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Transforming Poultry Supply Chains through Big Data Harmonization: Global comparisons, barriers, and lessons for Malaysia

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Abstract
Big Data Harmonization (BDH) is a disruptive technology that enhances decision-making in poultry supply chains by integrating and consolidating fragmented data to improve sustainability, reduce costs, and enhance data quality. This paper uses a systematic Literature Review (SLR) method to analyze BDH usage trends in six countries and the review reveals Malaysia's delay in adopting the technology due to fragmented systems, limited infrastructure, and low digital literacy. These barriers limit the progress of Malaysia's poultry industry in achieving data-driven efficiency. This paper offers solutions to accelerate BDH use, improve cost-effectiveness, and increase the resilience of Malaysia's poultry supply chain.

Keywords: Big Data Harmonization (BDH), poultry operators, blockchain, poultry supply chain.

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1.0 Introduction

1.1 Research *Background*

Poultry is essential to international agriculture, food, and socio-economic development. In Malaysia, the poultry industry constitutes 63% of the national meat consumption, enhancing the economy and trade. However, some issues persist in the sector, including inadequate data collection systems, poor integration of policies, and a lack of modern technological tools. These factors result in data acquisition gaps and isolation, communication barriers, and increased operations costs, all of which lower the efficiency and competitiveness in the global market. Big Data Harmonization (BDH) can connect data from production, logistics, and market systems, allowing for tracking time, predicting trends, and making important decisions based on data, which are essential for tracking products, managing diseases, and overseeing supply chains. Blockchain, a specific technology that enables distributed data creation, plays a crucial role in BDH by ensuring data security and transparency. However, the poultry sector in Malaysia has issues with the use of blockchain due to the disjointed systems, policy limitations, and high implementation costs (Mustafa, Halim & Majid, 2017). Further inadequate data merging and inefficient operations exacerbate supply chain efficiency (Govindan, Soleimani, & Kannan, 2018). Modernization of the sector is complex due to the expensive nature of technologies such as IoT and blockchain and the insufficient government support, which has significantly undermined Malaysia's competitive advantage among its immediate regions (Khan, Zhang, & Ahvanooey, 2022). Countries

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like the Netherlands, USA, Japan, Brazil, India, and Malaysia possess developed economies with a distinct leverage in technology, especially with Big Data Harmonization. Research has the ability to automate steps, cut expenses and optimize efficiency. Adoption of international benchmarks can improve the Malaysian poultry industry's competitiveness, resiliency as well as food safeness.This research addresses the adoption process of Big Data Harmonization (BDH) internationally by focusing on six countries: the Netherlands, the USA, Japan, Brazil, India, and Malaysia. The selected countries span a continuum of varying economic development and technological sophistication levels. The Netherlands, the United States, and Japan are good examples of highly developed countries because they have developed sophisticated policies and technologies to facilitate the implementation of BDH. On the other hand, developing economies such as India, Malaysia, and. Brazil face numerous structural challenges that hinder the adoption of BDH. These countries provide examples to highlight the most important obstacles and enabling factors for BDH adoption in constructing robust and sustainable poultry supply chains.

1.2 Research Purposes

The purposes of this study are as follows:

- To examine usage trends of Big Data Harmonization (BDH) adoption in six countries.
- To identify the barriers of Big Data Harmonization (BDH) adoption in six countries.
- To explore strategic opportunities throughout the poultry supply chains of six countries, focusing on Malaysia.

2.0 Literature Review

A literature review related to the study's problem was done. The literature review highlights the situation of BDH adoption trends in 6 developing countries and technological integration in poultry supply chains used to measure a detailed analysis of the BDH adoption trends, barriers, and opportunities.

