Digital Technology 4.0 on Halal Supply Chain

The halal supply chain is a focused type of supply chain that ensures halal products throughout the entire process, from upstream to downstream.

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1. Introduction

The halal supply chain, as defined in the literature, pertains to the effective oversight of the movement of materials, information, and capital to guarantee that products adhere to halal (permissible) standards throughout the entire production process, from farm to fork [1]. This approach underscores the importance of stakeholder coordination and collaboration to enhance supply chain performance and generate value, all while upholding halal principles across the entire chain [2]. Halal supply chain is also called halal logistics in several studies (e.g., [3][4][5]), so these terms are used interchangeably. The fundamental significance of the halal supply chain lies in its role as a cornerstone, wherein the prevention of direct contact with forbidden elements, management of contamination risks, and alignment with the perceptions of Muslim consumers are pivotal aspects [6]. These objectives set the halal supply chain apart from the conventional or standard supply chain, establishing it as a distinctive and crucial component.

The significance of the halal supply chain is underscored by the vast market for halal products, particularly in Muslim-majority countries. The primary target audience for halal products, necessitating the implementation of a halal supply chain, is the global Muslim population of 1.6 billion individuals, concentrated mainly in Asia, the Middle East, and Africa. The global halal market currently exceeds two trillion U.S. dollars and is anticipated to grow to 2.8 trillion U.S. dollars in the future [7]. As of 2021, Islamic finance dominated the halal industry with a market share of 51.6%, showcasing the success of the sector in implementing the halal supply chain. Following closely was the halal food industry, holding 31.46% of the global halal market share [8]. These statistics highlight the increasing importance of the halal supply chain, attracting attention and interest from both industry practitioners and researchers.

Research within the scope of the halal supply chain interacts with several dominant perspectives, such as supply chain management, certification, and marketing. In relation to marketing, previous research highlights the need for figurative understanding and halal brand elements for organizations [9]. Furthermore, in supply chain management, researchers [10] emphasize the opportunities and challenges in halal logistics, showing the importance of developing existing research in this area [10]. In addition, the adoption of the technology-organization-environment (TOE) framework is proposed for the development of the Halal warehouse adoption model, underlining the importance of integrating technology, organization, and environmental factors in the halal supply chain [11].

The use of innovative technologies has been widely employed in the field of supply chain management, including the concept of smart supply chain management, which offers unprecedented opportunities for cost reduction and efficiency improvement through intelligent decision-making and automation capabilities [12]. Additionally, the application of decision support systems and intelligent systems can overcome the challenges of unpredictable demand and rapidly changing market trends in the textile and apparel industry supply chain [13]. From a wood supply chain perspective, the use of Discrete Event Simulation (DES) can facilitate testing alternative strategies and provide decision support for tactical and operational planning [14][15]. Furthermore, innovative digital technology is crucial to enhance the efficiency and effectiveness of company activities, including in their supply chain [16][17][18], more specifically in the halal supply chain.

Prior studies have highlighted digital technology's role in improving transparency, integrity, and certification processes in the halal industry, thereby establishing international best practices alongside mainstream food industry sectors. Information technology has been identified as a factor that can improve performance and efficiency and expand supply chain networks in the context of HSC management [19]. Additionally, the adoption of halal warehousing has been found to

be significantly influenced by technological factors, emphasizing the importance of compatibility and perceived benefits [20].

There is a gap in the relationship between technology development and the supply chain of halal products. However, some of the literature has acknowledged the use of technology, such as digital tools in the halal supply chain [21] and sustainable halal supply chain using blockchain technology [22].

2. Halal Procurement

Halal procurement involves obtaining goods and resources in compliance with Islamic law, ensuring the halal product's integrity throughout the supply chain [2]. It includes sourcing halal-compliant inputs, by-products, and resources, extending beyond raw materials and production to encompass the entire supply chain, including distribution and logistics [2][23][24]. The concept has evolved due to growing awareness, emphasizing the need for organizations to establish a robust procurement function aligned with Islamic values [25]. A halal procurement maturity model can facilitate this development. The integrity of halal products is upheld through various supply chain activities, highlighting the importance of a holistic approach to ensure halal integrity at the point of consumption. It can be concluded that in the halal food supply chain industry, supplier flexibility plays an important role that can affect other criteria, such as cost and footprint. For instance, a hybrid approach to model halal supplier flexibility criteria emphasizes the influence of Blockchain Technology in enhancing traceability but, on the other hand, will increase operational costs [26]. Prior research also investigated the influence of service quality from halal suppliers and the preparedness of staff to embrace E-procurement technology on the performance of halal logistics [27]. It underscores the pivotal role of technology in improving order speed and traceability, with a cautionary note on the necessity to balance technological adoption with employees' proficiency.

