Examining the Factors Affecting the Digital Supply Chain in the Food Retail Industry

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Abstract

The present study aims to examine the factors affecting the digital supply chain in the food retail industry. In terms of purpose, the research is applied, and in terms of data collection, it follows a mixed-methods (qualitative-quantitative) approach. The statistical population in the qualitative phase includes professors, experts in technology and supply chain management, and senior managers in production and research and development within the online food retail industry. In the quantitative phase, the statistical population consists of all managers and employees of online supermarkets in Tehran. The sample size in the qualitative phase was determined based on theoretical saturation (10 participants) using purposive sampling, while in the quantitative phase, a sample of 380 participants was selected through stratified random sampling. Data collection tools included interviews in the qualitative phase and a researcher-developed questionnaire in the quantitative phase. The validity of the questionnaire was confirmed through face and content validity by several experts, convergent validity was verified by calculating the average variance extracted (AVE), and discriminant validity was assessed through the square root of AVE. The reliability of the questionnaire was established using Cronbach's alpha, which yielded a value of 0.898 for the entire instrument. Data analysis was performed using SmartPLS 3 software. Among the 29 available indicators (items), seven main components were identified. The results indicated that economic factors, social factors, technological factors, environmental factors, managerial factors, organizational factors, and industrial factors were recognized as causal conditions influencing the digital supply chain in the food retail industry. Additionally, the model fit was also evaluated.

Keywords: *Digital supply chain, retail, online food supermarket.*

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1. Introduction

Over the past decades, supply chains have undergone significant transformations, shifting from traditional supply chain models to digitalized structures. The Fourth Industrial Revolution (Industry 4.0), also known as the "Digital Revolution," has introduced major changes in the structure and performance of supply chains. Emerging technologies such as the Internet of Things (IoT), artificial intelligence (AI), and blockchain have provided new capabilities to enhance the efficiency and effectiveness of supply chains [1]. The significance of supply chain management is evident in all organizations and companies, as a digital supply chain enables firms to leverage new technologies for data collection and insight development, thereby optimizing their supply chain operations. Thus, a strong interconnection between Industry 4.0 and supply chain management can be observed [2].

A digital supply chain is essentially a supply chain that employs digital technologies and data analytics to optimize performance and respond rapidly to various conditions. Fundamentally, digital supply chains incorporate data warehouses that store all relevant information, allowing for subsequent analysis of conditions [3]. The nature of the digital era, driven by the emergence of advanced technologies, has necessitated that businesses align with

these changes and adopt innovative approaches to offering goods and services in order to remain competitive [4]. The utilization of transformative technologies in business environments to create competitive advantages marks the beginning of a new era known as digital transformation [5]. Historically, the food industry has played a crucial role in economic development due to its diverse production, low investment requirements, rapid returns, foreign exchange earnings, value creation, productivity enhancement, employment growth, and poverty reduction [6, 7].

The digitalization of various aspects of life has had a global impact, and supply chain processes have been significantly influenced by digitalization as well [8]. The digital supply chain serves as a competitive advantage for businesses by creating sustainable value for them [9]. A digital supply chain represents a form of information systems development and the adoption of innovative technologies that enhance supply chain integration and agility, thereby improving customer service and sustainable business performance. Forward-looking businesses prioritize integration for better financial analysis, customer relationship management, and human resource management. The digital supply chain leverages cutting-edge technologies such as augmented reality, big data, artificial intelligence, machine learning, and blockchain to enhance customer focus and reduce both intra-organizational and inter-organizational costs, ultimately creating greater value for businesses [10].

According to the electronic supply chain model, customers determine both the starting and ending points of an organization's activities. By obtaining real-time awareness of customer needs, product requirements can be continuously identified based on their preferences. This cycle can be continuously improved based on customer feedback and through the flexibility and restructuring capabilities that are among the effects of electronic supply chain management. This dynamic cycle enables restructuring, simultaneous adaptation to product variations, agility, and supply chain design in accordance with product type and life cycle, all aligned with customer perspectives in a volatile and competitive environment [11].

With technological advancements, consumer expectations are also evolving, compelling businesses to move towards innovation and embrace digital transformation. In this context, integrating and analyzing the factors influencing the supply chain is crucial [12]. The supply chain represents an intelligent and innovative approach that benefits both businesses and stakeholders. The integration of the supply chain facilitates a better understanding of market expectations and opportunities, enabling more precise and swift responses to the needs of supply chain stakeholders.