2.1 Big Data Harmonization (BDH) Adoption Trends In 6 Developing Countries

Big data Harmonization can redefine the global poultry supply chains, making them more efficient, sustainable, and resilient in the global agricultural sector. However, the application and use of BDH differ significantly due to factors such as available technologies, policies, and infrastructure in different regions and countries. These six countries span a range of economic and technological preparedness, which offers important lessons on impediments and facilitators to BDH adoption worldwide and in Malaysia within the context of multicounty studies. According to Sheng et al. (2020), BDH in the Netherlands aids in disease control and tracking in the poultry industry with an 85% market penetration. The USA has notably decreased supply chain fraud by 30% within the country through blockchain technology, which has improved stakeholder confidence and support (Doughman, 2023). Simultaneously, in Japan, cost and sustainability in agriculture were perfected using automation and data analytics (Kim & Lee, 2020). However, despite these technologies' possibilities, blockchain and data chain IoT technologies are still not widely used in advanced economies like Brazil for the poultry and agricultural sectors (Perçin, 2023).

In the case of India, these technologies, as articulated by Rahman et al. (2021), are indeed present, but their limited resources and funding restrictions prevent their use. Fragmentation causes inefficiency and data leaks, hindering marketing cooperation in decision-making. Integration barriers also restrict the introduction of other technologies. Moreover, Rahman et al. (2021) emphasize the poor and disjointed national policies that hinder the adoption of BDH technologies in the poultry supply chains. Government support is inadequate to enable investment in modern technology. Reduced cyberspace costs of operation, inter-dependency constraints, and supportive policies are important for encouraging BDH investments. Malaysian agriculture is similarly complemented by a low level of BDH adoption of 35% amidst the challenges of non-interconnected systems, weak infrastructure, and insufficient government policies. Some gaps have not been filled, such as a lack of mechanisms for sharing information, which, in the long run, will affect BDH. Addressing these gaps is crucial to the strength and competitiveness of supply chains (Report by Ministry of Agriculture and Food Industries Malaysia, 2022). For instance, this type of fragmentation causes inefficiencies and information leaks that hinder cooperation in marketing decision-making. The use of other technologies would be beneficial. Still, these segregation barriers make this almost impossible, highlighting the apparent lack of infrastructure policy and investment in developing countries, such as Malaysia.

2.2 Technological Integration in Poultry Supply Chains

The latest technologies, like IoT, AI, and blockchain, as mentioned by Lim & Mohd (2020), have revolutionized the poultry supply chain by eliminating inadequacies and ushering in change to the precision agriculture decision-making process. Using IoT, poultry operators can monitor production processes in real-time and mitigate human error. Blockchain technology greatly enables the credibility and accountability of supply chain data through improved traceability, reducing manipulations and inefficiencies (Smith, 2018). For example, adopting blockchain technologies in the USA has greatly mitigated packer and supplier fraud in the food industry (Doughman, 2023). Furthermore, predictive analytics, a novel AI ability, enhances resource use and minimizes waste (Sheng et al., 2020). In China, AI has been optimized to improve the system's disease management program and routine functioning, which has improved productivity (Chen et al., 2018).

On the other hand, financial limitations and the absence of adequate infrastructural development and skills hinder the progress of these technologies in countries such as Malaysia (Ismail & Masron, 2020). There appears to be a notable absence of BDH usage in the poultry supply chain in Malaysia, looking at it through the lens of technological developments like AI, IoT, and blockchain. According to Mustafa et al. (2017), the absence of such technological development will hinder the operationalization of the application, particularly in

the socio-economic and political spheres. The specific economic constraints within which the poultry operators in Malaysia are forced to operate have not been emphasized, thus limiting our knowledge of the possible adoption of BDH practices (Malaysia Global Business Forum, 2022). However, there is no adequate literature focusing on the range of policy options available and the relevant policy environment surrounding those options that would encourage BDH adoption in developing countries (Rahman et al., 2021). The poultry industry in Malaysia will be used as a case study, and these gaps will be addressed through a detailed analysis of the BDH adoption trends, barriers, and opportunities. This study intends to deepen the understanding of BDH's concrete implementation and provide approaches to solving the emerging market's problems by combining global practices with local ones (Khan et al., 2022).