Moreover, integrating blockchain and ERP can enhance corporate governance, leading to improved company performance in the long run and reducing operational costs. Through effective management of halal product procurement, companies can guarantee the delivery of products to consumers with halal assurance [28]. Overall, these studies contribute valuable insights into the dynamic landscape of halal procurement, highlighting the importance of technological advancements and flexibility criteria in shaping both financial and non-financial aspects of firm performance in the halal supply chain.

3. Halal Manufacturing

Halal manufacturing refers to the production of goods under Islamic Shariah law, ensuring that the ingredients, manufacturing processes, and techniques used comply with the standards set by Islamic guidelines [29]. It includes various aspects such as certification, transportation, and warehousing [20][30][31].

Furthermore, adopting halal practices in manufacturing can lead to improved business performance and expansion opportunities, particularly in countries with a significant Muslim consumer base [32][33][34]. The adoption of innovative digital technology in halal manufacturing has become increasingly significant. Various studies emphasize the impact of technology in improving the efficiency and competitiveness of halal supply chains [35][36]. Technologies like the Internet, Extranet, EDI, and electronic commerce can potentially enhance the efficiency of the family supply chain in the halal food business [37].

However, the financial commitment can challenge family business proprietors, particularly in the halal food sector. The prototype of Halal Supply Chain Management Transactions (HSCMT) with halal financial technology (FinTech) can improve the effectiveness of halal supply chain management for Malaysian Halal SME Owners (MHSO) [38]. Meanwhile, big data technology can improve companies' ability to become more sustainable in the halal food chain process [39]. On the other hand, a study by [35] suggests that while blockchain technology can improve the halal footprint, the investment required can be significant.

Furthermore, digitization and financial technology (FinTech) through waqf funds can increase the sustainability of MSMEs in Malaysia and Indonesia by 90%, highlighting the critical role of technology in increasing waqf participation and the performance of micro and small enterprises [40]. Also, blockchain provides an opportunity to promote value innovation in the halal industry, potentially increasing the transparency of transactions and value innovation in management decision-making [41]. It was highlighted that the development of synergies between Islamic banks and Muslim-friendly tourism involves technologies such as Machine Learning and Digital Innovation Services, which can create new offers and increase customer loyalty [42]. The study of the halal footprint system shows that the application of halal footprint technology can help reduce operational costs, improve the business performance of MSMEs, and improve the integrity of

the halal industry [43]. In the context of fintech, building an integrated Islamic financial ecosystem involves financial technology (fintech) to increase synergy in the halal industry [44]. In addition, highlighted that Information Technology Outsourcing (ITO) can help MSMEs in Malaysia accelerate e-Business adoption, reduce labor specialization costs, and increase cash flow [45]. Pertaining to quality-life improvement through technology, blockchain was proposed to improve the economy, education, and health industries [46]. Technology adoption in the halal supply chain, particularly in transportation, is essential to save costs and improve the image of halal products [30].

Finally, technology in halal warehousing can help companies measure products that comply with halal specifications and system values [20]. Overall, technologies such as blockchain, FinTech, Big Data, and RFID have a positive impact on the effectiveness and transparency of the halal supply chain. However, significant financial and investment challenges remain a concern for companies adopting them [35][37][38][39]. Furthermore, to enhance their success prospects in Muslim markets, marketing managers of multinational companies should employ advertising messages emphasizing the ethical aspects of their products and utilizing cognitive appeals rather than emotional ones using functional magnetic resonance imaging (fMRI) technology [47][48][49]. On the other hand, using a hybrid renewable energy system can minimize the excess energy that occurs during the production process and will improve the sustainability of environmentally friendly businesses [50].

