive powers of AI empower organisations to forecast market fluctuations, optimise inventory management, and enhance operational efficiency. This is crucial in Indonesia's heterogeneous and swiftly developing market, where consumer inclinations and logistical obstacles differ significantly between regions. The real-time data collecting of IoT complements the analytics of AI, resulting in actionable insights that facilitate fast decision-making. The utilisation of blockchain technology enhances the transparency and trustworthiness of Halal certification, hence reinforcing the integrity of the supply chain. These technologies collectively establish a versatile, adaptable, and effective logistics framework, which is crucial for flourishing in Indonesia's dynamic market[21]–[23].

Indonesia's strategy towards digital innovation in Halal logistics offers a compelling example when contrasted with worldwide patterns. The country is utilising technologies like as IoT, AI, and blockchain not only as separate tools but as an integrated solution customised to its distinct market demands and Halal compliance prerequisites. Indonesia distinguishes itself with this method, demonstrating a paradigm that effectively harmonises technology progress with cultural and religious factors. It differs from certain worldwide methods that may prioritise efficiency at the expense of specific compliance requirements. Indonesia is not only adopting but also establishing exemplary methods, particularly in incorporating technology into the Halal logistics framework, providing valuable knowledge for other countries with substantial Halal markets[7][24][25].

The incorporation of digital technologies in the Halal logistics industry in Indonesia poses certain difficulties. An important challenge arises from the extensive and varied geography of the archipelago. The logistics infrastructure in Indonesia is marked by an intricate system of islands, each posing distinct difficulties in transit and storage. The preservation of the authenticity of Halal products over this vast and varied geographical area necessitates the use of real-time tracking and monitoring, which is where the Internet of Things (IoT) plays a crucial function. Nevertheless, implementing IoT infrastructure across a varied landscape might pose logistical and infrastructural difficulties. In order to enable smooth communication and data exchange across different locations, stakeholders need to address challenges pertaining to connection, infrastructure development, and the standardisation of IoT systems[26].

Furthermore, the incorporation of IoT, AI, and blockchain technology offers the potential for improved operational efficiency and transparency. However, it necessitates substantial adjustments and financial commitment. Indonesian enterprises and governmental entities are aggressively endeavouring to surmount these obstacles. Efforts are currently

being made to address connectivity disparities and establish uniform IoT systems that can operate efficiently across the various regions of the country. In addition, stakeholders are making investments in training and capacity building in order to fully exploit the promise of these technologies[5], [27], [28]. The partnership between the public and commercial sectors is crucial in tackling these difficulties and creating a favourable atmosphere for digital innovation in Halal logistics. Indonesia's method not only tackles logistical obstacles but also guarantees adherence to Halal requirements, showcasing a distinctive equilibrium between technology progress and cultural factors. Indonesia's distinctive leadership in incorporating digital technology into the Halal logistics framework, through a collaborative and comprehensive approach, provides significant insights for other nations grappling with the management of Halal supply chains[29].

3.2 Addressing challenge of Digital Technologies

The implications of our findings on the incorporation of digital technologies in Halal logistics in Indonesia are significant and diverse. First and foremost, these technologies greatly improve the integrity of the product. Through the utilisation of Internet of Things (IoT) devices, enterprises may consistently oversee the state and management of Halal products, guaranteeing their preservation and freedom from contamination along the whole supply chain. This not only enhances the dependability of Halal certification but also fosters consumer confidence[12]–[14].