3.0 Methodology

3.1 Systematic Literature Review (SLR) Approach

The research employs a systematic literature review (SLR) to address the scope's coverage, depth, specificity, and completeness issues. This study employed the PRISMA checklist drafted by Moher et al. (2009, including the quantitative measures, such as inclusion and exclusion criteria, and structured search data collection and analysis procedures. Adhering to this guideline reduces bias while increasing the credibility and reliability of the study.

3.2 Search Strategy

The research employed academic databases Scopus, Web of Science, and IEEE Xplore to search for pertinent studies methodically.

- Scopus: Scopus allows access to volumes of scientific journals, conference proceedings, and technical papers, together with its rich collection of abstracts and citations. This ensures intensive coverage of interdisciplinary research, which is very importance for Big Data Harmonization (BDH) studies.
- Web of Science: Web of Science prioritizes high-impact, peer-reviewed research publications and does much better in providing tools for citation analysis and literature reviews or surveys, which is very helpful in mapping the adoption and resistance within the context of BDH.
- IEEE Xplore: IEEE Xplore, which focuses on engineering and technology, was chosen because of its specialized focus on important subjects like IoT, AI, and blockchain, which are relevant to the poultry supply chain.

This review utilized specific keywords such as "Big Data Harmonization," "Poultry Supply Chains," "Technology Integration in Agriculture," and "Adoption Metrics." To incorporate the latest developments and trends, documents published between 2010 and 2023 were chosen. Furthermore, in an attempt to gather important data, this review was substantiated by manually checking the reference lists.

3.2.1 Inclusion and Exclusion Criteria

The inclusion and exclusion criteria were rigorously defined to ensure the relevance and quality of selected studies. Peer-reviewed articles formed the core of the analysis, with a focus on studies that met specific criteria:

- Discuss BDH in the poultry industries.
- Highlight adoption metrics, barriers, or global practices.
- Provide empirical data or theoretical contributions to the understanding of BDH.

Studies were excluded if they:

- were non-peer-reviewed articles, such as grey literature, opinion pieces, or conference abstracts.
- addressed topics unrelated to poultry supply chains or BDH.
- lacked methodological rigor or failed to provide actionable insights.

This systematic filtering process ensured that the final selection of studies was high-quality and closely related to the study goals, providing a strong basis for the following thematic analysis and synthesis.

3.3 Data Extraction and Analysis

All articles were screened for relevance and quality based on their title, abstract, and full text, and more than 600 articles passed the criteria provided. Out of these, 70 were kept for further readings to ascertain relevance. For the relevant outcomes, thematic analysis was performed to self-review the data from 2010 to 2023.

3.*3.1 PRISMA Flow Diagram*

The PRISMA flow diagram in Figure 1 gives a clear overview of how the systematic review was done, showing how studies were chosen and included for the final analysis from Scopus, Web of Science (WoS), and IEEE Xplore databases. A structured approach is essential to maintain integrity in systematic reviews since it enhances reproducibility and transparency. Table 1 highlights the rigorous process of refining the dataset to include only relevant and high-quality studies in the analysis. The table outlines four critical steps as shown in the table below: The table outlines four critical steps as shown in the table below:

