

Towards Smart Food Distribution: Integrating Supply Chain Strategic Fit and Artificial Intelligence for National Food Independence

Ari Okta Viyani¹, Inna Zahara², Arnes Tassa³, Laura Dika^{4*}✉

Program Studi Manajemen, Universitas Jenderal Achmad Yani Yogyakarta

Program Studi Akuntansi, Universitas Jenderal Achmad Yani Yogyakarta

Abstract

Food self-sufficiency is an essential foundation in supporting national resilience. Food distribution in Indonesia still experiences serious obstacles, such as slow delivery, fuel waste, and inefficient distribution routes. AI technology has the potential to be a strategic solution to optimize the distribution system through route efficiency, energy savings, and increased delivery speed. This study aims to: (a) Test the effect of supply chain strategic fit, performance, and AI adoption in food distributors; (b) Dig deeper into the implementation, obstacles, challenges, readiness and opportunities, as well as driving factors for AI implementation in the food supply chain in Indonesia. The method used is a mixed method, namely a quantitative approach with SEM-PLS and a qualitative approach using N-Vivo. The results of the quantitative analysis show that AI adoption mediates the relationship between supply chain strategic fit and rice distributor performance. Furthermore, the results of the qualitative analysis also support the idea that the distribution system using AI is considered to have great potential in optimizing food distribution in Indonesia. However, this adoption has several challenges, including costs, human resources, infrastructure, regulations, differences in regional topology, privacy and security, and ethics.

Keywords: *Food Independence; Supply Chain Strategic Fit; Artificial Intelligence; Food Distributor Performance; Mix Method*

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✉ Corresponding author:

Email Address: ariokta902@gmail.com

INTRODUCTION

The introduction mainly contains: (Firmansyah et al., 2024) research problems; (National Food Agency, 2024) insights and problem-solving plans; (Hibatullah et al., 2024) formulation of research objectives; (Ivanka et al., 2024) summary of theoretical studies related to the problem being researched. This section sometimes also includes expectations regarding the results and benefits of the research. The introduction is approximately 2-3 pages long and typed with 1.15 spacing (or following the writing provisions of the scientific journal where the article is to be published).

The government-initiated Free Nutritious Food Program faces diverse challenges that require a comprehensive strategy to address (Firmansyah et al., 2024). According to the latest data from the National Food Agency, in 2024, 23,288,634 people in Indonesia experienced insufficient food consumption, equivalent to 8.27% of the total population of 281,603,799 (

National Food Agency 2024) . This underscores the continued need for a strategy to achieve food security and self-sufficiency in Indonesia.

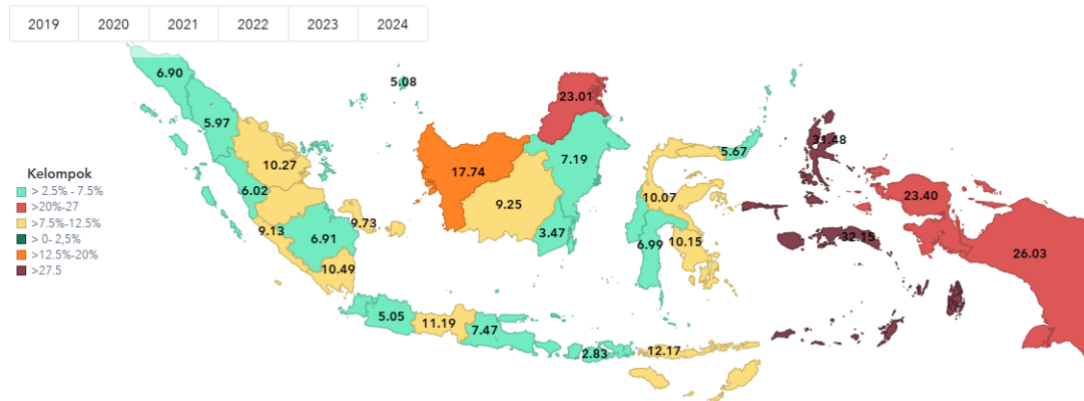
Data Jumlah Penduduk yang Mengalami Ketidacukupan Konsumsi Pangan Nasional Update Tahun 2024

TAHUN	POU	JUMLAH_PENDUDUK	PENDUDUK_UNDERNOURISH
2021	8.49	272679153	23150460
2022	10.21	275719905	28151002
2023	8.53	278696193	23772785
2024	8.27	281603799	23288634

Sumber : Badan Pangan Nasional 2024

The context of food security in Indonesia is complicated by the high demand for rice, a staple food, and declining rice production due to the conversion of rice fields to non-harvesting areas. In 2023, rice production decreased from 31.54 million tons to 30.90 million tons. Furthermore, the area dedicated to rice cultivation has also shrunk by 2.45%. Rice fields in Indonesia have also decreased from 8.4 million hectares in 1990 to 7.18 million in 2022 (Hibatullah et al . , 2024; Ivanka et al., 2024) .