Recent studies have extensively examined the impact of digital transformation on supply chains across various industries. Abdollahi et al. (2024) found that supply chain digitalization significantly influences absorptive capacity, improvement capacity, responsiveness capacity, and overall supply chain performance. Their study also highlighted the mediating roles of these capacities in strengthening the effect of digitalization on supply chain performance [13]. Similarly, Jahandideh and Bahramzadeh (2023) demonstrated that digital capabilities positively affect export performance through the mediating roles of exploration, exploitation, supply chain agility, operational agility, and marketing agility, indicating that improved digital capabilities enhance cement export performance [14]. Roknaldini et al. (2023) identified organizational, production system, environmental, product, economic, technological, and social factors as key elements affecting digital supply chains, with technology being the most influential factor, product being the most affected, and economic aspects being the most critical dimension [15]. Jantarani et al. (2022) explored the requirements for industrial IoT adoption in the automotive supply chain, identifying five categories and twenty components, including organizational, social (environmental), managerial, industrial, and financial factors [16]. Nozari et al. (2021) highlighted that a lack of technological infrastructure and security challenges are major barriers to implementing Supply Chain 4.0 in the digital transformation era. International research has also supported these findings [17]. Duan et al. (2025) ranked emerging technologies based on their impact on supply chain characteristics and post-implementation benefits, identifying cyber-physical systems, the Internet of Things, cloud manufacturing, and big data analytics as critical enablers of circular economy benefits [18]. Eslami et al. (2024) found that supply chain agility fully mediates the relationship between supply chain integration and financial performance. However, while Industry 4.0 digital technologies enhance the impact of agility on financial performance, they do not moderate the link between supply chain integration and agility [19]. Gagliardi et al. (2023) emphasized the growing research attention on digital supply chains and the role of knowledge management in shaping corporate culture and technological evolution [20]. Kurdi et al. (2022) demonstrated the

significant positive impact of blockchain and intelligent inventory systems on supply chain performance, noting that businesses leveraging blockchain technology can gain a competitive advantage and strengthen their market position [21]. Finally, Burgos and Ivanov (2021) examined the effects of emerging technologies on supply chains in the Fourth Industrial Revolution, revealing that while digitalization enhances supply chain tracking and efficiency, issues such as lack of transparency and trust persist, which can be mitigated through blockchain integration [22]. These studies collectively underscore the transformative potential of digital technologies in optimizing supply chains, enhancing agility, and improving overall business performance.

Studies conducted in Tehran indicate that fresh food has become a highly competitive segment within the grocery retail market, as discount stores and online retailers have recognized the value of fresh food categories in fostering customer loyalty. Retailers constantly face complex trade-offs in their supply chains: overordering results in food spoilage, while underordering leads to lost sales and diminished customer loyalty. Given the daily fluctuations in demand, how can retailers accurately determine optimal order quantities? Most traditional supply chain planning systems rely on fixed, rule-based approaches to demand forecasting and inventory replenishment. While this method works well for predictable product categories, the dynamics of fresh food supply chains are more complex. Since demand and local conditions vary daily, planners must manually input various data types—ranging from price fluctuations to promotions—into their inventory management systems. These manual processes are not only time-consuming but also prone to errors and heavily reliant on individual planner experience.

Managers in the food industry continually seek new methods to integrate technology into the supply chain to minimize environmental impact and enhance sustainability. This study selects online supermarkets as the case study. Accordingly, the main research question of this study is: What factors influence the digitalization of the supply chain in online food retailing?

2. Methodology

Given that the present study examines the factors influencing the digital supply chain in the food retail industry, the research method is applied in terms of purpose, mixed-methods (qualitative-quantitative) in terms of data type, and descriptive-survey in terms of data collection and research nature.

The statistical population in the qualitative phase includes professors, experts in technology and supply chain management, and senior managers in production and research and development in the online food retail industry. In the quantitative phase, the statistical population consists of all managers and employees of online supermarkets in Tehran. The sample size in the qualitative phase was determined through theoretical saturation (10 participants) using purposive sampling, while in the quantitative phase, a sample of 380 participants was selected through stratified random sampling. Data collection tools included semi-structured interviews in the qualitative phase and a researcher-developed questionnaire in the quantitative phase.

Qualitative data analysis was conducted based on document analysis and semi-structured interviews using the grounded theory method. The data collection tools included interviews in the qualitative phase and a researcher-developed questionnaire with a five-point Likert scale in the quantitative phase. The validity of the questionnaire was confirmed through face and content validity by several experts, convergent validity was verified by calculating the average variance extracted (AVE), and discriminant validity was assessed by computing the square root of AVE. The reliability of the questionnaire was established using Cronbach's alpha, which yielded a value of 0.898 for the entire instrument.