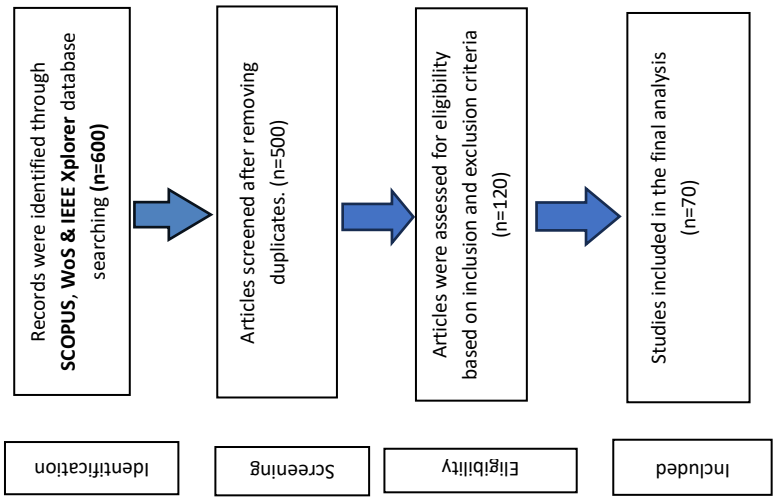

Figure 1: PRISMA Flow Diagram on Scopus, WoS and IEEE Xplore

Table 1: PRISMA Flow Diagram on Scopus, WoS and IEEE Xplore

Step	Description	SCOPUS	Web of Science (WOS)	IEEE Xplore	Total Number of Records
Records Identified	Articles were retrieved through database searches	300	200	100	600
Records Screened	Articles screened after removing duplicates.	250	180	70	500
Full-Text Articles Assessed	Articles assessed for eligibility based on inclusion and exclusion criteria.	60	45	15	120
Studies Included	Studies included in the final thematic analysis.	35	25	10	70

1. Records Identified: Through keyword searches in comprehensive databases, the total set of records was 600, including 300 for Scopus, 200 for Web of Science, and 100 for IEEE Xplore. Big Data Harmonization and supply chain optimization were the two fields of literature from which these peer-reviewed articles were picked, which is why these databases were selected.
2. Records Screened: After removing duplicate records, only 500 articles were left, which were then screened. These include 250 articles from Scopus, 180 from Web of Science, and 70 from IEEE Xplore. Each unique and significantly relevant study advanced to the next level, providing the researcher with unique and relevant works.
3. Full-Text Articles Assessed: Out of those records, 120 articles from Scopus (60), Web of Science (45), and IEEE Xplore (15) were evaluated for eligibility based on predefined inclusion and exclusion criteria. The evaluation ensured that the articles about Big Data Harmonization in poultry multidimensional supply chains were fully present and, more importantly, to those that offered upper-edge robust quantitative or qualitative conclusions.
4. Studies Included: In the end, 70 studies were selected to reach the benchmark of being fully ready for the final round of analysis. It comprises 35 studies from Scopus, 25 from Web of Science, and 10 from IEEE Xplore. These studies were selected because of their relevance to this paper's goals, particularly adoption trends, barriers, and opportunities for BDH in poultry supply chains. This section examines important data from each country regarding the main issues related to adopting BDH technology, infrastructure, and policies, which are essential for developing strategies to strengthen and make the poultry industry in Malaysia more sustainable. In line with the study's objective, the selected literature is the foundation for identifying practical solutions to address the gaps in BDH adoption specific to Malaysia's context. From 600 identified records, 70 studies met the criteria for in-depth analysis. This paper focuses on 24 studies most relevant to Malaysia's context, as they provide the most actionable insights and directly address the barriers and opportunities specific to the Malaysian poultry industry.

4.0 Findings

4.1 Adoption Trends

The study identifies six countries for poultry adoption based on economic contribution, available data, and technological readiness index. The US, Japan, and the Netherlands have high adoption rates due advanced infrastructure and strong policies. However, emerging

economies in Brazil, India, and Malaysia reveal financial, infrastructural, and policy barriers. BDH adoption varies by country due to technology levels, policy setup, and infrastructure development (Doughman, 2023; Kamilaris et al., 2017). Unlike, Brazil, India, and Malaysia face challenges due to high expenses, inadequate data systems, and fragmented coastal management (Rahman et al., 2021; Pervin, 202).

COUNTRY	BDH ADOPTION RATE (%)	KEY FACTORS FOR ADOPTION
USA	90	Advanced technology integration, robust policies
NETHERLANDS	87	Collaborative frameworks, high digital readiness
JAPAN	85	Automation and AI-driven farming practices
MALAYSIA	35	Fragmented systems, limited infrastructure
INDIA	40	Funding constraints, technological challenges
BRAZIL	38	Policy gaps, fragmented data systems

Table 2: BDH Adoption Rates Across Selected Countries

This analysis examines the interconnected factors as stated below:

1. USA: Leading with Advanced Technology and Robust Policies

Based on data estimated up to October 2023, the United States of America has the highest BDH adoption level globally at 90%, attributed to advanced technology, robust policies, and research funding. The country's commitment to technology integration, particularly in IoT, blockchain, and AI across various industries, including agriculture (Smith, 2018; Sheng et al., 2020).