PREVALENSI KETIDACUKUPAN KONSUMSI PANGAN/PREVALENCE OF UNDERNOURISHMENT (POU)
Sumber : Badan Pusat Statistik



Food self-sufficiency is a key pillar in achieving sustainable national resilience. Research shows that food self-sufficiency is influenced by various factors, including natural resources, agricultural land availability, effective infrastructure, and a reliable supply chain (Larasati et al., 2023). **Based on the data on the prevalence of insufficient food consumption below, significant disparities in food inadequacy remain between regions. Thus, effective distribution of food supplies is very important to do.**

Food independence is significantly influenced by the reliability of the food supply *chain*. (Sharma et al., 2021). This is because an effective supply chain ensures timely delivery and the continued good quality of food products (Sharma et al., 2021). **Unfortunately, the current national food distribution system still faces various obstacles, such as suboptimal distribution routes, delivery delays, and high fuel consumption and logistics costs.**

The National Food Agency (Bapanas) or the National Food Agency (NFA) assesses that food distribution in Indonesia is still uneven, as evidenced by the fact that some regions still experience food deficits, while other regions experience food surpluses (Uly, 2022). This inequality causes significant price differences between regions. **The urgency and formulation of the problem in this study: the food supply chain system in Indonesia still experiences obstacles such as inefficient distribution routes, slow deliveries, and fuel waste. These problems lead to wasted resources, high logistics costs, and unequal access to food, which hinders the achievement of food self-sufficiency.** These inefficiencies, if not addressed, could exacerbate hunger and malnutrition, affecting millions of people in Indonesia (Larasati et al., 2023).

METHODOLOGY

This research will use *a mix of quantitative and qualitative methods*. The combination of these two methods is expected to validate more accurate results. The quantitative approach aims to examine the relationship between research variables using SEM PLS (Hair et al., 2017). Meanwhile, the qualitative approach is carried out through semi-structured interviews to explore in-depth perspectives from stakeholders in the food supply chain (Hirsch et al., 2024). These interviews will be directed at understanding food distribution practices; the level of suitability of food supply chain strategies; stakeholder perceptions and readiness *towards* the use of AI technology in *supply chain management*; obstacles and opportunities for implementing technology in the food distribution system; as well as driving factors and challenges.

Population and Sample

The population in this study was food distributors and the government. The sampling technique used was *purposive sampling*, with the following criteria:

- A grocery distributor adopting AI to help its supply chain.
- Government agencies that have policies related to the food supply chain.

The minimum sample size in this study is 50 samples. This refers to the provisions of (Sugiyono, 2019) that a reasonable sample size in research is between 30 and 500, as well as the provisions of (Hair et al., 2017) that *the rules of thumb* for PLS testing, the minimum sample size is 10 times the maximum number of arrows pointing to the latent variable anywhere in the PLS path model. The number of arrows pointing to the latent variable in this study is only 2 arrows. So, if 2×10 , the minimum sample in this study is 20 samples. However, the researcher targets 50 samples in this study. This is to provide a better level of data accuracy and credibility.

Variables

The research variables used in quantitative analysis include:

- Independent variable: *Supply Chain Strategy Fit*
- Dependent variable: Food Distributor Performance
- Mediating variable: AI adoption

Variable measurement will use a 5-point Likert scale, with validation through reliability and validity tests (*convergent and discriminant validity*). The variable measurement in this study refers to (Kim et al., 2023; Al-Shboul, 2024).

Quantitative Data Analysis Techniques

Quantitative data analysis was conducted using the SEM-PLS method using software such as SmartPLS. This technique was chosen because this study had a moderating variable, namely AI adoption, so the analysis technique using this model would be more appropriate (Hair et al., 2017).