For data analysis, tests including Cronbach's alpha, AVE, the AVE square root matrix, Kolmogorov-Smirnov, and confirmatory factor analysis were conducted using PLS software. Based on the collected data, the reliability of the dimensions was confirmed, as Cronbach's alpha and composite reliability coefficients were above 0.7, and AVE was greater than 0.5. Convergent validity was confirmed as CR > 0.7, CR > AVE, and AVE > 0.5. Discriminant validity was also verified since MSV < AVE and ASV < AVE.

3. Findings and Results

The following section and table describe the demographic characteristics of the sample as well as the research variables in terms of central tendency indices, dispersion indices, and distribution shape indices.

In the quantitative phase of this study, 27% of the participants were female and 63% were male. Regarding educational background, 67% of the respondents held a bachelor's degree, 18% had a master's degree, and 15% possessed a doctoral degree. Moreover, 40% of the respondents were employees, 20% were senior managers, 10% were middle managers, and 30% were lower-level managers in the food industry.

To identify the dimensions and components of the factors influencing the digital supply chain in the food retail industry, interviews were conducted with 10 experts. The qualitative data were analyzed using MAXQDA, a professional software for qualitative and mixed-methods data analysis. Through open, selective, and axial coding, the components were identified. The results of the factor analysis indicate that, following content analysis and expert interviews, the dimensions and components influencing the digital supply chain in the food retail industry are as follows:

Table 1. Dimensions and Components Influencing the Digital Supply Chain in the Food Retail Industry Based on Expert Opinions

Component	Indicator
Managerial Factors	Beliefs and attitudes of managers
	Support and cooperation of industry policymakers
	Managers' attitudes toward financial and supply chain issues
	Support and backing from senior management
	Awareness of the benefits of Industry 4.0 and the digital supply chain
	Systems thinking in management and supply chain system integration
Technological Factors	Advanced information technology infrastructure and facilities
	Availability of strong signals and broad bandwidth (high-speed internet)
	Product and data security for supply chain members
	Development of a suitable database to store vast volumes of complex information
Organizational Factors	Regulatory, legal, and contractual mechanisms
	Employee expertise and awareness regarding Industry 4.0
	Data integration across all stages of the product life cycle
	Confidentiality of information and lack of transparency in company strategies
	Alignment of organizational policies with digital technology
	Organizational policy support for supply chain digitalization
Environmental Factors	Reduction of environmental impacts (greenhouse gas emissions, water consumption, noise pollution, and environmental hazards)
	Reduction of total waste and byproducts
	Fear of losing customers (loss of collaboration)
	Use of renewable energy and energy efficiency
Industrial Factors	Availability of experts in the online retail industry
	Lack of stakeholder and customer awareness regarding the effectiveness of the digital supply chain
	Industry readiness for the adoption of digital supply chain technologies
Economic Factors	Investment in implementing Industry 4.0 and related infrastructure
	Financial resources and budget for training and research and development
	Financial support for equipment and machinery failures
	Transparency in cost tracking
	Reduction of organizational costs (logistics costs, inventory costs, cycle time, and labor costs)
Social Factors	Industry interaction and collaboration with local markets and communities
	Corporate social responsibility (CSR)
	Improved ergonomics and workplace safety

The dimensions and components influencing the digital supply chain in the food retail industry were measured using 29 indicators. Initially, factor analysis was performed on the core categories.

The standardized parameter estimates in the figure below indicate that all indicators are statistically significant, with high factor loadings. Analyzing the model fit indices confirms the model’s adequacy.

Table 2. Confirmed Items of Dimensions and Components Influencing the Digital Supply Chain in the Food Retail Industry