2. Netherlands: A Pioneer in Collaborative Frameworks

Has an impressive 87% BDH adoption rate due to high digital preparedness and public-private partnerships (Verdouw et al., 2016; Wolfert et al., 2017; Ismail & Masron, 2019).

3. Japan: Focused on Automation and AI

Japan has adopted BDH at a rate of 85%, pointing toward the nation's focus on robotics and AI-based agricultural implementations. It is made possible by the existing collaboration among the country's government, industry, and educational institutions. (Ismail & Masron, 2019).

However, countries with emerging economies remain stuck at adoption levels with systemic challenges as the core cause of this failure:

1. Malaysia: Hampered by Fragmented Systems and Limited Infrastructure

For instance, Malaysia's modem usage is 35 % lower than that of some other nations due to gaps in its data systems and constraining infrastructure. (Department of Veterinary Services Malaysia, 2022; Malaysia Global Business Forum, 2022; Ministry of Agriculture and Food Industries Malaysia, 2022). National standardization and Unified Data Sharing protocols are lacking limiting information dissemination and preventing information storage in different repositories.

2. India: Financial Barriers and Technological Challenges

India's adoption rate is 40%, which shows some improvement but not enough. The government's policies regarding digital transformation have been beneficial but investment in new rural regions is lacking and has slowed momentum (Singh & Chandra, 2019; Rahman et al., 2021). Resources are a significant issue, as poultry operators without government subsidies struggle to invest in advanced farming tools.

3. Brazil: Policy Gaps and Fragmented Systems

In short, Brazil has policy gaps and fragmented systems.

The comparative analysis reveals a clear divide between high adopters and emerging adopters, with the USA, Netherlands, and Japan in the former group and Malaysia, India, and Brazil in the latter.

4.1.1 Technological Adoption in Developed Nations

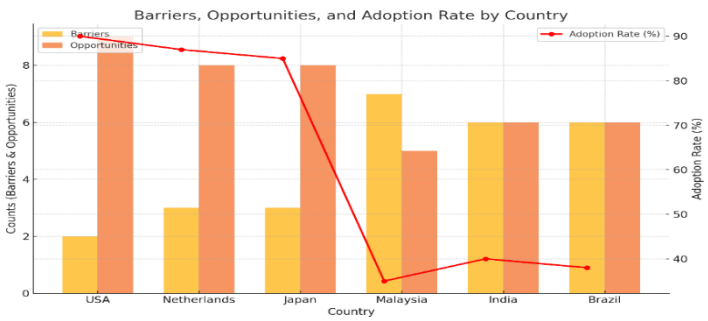

Figure 1: Adoption Rates of IoT, Blockchain, and AI by Developed Country

The Netherlands, the USA and Japan are leading the way in integrating IoT and blockchain technologies in poultry supply chains. The Netherlands has 85% adoption, enabling real-time monitoring and predictive analytics for disease management and supply optimization (Kamilaris et al., 2017; Sheng et al., 2020). With 90% of adoption, the USA uses blockchain for traceability, mitigating fraud and inefficiencies by approximately 30% (Doughman, 2023). Japan also have adopted AI, optimized feed dispensing systems that reduce feed costs by 15% annually (Kim & Lee, 2020).