Qualitative Data Analysis Techniques

This study used a qualitative approach through semi-structured interviews with key stakeholders in the food supply chain. The aim was to explore in-depth the implementation, barriers, challenges, readiness and opportunities, and driving factors for AI implementation in the food supply chain in Indonesia. To analyze the interview data, NVivo was used as a digital tool to facilitate a systematic thematic analysis process (Woods et al., 2016).

Data Triangulation and Validity

To increase the validity and reliability of the findings, this study uses **method triangulation** , namely by comparing the results of quantitative and qualitative approaches. Quantitative findings obtained through **Structural Equation Modeling-Partial Least Squares (SEM-PLS) analysis** will be confirmed and deepened through **thematic analysis of semi-structured** interview data . This process allows researchers to gain a more comprehensive and contextual understanding of the relationship between Artificial Intelligence (AI) adoption, supply chain strategic fit, and food distribution performance in supporting national food independence.

mixed methods approach in this research offers integrative benefits. **The quantitative approach** provides empirical evidence on the relationships between variables, including testing the role of AI adoption as a moderating variable. Meanwhile, **the qualitative approach, using semi-structured interviews**, allows for in-depth exploration of implementation, barriers, challenges, readiness and opportunities, and driving factors for AI implementation in the food supply chain in Indonesia.

RESULTS AND DISCUSSION

Quantitative data collection was conducted using a direct survey method using an electronic questionnaire utilizing the Google Forms feature. The questionnaire was distributed to several stakeholders, namely rice distributors, the government, Bulog, and rice mills. Respondents were asked to fill in the questionnaire using a barcode provided by the researcher. Survey samples were taken from several regions in Indonesia. The categorization was based on regions within Java and regions outside Java. The survey resulted in a sample of 72, each representing one organizational unit. The results of the research survey revealed the following characteristics of the respondents.