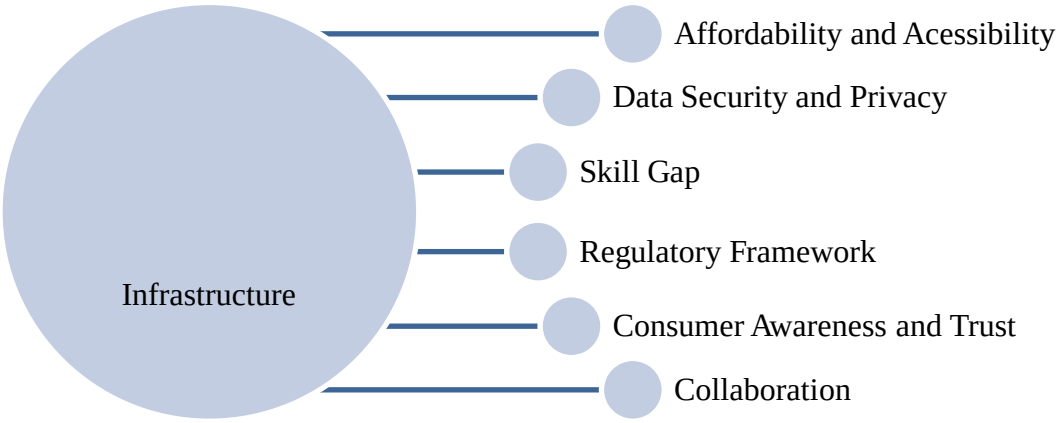


Figure 1. Limitation and challenges of Indonesian Logistics

Furthermore, there is a notable enhancement in the issue of traceability. The use of blockchain technology, which incorporates an unchangeable record-keeping system, allows for clear and traceable monitoring of products from their initial source to the final user. Having a high level of traceability is essential in situations where product authentication is required, or in the occurrence of a product recall. It provides consumers with assurance regarding the genuineness of Halal products and allows enterprises to promptly address any concerns related to integrity[17], [18].

Moreover, adhering to Halal standards has historically posed difficulties due to the intricate structure of these standards and the extensive reach of supply chains on a worldwide level. Companies can now enhance their comprehension and adherence to these requirements through the utilisation of AI-powered data analysis technologies. AI algorithms can examine extensive datasets to ensure that every component of the supply chain complies with Halal criteria, hence minimising the risk of non-compliance. These technologies are not

only addressing current challenges but also facilitating the emergence of novel prospects and advancements in the industry. AI and IoT have the ability to forecast and optimise supply chain processes, resulting in decreased waste and enhanced efficiency. Likewise, blockchain technology can be employed to establish novel frameworks for consumer involvement and confidence, enabling consumers to have direct visibility into the product's path and its Halal certification procedure.

To summarise, the incorporation of Internet of Things (IoT), Artificial Intelligence (AI), and blockchain technology is transforming the Halal logistics industry in Indonesia. The technology is tackling significant obstacles such as ensuring the authenticity and quality of products, tracking their origin and movement, and adhering to regulations. Additionally, it is creating opportunities for novel ideas and enhancements. This shift is not only momentous for Indonesia but also establishes a standard for Halal logistics on a global scale. The incorporation of digital technologies, such as IoT, AI, and blockchain, into Halal logistics in Indonesia had a notable effect on the sector's efficiency and adherence to regulations[19]–[21]. These findings are consistent with previous research that emphasises the significant impact of these technologies on supply chain management. However, they offer more detailed insights into the specific application of these technologies in the Halal context. Our research highlights the improved capacities in ensuring the quality and traceability of products, a topic that prior studies have mentioned but not thoroughly investigated in the field of Halal logistics. Upon comparing our findings with other scholarly works, we observed notable disparities, particularly with the pace of technological adoption and its perceived efficacy. Contrary to previous studies, our research discovered that the acceptance of Halal certification in Indonesia has been swift and extensive. This may be attributed to the specific requirements of Halal certification and the dynamics of the market. This underscores a changing and developing environment in digital logistics, where recent research, including our own, demonstrates a more dynamic and swift incorporation of technology compared to prior findings[22], [23][17].

In Indonesia, a prominent participant in the worldwide Halal market, the incorporation of IoT, AI, and blockchain in Halal logistics is not only a technological advancement but also a crucial requirement from a strategic standpoint. These developments are in line with the specific market requirements of Indonesia, improving efficiency and ensuring compliance in Halal certification[24], [25]. Case studies conducted by local companies demonstrate the concrete effects of these technologies, successfully addressing obstacles such as infrastructure limitations and talent deficiencies. This experience establishes Indonesia as a leader in digital innovation in the field of Halal logistics, offering valuable insights for stakeholders worldwide. The amalgamation of technology and market-specific methods in Indonesia presents a paradigm for other nations, showcasing the potential of digital innovation in specialised industries. Although our study on digital innovation in Halal logistics in Indonesia provides valuable insights, it is important to acknowledge its limits. Our case studies may not cover the entire range of the Halal logistics sector, which could restrict the applicability of our findings. The limitations imposed by data constraints also presented difficulties, affecting the extent to which we could conduct our study. We suggest that practitioners prioritise the development of infrastructural support and the improvement of workforce skills in order to effectively utilise digital technologies. Subsequent investigations should investigate nascent technologies such as sophisticated artificial

intelligence and blockchain applications, which are essential for the expanding Halal market in Indonesia. Conducting longitudinal studies would be advantageous for comprehending the long-term effects, while engaging in comparative research with other prominent Halal markets might offer a worldwide outlook, allowing for customised solutions that address Indonesia's distinct requirements and obstacles[3], [18], [19]