4. Halal Distribution

The Halal distribution network plays a crucial role in preserving the halal status of products and implementing protective and preventive measures to guarantee the continuity of halal status from production to consumer delivery [51]. Several technologies have been used in halal distribution to improve company performance. For example, the Traceability system-based algorithm (TS-Based Algorithm) is used to optimize the distribution of halal products [52]. The use of this algorithm has the potential to make a significant contribution to company performance by reducing transportation costs while ensuring the sustainability and authenticity of halal products. Meanwhile, GPS tracking technology (Halaltracer Technology) monitors and tracks cargo and vehicles carrying halal commodities during the shipping process [53]. This tracking technology can positively contribute to company performance by increasing the effectiveness of tracking halal products and vehicles during the shipping process, which automatically facilitates more efficient verification. The food sector focuses on applying named-entity recognition (NER) and optical character recognition (OCR) to identify halal food ingredients in Indonesia. This will increase firm performance, such as Ensuring products received by consumers are under halal standards [54].

Additionally, the use of blockchain technology will Improve the traceability of halal documents [55]. It is in line with research on the use of Blockchain, RFID, and QR Codes, which can enhance consumer trust in halal products [56]. Using OCR, RFID, and Augmented Reality will Improve efficiency in checking the halal status of products [57][58][59]. However, the financial impact of using the technology is not explicitly known.

5. Halal Logistics

Halal logistics refers to the implementation of Shariah-compliant processes in handling and distributing goods throughout the entire supply chain [60]. This definition underscores the adherence to Shariah principles in logistics operations. The concept of Halal logistics is indeed gaining significance within the supply chain management domain [61]. Key elements essential for the successful adoption and execution of Halal logistics within the Halal supply chain encompass the establishment of suitable guidelines, standards, and codes for the training of Halal logisticians [62]. Additionally, the involvement of Halal logistics in the industry is becoming more complex due to the integration of components such as Shariah governance, halal assurance, and logistics [63]. Moreover, the readiness of consumers to pay for Halal products is associated with the necessity for Halal logistics certification [39]. Halal logistics encompasses a range of activities and processes, including transportation, warehousing, terminal operations, and traceability throughout the supply chain [64][65].

There are variations in the use of technology in halal logistics. For example, Ref. [66] highlighted the importance of separating halal and haram products and considering the chain effect of haram facilities on the entire halal food logistics network by using CPLEX technology and hybrid genetic algorithms for the optimization of the location and allocation of halal logistics networks, including farms, slaughterhouses, and food factories that follow Islamic food regulations. While there are indications of increasing costs in the development of halal logistics networks, this does not mean that every cost element continues to increase. This technology can improve efficiency in locating farms, slaughterhouses, and food factories.

Furthermore, the importance of technology readiness in improving customer satisfaction and organizational operations in the halal meat industry was highlighted [67]. Internet of Things (IoT), RFID, and EDI were found to improve information

quality, personnel contact, order accuracy, order conditions, order discrepancies, and order spending amounts. In line with this, halal logistics brand building through halal tracking technology and training use Halal Tracking Technology (Product ID and RFID) to improve the performance of logistics service providers and increase their halal logistics brand recognition in a competitive market [68]. The specific use of technology in the ASEAN region focuses on developing a digital society and its impact on the region's potential to become a global leader in halal logistics [69]. In that study, information and communication technology (ICT) were used to foster a digitally connected society.

Furthermore, using ICT (RFID) can help companies monitor their transportation [70]. The impact includes increased halal logistics efficiency, better logistics organization, and improved halal performance. On the other hand, in the cosmetics industry, the use of Pharmaniaga Lifescience technology can improve the efficiency of the inspection process and the verification of halal documents to facilitate the flow of products in the warehouse [71]. In addition to focusing on technological development in halal logistics, it shows that the emerging resource capabilities of halal logistics services significantly impact customer service innovation and cost advantages [72]. Halal-based third-party logistics service providers should focus on developing their resource capabilities to improve competitiveness in the dynamic halal market.

The technologies in use today prove that the challenges and opportunities associated with emerging technologies in conventional supply chains also apply to halal supply chains. The initial disillusionment with emerging supply chain technologies, as discussed by [73], can be paralleled with the challenges faced in implementing technology-based solutions in halal supply chains. Similarly, the insights regarding digital technologies for real-time data collection and decision support systems can be applied to the halal supply chain, where ensuring the integrity of halal products from source to consumption is critical [74]. In addition, game-based workshops for knowledge transfer within the timber supply chain can be adapted to the halal supply chain [75]. This adaptation aims to enhance comprehension, ensure compliance with halal standards among supply chain stakeholders, and provide decision support for contingency planning and bottleneck analysis in halal supply chain management [75][76].

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