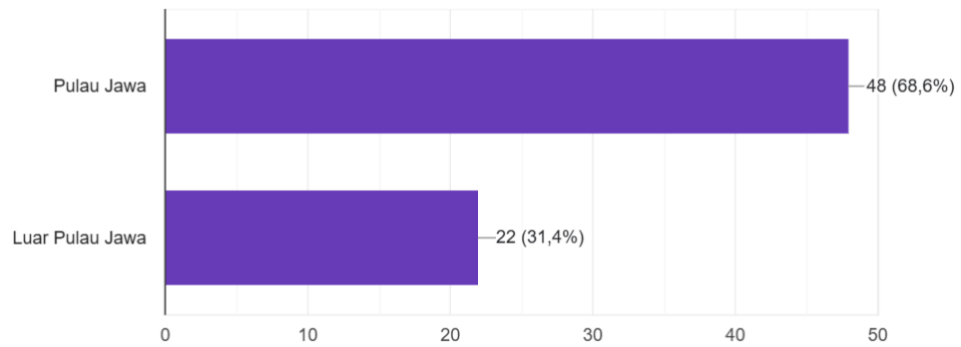


Figure 1. Based on Respondent Location

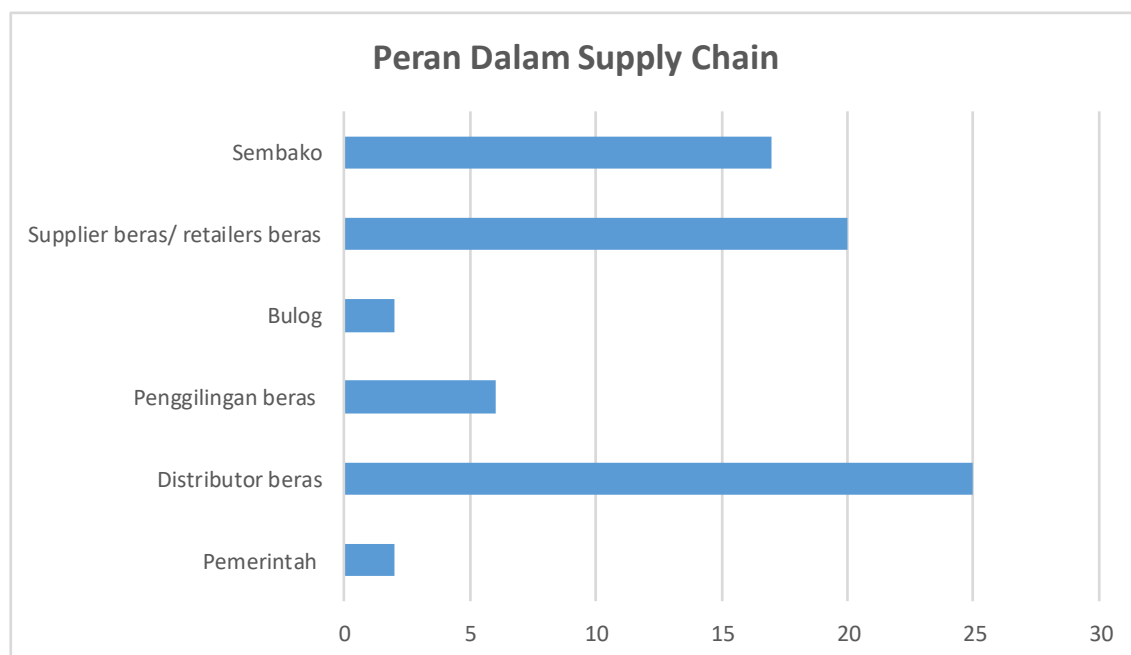


Figure 2. Based on Respondent Role

Based on the results of descriptive analysis, the majority of research respondents came from Java Island (68.6%), while the rest came from outside Java Island (31.4%), indicating that most of the food distribution in this study is still concentrated in areas with relatively more developed logistics infrastructure. In terms of roles in the supply chain, the majority of respondents work as rice distributors ($\pm 60\%$), followed by rice suppliers/retailers ($\pm 30\%$), and a small portion from rice mills and regulators (each $\pm 5\%$). This composition illustrates that the research has involved the main actors in the rice supply chain, with the dominance of distributors as the main focus, so that the research results are expected to be able to represent the real conditions of food distribution and the potential for implementing supply chain strategic fit and AI adoption in improving food distribution performance in Indonesia.

Before conducting the hypothesis testing, the researcher conducted instrument testing to check the validity and reliability of the instrument. The results of this instrument testing are as follows.

Table 3. Convergent Validity

Supply Chain	Performance	AI	<i>P value</i>
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	Strategy	Adoption	
SCS1	(0.770)		< 0.001
SCS2	(0.785)		< 0.001
SCS3	(0.794)		< 0.001
SCS4	(0.822)		< 0.001
KN1		(0.884)	< 0.001
KN2		(0.909)	< 0.001
KN3		(0.868)	< 0.001
KN4		(0.904)	< 0.001
AAI1		(0.843)	< 0.001
AAI2		(0.737)	< 0.001
AAI3		(0.864)	< 0.001
AAI4		(0.834)	< 0.001
AAI5		(0.757)	< 0.001
AAI6		(0.742)	< 0.001
AAI7		(0.832)	< 0.001
AAI8		(0.823)	< 0.001
AAI9		(0.827)	< 0.001

Source: Processed Primary Data

Table 3 Convergent Validity above shows that all questionnaire items from the SCS4-AAI9 have loading factor values above 0.5 and produce a significant p-value <0.05. Thus, it means that all question items in the questionnaire meet good convergent validity.

Table 4. Discriminant Validity

Construct	Supply Chain Strategy	Performance	AI Adoption
Supply Chain Strategy	(0.793)	0.536	0.488
Performance		(0.892)	0.484
AI Adoption			(0.808)

Source: Processed Primary Data

Table 4. Discriminant Validity shows that the square root of the AVE value for each construct is greater than the correlation value between constructs. Thus, this research instrument has good discriminant validity.

Table 5. Reliability

Construct	Supply Chain Strategy	Performance	AI Adoption
Composite Reliability	0.871	0.939	0.944
Conclusion	Reliable	Reliable	Reliable

Source: Processed Primary Data

1.

Table 5 above shows that all constructs in this study have a Composite Reliability value of 0.7. Thus, the instruments in this study have good reliability or a good level of reliability or consistency. Before testing the hypothesis, the researchers also conducted a model fit test, and the results of the goodness of fit test also found that the SRMR value was <0.08. Thus, it can be said that this research model is fit.