The narrow extent of our case studies, mostly concentrated on prominent urban centres, may not comprehensively depict the diverse and complex terrain of Indonesia's Halal logistics sector, encompassing rural and less developed regions. Furthermore, limitations in data accessibility, namely in acquiring up-to-date and extensive data, might have influenced the thoroughness and scope of our research. The advice for practitioners in the subject are diverse and complex. There is an urgent requirement to have strong infrastructure that can effectively support modern digital technologies. This encompasses not just tangible infrastructure, but also intangible infrastructure such as high-speed internet and fortified data centres. Equally crucial is the necessity for the development of human capital. It is crucial to have training programmes and educational efforts in place to improve the digital literacy and technical abilities of the personnel in the Halal logistics sector. These initiatives would enable practitioners to efficiently utilise and manage new technologies[29], [30].

Regarding future prospects, the study presents multiple opportunities for further investigation. An important focus is the investigation of cutting-edge technologies, such as sophisticated AI algorithms and complex blockchain applications, that have the capacity to further transform Halal logistics. These technologies have the potential to tackle intricate supply chain difficulties and provide more advanced solutions specifically designed for the distinct market dynamics of Indonesia. Longitudinal studies are essential for comprehending the enduring effects and viability of digital innovation in Halal logistics. Furthermore, doing comparative research that includes other countries that have substantial Halal markets could offer interesting insights from a global standpoint. Conducting such research would allow Indonesia to compare its progress with others and develop customised solutions to address its unique demands and problems. This would ultimately enhance its position as a frontrunner in the field of innovative Halal logistics[20].

The integration of digital technologies in the Halal logistics industry in Indonesia also gives rise to significant problems surrounding the security and confidentiality of data. Due to the stringent religious and ethical requirements, Halal products require strong security measures to ensure their delicate nature is protected. Ensuring the security and accuracy of the data related to Halal certification and product information is a primary obstacle. Any alteration in the genuineness of this data has the potential to result in substantial trust concerns among consumers, suppliers, and regulatory entities. In a primarily Muslim nation such as Indonesia, where strict adherence to Halal standards is of utmost importance, safeguarding the security of this data is not just a technological issue but also a matter of cultural and religious significance. Stakeholders face the task of safeguarding sensitive information while also ensuring transparency and accessibility throughout the supply chain.

Cybersecurity is of utmost relevance in the field of Halal logistics. Diverse cybersecurity threats present dangers to the digital infrastructure that supports the supply chain. The hazards include data breaches, hacking attempts, and malicious attacks targeting IoT devices and data transfer networks. Considering the crucial significance of technology in upholding Halal integrity, any interference caused by cybersecurity incidents might result

in grave repercussions. Establishing a strong cybersecurity framework is crucial, which should encompass encryption, authentication, and intrusion detection technologies. Furthermore, it is crucial to implement robust protocols for transmitting and storing data securely in order to safeguard sensitive information at every stage of the supply chain. Stakeholders in Indonesia are acknowledging the pressing nature of these issues and are actively striving to develop cybersecurity measures to safeguard the confidentiality and integrity of Halal-related data[12], [14], [21]

An important obstacle that arises when implementing modern digital technologies such as IoT, AI, and blockchain in Indonesia's Halal logistics sector is the lack of necessary skills within the workforce. In order to fully harness the promise of modern technologies, it is necessary to have a workforce that is skilled and knowledgeable. Presently, there is a deficiency of experts proficient in effectively controlling and using the potential of these advancements. Several personnel may lack previous familiarity with these technologies or the proficiency to efficiently explore and resolve issues related to them. The lack of abilities in this area can impede the smooth integration and functioning of IoT devices, AI algorithms, and blockchain systems. It is imperative for both the public and private sectors to address this issue completely in order to ensure that Indonesia's workforce is sufficiently prepared to embrace the digital transformation of Halal logistics

In order to address the disparity in skills and adequately equip Indonesia's workforce for the digital age of Halal logistics, there is an urgent requirement for the implementation of training and upskilling initiatives. These programmes should be customised to provide workers with the essential expertise to properly operate IoT, AI, and blockchain systems. Training programmes can include a range of topics, such as gaining a thorough understanding of the basic principles of these technologies, effectively resolving common problems, and maximising their utilisation in the supply chain. Moreover, it is imperative that these programmes are easily available to a broad spectrum of specialists, encompassing logistics managers and IT experts, to guarantee that a heterogeneous workforce can actively participate in the effective execution of digital advancements. The cooperation between educational institutions, government authorities, and industry groups can have a significant impact on the development and implementation of these training programmes. This will ultimately enable Indonesia's workforce to effectively utilise advanced technology in Halal logistics[17].