The chart shows the correlation between obstacles and possibilities in the adoption of Big Data Harmonization (BDH) in countries like the US, Netherlands, Japan, Malaysia, India, and Brazil. It shows that adopting BDH requires reducing barriers and increasing economic opportunities for low-consuming regions. For example, Malaysia needs advanced countries to provide guidance on infrastructure development, cooperative enterprises, and BDH forward policies. Barrier Opportunity Mapping by Country confirms this relationship, highlighting the need for other low-income countries to improve their adoption rates. Countries with low barriers but high opportunities, like the USA, Netherlands, and Japan, achieve high adoption rates due to policies, stakeholder collaboration, and investment (Verdouw et al,; 2016Smith, 2018). Malaysia and Brazil, with systemic fragmentation and underdeveloped infrastructure, face high barriers. Overcoming these barriers and creating an environment conducive to BDH adoption is crucial for developing nations (Mustafa et al., 2017; Perçin, 2023; Ministry of Agriculture and Food Industries, Malaysia, 2022). This combination of lowering barriers and raising potential opportunities is paramount for developing nations to catch up with the more successful countries.

5.0 Discussion

The primary purpose of this study is to identify the relationship between the effectiveness of information literacy instruction (ILI) and the The results reveal significant disparities in Big Data Harmonization (BDH) adoption rates between developed and emerging economies. The US, Netherlands, and Japan use IoT, AI, and blockchain technologies to enhance operational performance, monitor supply chains, and maintain environmental stability. On the contrary, developing countries such as Malaysia, India, and Brazil appear to have many systemic issues and shortcomings, as Ferlito (2020) has mentioned. For countries like these, it is very challenging to incorporate BDH technologies in decisive industries like agriculture and the poultry industry, but it is not impossible. Considering the gap highlighted, the need for such strategies for the aforementioned countries arises. As a result of being exposed to standardized control methods or even a lack of them, combined with issues of high costs and fusion of data, the adoption and transition to BDH in Malaysia is also very low.

Furthermore, integrating broadband facilities with the infrastructure available to rural IoT BDH devices is exceedingly difficult. The inability to comprehend new technology among most poultry operators and their unwillingness to implement it create a significant barrier. The study indicates that Malaysia needs a national strategy for implementing BDH, which consists of data-sharing mechanisms and financial incentives for small-scale poultry operators. It points out the need for literacy advancement and enhanced digital networks. Such studies may enable Malaysia to integrate BDH with food and agricultural policies and become a regional hub for the use of technology.

6.0 Conclusion and Recommendation

The results reveal significant disparities in Big Data Harmonization (BDH) adoption rates between developed and emerging economies. Although using BDH can improve supply chains, economic growth, and decision-making in developed countries, Malaysia is adopting it more slowly because of problems like fragmented data systems, limited infrastructure, low digital literacy, and unclear policies. Considering the global best practices and frameworks, it is clear that investments in time, energy, and funding need to be well structured if Malaysia is to lessen the gap. There is a need for Malaysia to enhance its poultry supply chain systems by creating a national BDH policy, increasing digitalization, and scaling capacity for major stakeholders. By replicating resources and innovation development and offering subsidies and tax benefits to the people of Malaysia, it can push for upgrades into AI, IoT, and blockchain, which will aid in real-time data access, accompany the history of the supply chain, and forecast patterns. BDH technology must be further implemented within the specific socio-economic environment of Malaysia in the coming years. This enhancement will allow Malaysia to strengthen its BDH technology, helping ensure a poultry supply chain that is resilient, efficient, and sustainable over the long term. These developments would allow for the country's self-sufficiency and economic growth while allowing Malaysia to be among the possible pioneers of eco-friendly agricultural practices. The only constraints to this study are secondary data and the analysis of existing literature. Therefore, future studies could design a cohesive policy framework to enhance BDH adoption in Malaysia's agri-food sectors and assess the impact of artificial intelligence-powered platforms on supply chain resilience.

7.0 Acknowledgements

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8.0 Paper Contribution to Related Field of Study

By investigating the existing challenges within the Malaysian poultry supply chain, this study contributes practical resolutions to address the infeasibility issues surrounding BDH integration by cross-referencing the already established use of BDH in the USA and Netherlands. The paper also offers policy suggestions as this study deepens the understanding of BDH practices by enabling the

Malaysian poultry sector to serve better its social and economic goals of resilience and sustainability while paving the way for actionable strategies to address BDH integration hurdles to be fulfilled.

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