Table 6. Hypothesis Testing

	Original Sample (O)	P Value
Supply Chain Strategy → Performance	0.394	0.000
Supply Chain Strategy → AI Adoption	0.488	0.000
Performance Adoption →	0.292	0.003

Based on the hypothesis testing output in Table 6, it can be seen that all relationships between variables in the research model show a statistically significant influence, with a p-value of 0.000 – 0.003 ($p < 0.05$). First, supply chain strategy shows a positive influence on performance with a coefficient value of 0.394. This indicates that supply chain strategy provides a direct contribution to improving performance. The right strategy helps companies to reduce operational costs, increase distribution speed, and improve customer satisfaction. Furthermore, supply chain strategy is also proven to have a positive and significant influence on AI adoption, with a coefficient value of 0.488. This finding indicates that a well-designed and precise supply chain strategy in planning, controlling, and coordinating each department will encourage organizations to be more open and ready to adopt new technologies. Finally, AI adoption has a positive and significant influence on performance with a coefficient value of 0.292. This indicates that the higher the level of AI adoption, the greater the improvement in performance that can be achieved. With this technology, it can facilitate operational accuracy, accelerate decision-making, and help optimize cost efficiency.

Table 7. Specific Indirect Effect

	Original Sample (O)	Sample Mean (M)	Standard Deviation (Stdev)	T Statistics	P Values
Supply Chain Adoption Strategy → AI → Performance	0.142	0.148	0.058	2,443	0.015

Based on the results of the specific indirect effect analysis in Table 7, it is known that supply chain strategy has a positive and significant effect on performance through AI adoption with an original sample value of 0.142, a t-statistic of 2.443 (>1.96), and a p-value of 0.015 (<0.05). This indicates that AI adoption acts as a mediating variable that strengthens the relationship between supply chain strategy and improved company performance. Thus, the implementation of supply chain strategy not only has a direct impact but will provide more optimal results when accompanied by the use of AI technology in operational processes, so that company performance can be significantly improved.

Furthermore, the results of interviews with 10 interviewers were also processed using the NVivo application. Based on the data processing using NVivo, the following results were obtained.

Table 8. Main Themes and Sub-Themes of Coding

Main Theme	Sub-Theme	No. of Coding Reference
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Driving Factors for AI Implementation	Infrastructure and Information Systems	3
	Government policy	7
	Need	19
	Stakeholders	0
Distribution Barriers	Weather	5
	Price	2
	Infrastructure	8
	Mileage	2
	Congestion	17
	Coordination	1
	Overload	2
	Delivery Not on Time	5
	Road repair	1
	Problem with Address	2
	Travel Risks and Traffic	2
	Challenges	
	High Shipping Volume	5
Implementation of Supply Chain Strategy and AI	End User	1
	Manual	9
	Map	13
	Retail	8
	Retailers, Suppliers, Distributors	4
	The system has been well integrated	2
	Stepan, Ricemill, Rice Milling	5
	Tengkulan	5
	Systematic but only simple	34
	Not ready	1
Readiness	Perpetrator	2
	Regulator	2
	Ready	4
	System	2
Opportunity	Big Opportunity	23
	Small Chance	0
Challenge	Cost	6
	Data Not Available	1
	Ethics	1
	Infrastructure	5
	Privacy Security	1
	Differences in Regional Topology	3
	Regulation	1
	HR	5