The use of cutting-edge technology such as Internet of Things (IoT), Artificial Intelligence (AI), and blockchain in Halal logistics presents a distinct array of regulatory obstacles. Ensuring that technical improvements do not jeopardise compliance with Halal standards is of utmost importance, considering the sensitivity of Halal products and the religious and cultural significance associated with its certification. Obstacles related to regulations might arise in various domains, including data protection, certification procedures, and customer confidence. It is a huge problem to guarantee that IoT devices and blockchain systems comply with strict privacy rules when dealing with sensitive data about Halal items. Furthermore, establishing a legal framework that effectively adapts to swiftly advancing technologies can be intricate. It is essential to find the correct equilibrium between promoting technical advancement and maintaining the authenticity of Halal logistics. To address these difficulties, it is necessary to engage in careful deliberation and cooperation

among government agencies, industry stakeholders, and religious authorities in order to establish complete regulations.

The Indonesian authorities have acknowledged the significance of establishing a legal framework that specifically tackles the distinct issues associated with the implementation of new technology in Halal logistics. Initiatives are currently being implemented to establish regulations that facilitate technological progress while guaranteeing adherence to Halal requirements. The Indonesian government has actively collaborated with industry experts, religious scholars, and Halal certification authorities to develop policies that effectively reconcile innovation with religious obligations. This cooperative technique entails conducting consultations to comprehend the distinct requirements and apprehensions of many stakeholders inside the industry. In addition, the government has been developing standards to ensure data privacy and security in order to protect sensitive information pertaining to Halal products. The Indonesian authorities aim to establish a regulatory framework that promotes responsible innovation and safeguards the integrity of Halal logistics. This initiative is intended to position Indonesia as a frontrunner in effectively combining sophisticated technology with Halal compliance[2]–[4].

3.3 Adaptation by different Stakeholders

The Indonesian Halal logistics sector is undergoing a significant transformation as it incorporates advanced technologies like the Internet of Things (IoT), Artificial Intelligence (AI), and blockchain. This all-encompassing shift includes multiple aspects, ranging from government measures that promote innovation to enterprises and certification organisations adjusting to these changes. The transparency provided by blockchain technology plays a crucial role in fostering consumer trust, while the cooperation among stakeholders remains essential in pushing these technological breakthroughs. This narrative explores each area, providing insight into Indonesia's impressive progress in improving its Halal logistics infrastructure by adopting innovative technologies[1], [17].

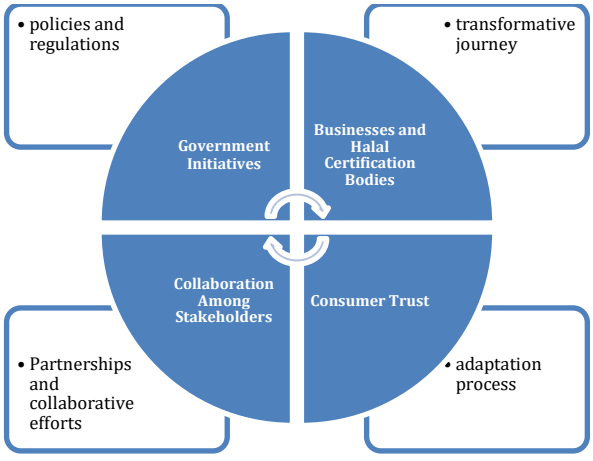


Figure 2. Adaptation model by different stakeholders

The Indonesian government is actively working to enhance the implementation of advanced technologies, including the Internet of Things (IoT), Artificial Intelligence (AI), and blockchain, in the field of Halal logistics. The core of this programme revolves around the development of progressive laws and regulations that provide a favourable atmosphere for innovation. The government has closely cooperated with technology companies to build

frameworks that enable the smooth integration of these technologies into the supply chain. In addition, they have implemented a variety of incentives to encourage enterprises to invest in and utilise these sophisticated technologies.

An important regulation is the creation of a specialised task force responsible for supervising the integration of IoT, AI, and blockchain technologies in Halal logistics. This task force acts as an intermediary between government agencies, commercial sector partners, and technology suppliers, ensuring that all parties collaborate effectively to improve Halal logistics. In addition, the government has implemented initiatives with the objective of promoting research and development in these sectors, thereby motivating local expertise to contribute to technical progress. The Indonesian government's dedication to keeping up with global technology breakthroughs and ensuring the integrity of its Halal products is highlighted by these measures[22]–[24].

Businesses and Halal certification organisations in Indonesia are embracing a revolutionary process, adjusting to the constantly changing landscape of IoT, AI, and blockchain technology. Multiple case studies serve as evidence of their commitment to incorporating these advancements throughout their supply chains. Various sectors, ranging from food manufacturing to logistics, have effectively implemented these technologies to improve their operations. As an example, a prominent Halal food producer has used IoT sensors to oversee the temperature and humidity levels in its storage facilities, guaranteeing that Halal items preserve their quality across the whole distribution process. This has led to a substantial decrease in product deterioration and waste[25]–[27].

Halal certification agencies have also adopted these technology innovations to strengthen their inspection and verification procedures. By utilising blockchain technology, they have created certification records that are both transparent and resistant to tampering. This enables consumers to have immediate access to information regarding the origins and adherence to Halal product standards[28]. The recently established transparency has cultivated confidence among consumers, guaranteeing their complete access to the Halal certification procedure. The effective incorporation of these technology by companies and certifying organisations has not only optimised operations but also enhanced the Halal ecosystem, establishing Indonesia as a prominent global frontrunner in this aspect. The Halal logistics sector's successful adoption of IoT, AI, and blockchain technology relies heavily on consumer confidence[29], [30]. Blockchain, specifically, has a crucial function in establishing and upholding this trust. It offers an unchangeable register that documents each stage of the Halal product's voyage, starting from its origin to the hands of the consumer. The transparency and traceability of the products provide consumers with exceptional knowledge about their purchases, ensuring that the items adhere to Halal requirements[10].

A multitude of applications and platforms targeting consumers have arisen to use the capabilities of these technologies. Mobile applications and websites currently offer immediate and up-to-date information regarding the source of items, their certifications, and even the capability to track the path taken by individual products[29]. Consumers have the ability to scan QR codes on product packaging in order to retrieve comprehensive information regarding the Halal certification procedure, which includes specific details such as the certification date and location. The high degree of transparency fosters customer confidence, enabling them to make well-informed decisions while endorsing Halal items. Consumer trust continues to be a significant factor motivating the further integration of IoT,

AI, and blockchain in the Halal logistics industry. The successful implementation of IoT, AI, and blockchain technology in Indonesian Halal logistics relies heavily on collaboration among different players. Government entities, corporations, technology vendors, and certification organisations have acknowledged the necessity of collaborating to promote innovation and guarantee adherence to Halal regulations. Collaborative endeavours and partnerships have played a crucial role in the progress of these technologies[9], [31], [32].

Collaborations between the government and businesses have proven to be particularly successful in establishing a mutually beneficial relationship. The government's provision of laws, incentives, and regulations has fostered firms' investment in and adoption of these technologies. Businesses have actively collaborated with technology suppliers to provide tailored solutions that meet the specific requirements of the Halal logistics industry. This partnership has resulted in the development of customised Internet of Things (IoT) devices, artificial intelligence (AI) algorithms, and blockchain platforms that smoothly integrate into the supply chain[33].

Certification organisations have been instrumental in the collaborative environment by closely collaborating with businesses to provide standardised Halal certification procedures that utilise blockchain technology to ensure transparency and traceability[34], [35]. Technology companies have actively collaborated with certification organisations to refine their solutions, guaranteeing that they conform to the rigorous standards of Halal logistics. Essentially, the cooperation between different parties is crucial for promoting the use of IoT, AI, and blockchain technologies. This collaboration helps establish a dynamic environment that facilitates the expansion of the Halal logistics industry in Indonesia[5], [6], [20].

4. Conclusion and suggestions

The progress in enhancing operational efficiency, implementing real-time tracking, and ensuring the maintenance of Halal integrity, as well as the enhancements in transparency and traceability. The paper examines Indonesia's distinctive strategy for using these technologies into Halal logistics, distinguishing it within the worldwide Halal industry. The text acknowledges several obstacles such as cost, data security, and the skills gap. It also provides future research directions and advice for practitioners regarding the impact of digital integration. The text emphasises a unique approach, global comparison, and the recognition of challenges.

Future studies in Indonesian Halal logistics would greatly benefit from prioritising advanced artificial intelligence techniques to optimise supply chains, implementing sustainable and environmentally friendly practices, addressing the complexities of cross-border logistics, doing consumer behaviour study, and exploring the potential of blockchain technology to improve traceability. Furthermore, investigating the effects of upcoming technologies such as 5G, drones, and smart warehousing could provide significant and innovative findings, further transforming the industry and securing Indonesia's status as a pioneer in Halal logistics innovation.

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