Source: Processed Primary Data

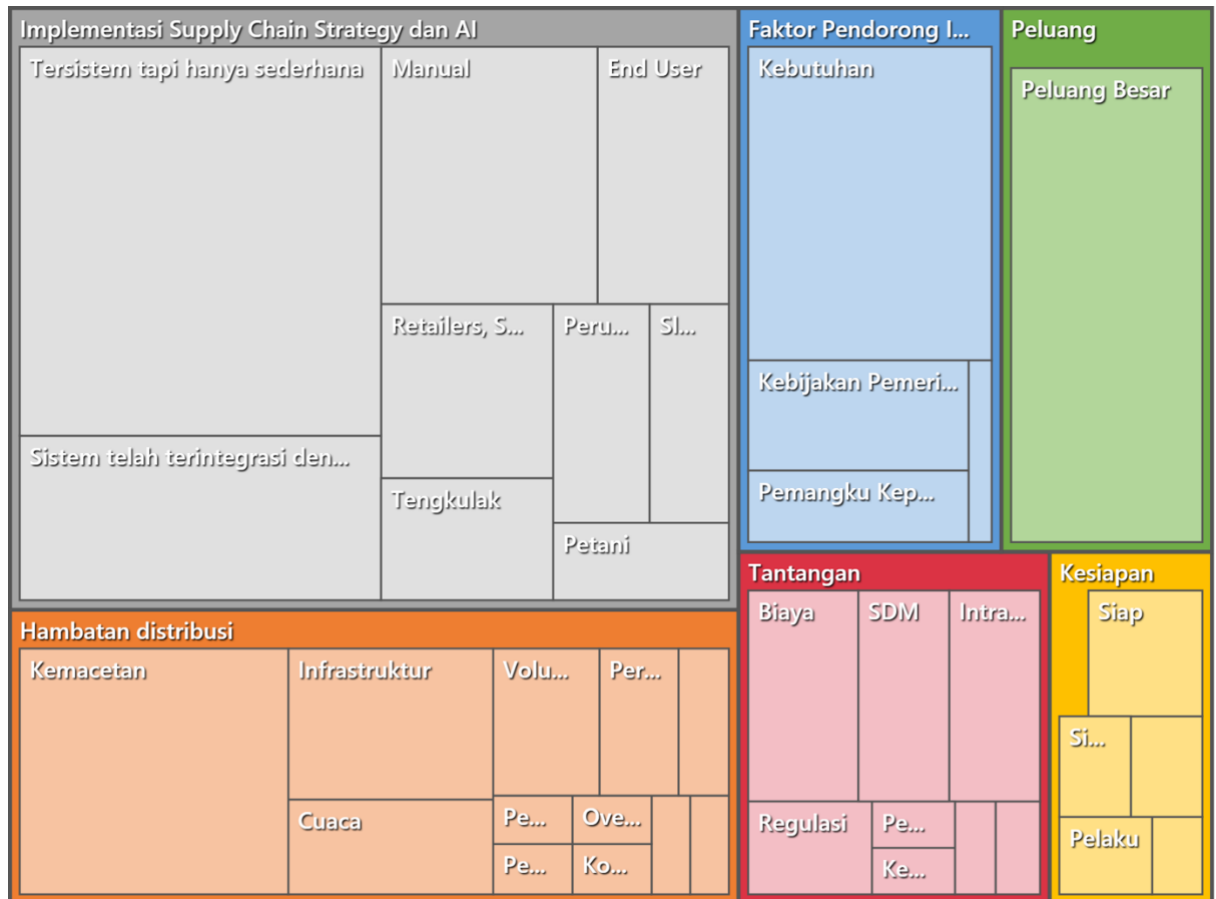


Figure 3. NVivo Chart Hierarchy

Qualitative analysis using NVivo yielded several key themes reflecting the dynamics of *artificial intelligence* (AI) implementation in the food supply chain. The results show that the driving factors for AI implementation are dominated by the need aspect (19 references), indicating the urgency of utilizing technology to improve distribution efficiency. This aligns with the pressing needs of supply chain actors, including farmers, mills, distributors, and retailers, in responding to changing demand and market challenges. Government policies (7 references) also play a key role, particularly in encouraging the adoption of digital food distribution through regulations and strategic programs. However, the role of external stakeholders remains low (0 references), resulting in suboptimal cross-actor collaboration in supporting the digital transformation of food distribution.

On the other hand, distribution barriers remain a crucial issue. The main identified barrier was congestion (17 references), indicating that transportation and traffic congestion are significant obstacles to maintaining the speed and timeliness of food distribution. Limited road infrastructure (8 references) and weather conditions (5 references) further exacerbate this problem. Other barriers, such as high delivery volumes (5 references), delivery delays (5 references), and coordination challenges (1 reference), highlight the complexity of food distribution in the field. These results confirm that while AI technology has significant

potential for distribution optimization, physical factors such as transportation facilities and geographic conditions remain dominant variables that must be addressed simultaneously.

Regarding the implementation of supply chain strategy and AI, the majority of informants stated that the distribution system is systematic but still simple (34 references). This indicates that the food supply chain in Indonesia has a structured framework, but is not yet fully digitally integrated. Most actors still use manual methods (9 references), while others have begun to shift to the use of digital maps (13 references) and data-driven retail systems (8 references). The role of rice mills (5 references) and middlemen (5 references) also indicates that the distribution chain still involves traditional actors operating with conventional systems. Thus, the integration of supply chain and AI is still partial and has not yet formed a fully interconnected ecosystem.

The readiness of actors to adopt AI shows disparities. Some actors believe they are ready (4 references), while others are still not (1 reference). This is primarily related to limited resource capacity, both in terms of digital competency and supporting infrastructure. Regulatory readiness (2 references) and systems (2 references) are also still limited, which can be a barrier to accelerating the digitalization of the food supply chain. This difference in readiness among supply chain actors demonstrates that digital transformation requires a phased approach that adapts to the capacity of each party.

Despite various obstacles and limitations, the potential for AI application in food distribution is significant. This is evident in the dominant positive perception that digital transformation opportunities are wide open (23 references), while no one considered the opportunities to be small. This optimism stems from AI's perceived ability to increase efficiency, accelerate distribution processes, and improve transparency of food pricing and availability information. This significant opportunity can be leveraged if supply chain and AI integration is carried out effectively and actively with the involvement of all stakeholders.

Identified challenges include relatively high technology investment costs (6 references), limited human resources in mastering digital technology (5 references), and limited infrastructure (5 references). Furthermore, other challenges such as differences in regional topology (3 references), unclear regulations (1 reference), and ethical and privacy security issues (1 reference) indicate the need for greater attention from the government and stakeholders. If these challenges are not addressed, AI implementation could potentially be non-inclusive and limited to certain actors with greater capacity.

Overall, the results of this study indicate that the implementation of AI in food distribution in Indonesia is still in its early stages, characterized by the dominance of simple and partial systems. Physical barriers such as traffic jams, infrastructure, and weather still outweigh digital ones, while the readiness of actors indicates a capacity gap. Nevertheless, the opportunity for AI implementation is considered significant and crucial for increasing efficiency and supporting national food self-sufficiency. Therefore, efforts towards smart food distribution must consider *the strategic fit* between the supply chain, AI technology, government policies, and actor readiness, so that digital transformation can be inclusive, sustainable, and strengthen national food security.

CONCLUSION

This study aims to analyze how supply chain strategies combined with the adoption of Artificial Intelligence (AI) technology can provide a real contribution to improving the performance of the food supply chain in order to support food security in Indonesia, where the results of the study show that supply chain strategies have a significant effect on food supply chain performance because a mature, targeted, and adaptive strategy can increase operational efficiency, improve food distribution processes, optimize logistics costs, and ensure more equitable food availability to the end consumer level, in addition, supply chain strategies have also been proven to have a positive effect on AI adoption because clear and

structured planning makes it easier for organizations to implement the technology with the support of infrastructure, human resources, and appropriate policies, while the application of AI itself has a significant effect on improving supply chain performance through accurate demand flows, improved inventory management, optimization of distribution channels, and acceleration of decision making, so that the risk of scarcity, waste, and distribution delays can be suppressed, and overall there is a synergistic relationship between supply chain strategies, AI adoption, and food supply chain performance, where a good supply chain strategy encourages AI adoption and AI adoption ultimately strengthens performance, so that the combination of the two is able to produce a more adaptive, responsive, competitive, and sustainable food supply chain in supporting national food security.

Qualitative data testing indicates that the application of artificial intelligence (AI) in the food supply chain in Indonesia is still in its early stages and is partial, with a predominance of systematic but simple systems and the use of manual methods by many supply chain actors. The primary drivers emerging are operational and efficiency needs, followed by government policy support, although the role of external stakeholders remains very limited. The most significant distribution barriers are physical and infrastructure factors such as congestion, weather conditions, and road quality, while the readiness of actors – including businesses and regulators – remains varied and uneven. The opportunities for AI implementation are considered significant, particularly in improving efficiency, transparency, and speed of distribution. However, real challenges such as investment costs, limited human resources, regulations, and privacy security must be immediately eliminated for AI implementation to be more comprehensive and inclusive.

The findings of this study align with previous studies showing that in developing countries, AI can improve operational efficiency, supply chain resilience, and responsiveness to market fluctuations, although barriers such as high costs, limited data, and regulations remain prominent (Albert & Alijoyo, 2024). Other research also confirms that in the context of the COVID-19 pandemic, AI has the potential to strengthen food distribution, but barriers such as uneven infrastructure, cost issues, and limited human resources remain significant (Kumar, Gupta, & Sharma, 2023). Furthermore, systematic reviews show that AI implementation in supply chain management generally focuses on demand forecasting, logistics optimization, and risk management, emphasizing the importance of the interconnectedness between technology and regulations (Zhang, Wang, & Chen, 2024).

Thus, the main conclusion of this study is that the transformation towards smart food distribution in Indonesia requires a strategic fit that aligns traditional supply chains with AI capabilities, strengthens infrastructure and human resources, and supports and inclusive policies and regulations. Without addressing these key barriers, particularly the physical and structural ones, the significant opportunities available risk being difficult to realize broadly and equitably.

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