Component	Item	Item Label	Factor Loading	t-Value	Item Status	Indicator Ranking
Managerial Factors	Question 1	Q1	0.836	48.316	Confirmed	1
	Question 2	Q2	0.822	43.366	Confirmed	2
	Question 3	Q3	0.756	30.802	Confirmed	5
	Question 4	Q4	0.818	43.634	Confirmed	3
	Question 5	Q5	0.813	46.107	Confirmed	4
Technological Factors	Question 6	Q6	0.805	36.274	Confirmed	4
	Question 7	Q7	0.866	50.858	Confirmed	2
	Question 8	Q8	0.850	48.082	Confirmed	3
	Question 9	Q9	0.888	54.164	Confirmed	1
Organizational Factors	Question 10	Q10	0.810	33.845	Confirmed	2
	Question 11	Q11	0.783	21.650	Confirmed	4
	Question 12	Q12	0.836	50.015	Confirmed	1
	Question 13	Q13	0.800	36.881	Confirmed	3
	Question 14	Q14	0.781	35.517	Confirmed	5
Environmental Factors	Question 15	Q15	0.809	40.722	Confirmed	3
	Question 16	Q16	0.612	4.191	Confirmed	4
	Question 17	Q17	0.865	63.018	Confirmed	1
	Question 18	Q18	0.842	47.606	Confirmed	2
Industrial Factors	Question 19	Q19	0.891	84.921	Confirmed	3
	Question 20	Q20	0.902	74.807	Confirmed	2
	Question 21	Q21	0.914	95.564	Confirmed	1
Economic Factors	Question 22	Q22	0.811	36.487	Confirmed	5
	Question 23	Q23	0.883	69.141	Confirmed	1
	Question 24	Q24	0.855	45.671	Confirmed	2
	Question 25	Q25	0.850	55.661	Confirmed	3
	Question 26	Q26	0.824	36.482	Confirmed	4
Social Factors	Question 27	Q27	0.870	58.254	Confirmed	2
	Question 28	Q28	0.892	66.669	Confirmed	1
	Question 29	Q29	0.855	50.756	Confirmed	3

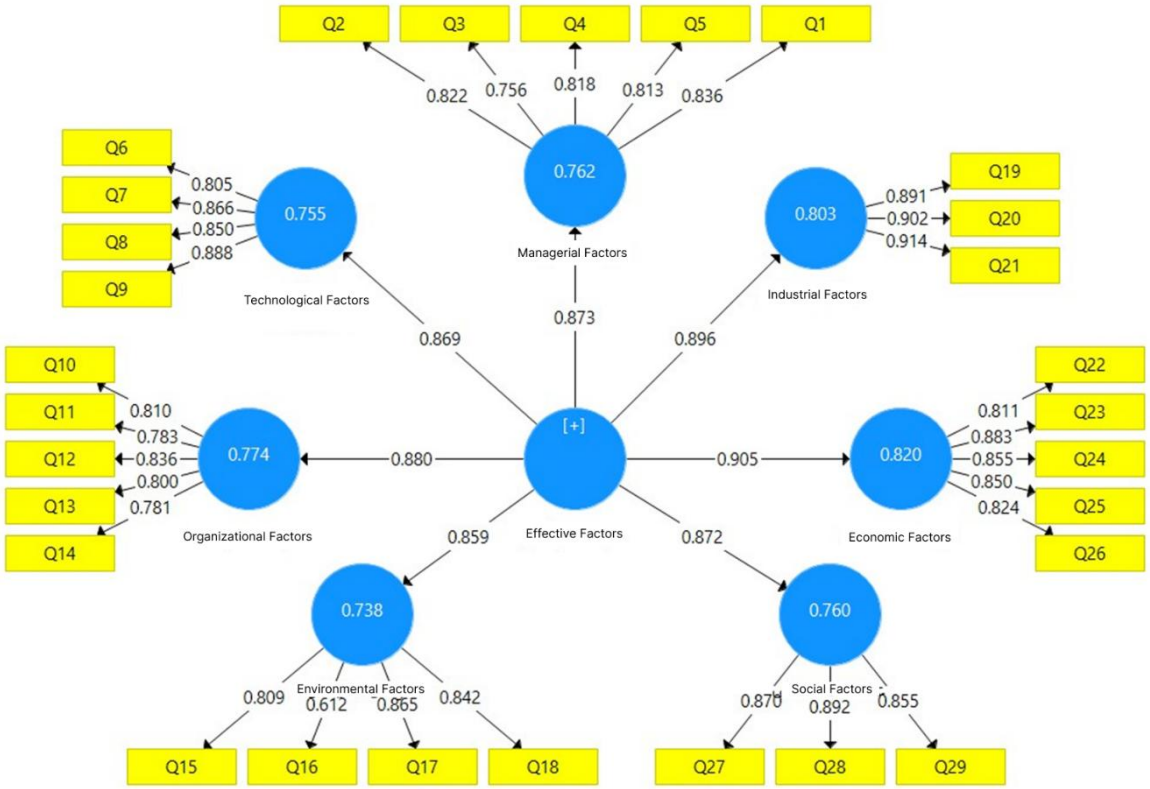

Figure 1. Model of Components and Indicators Influencing the Digital Supply Chain in the Food Retail Industry – Standardized Coefficients

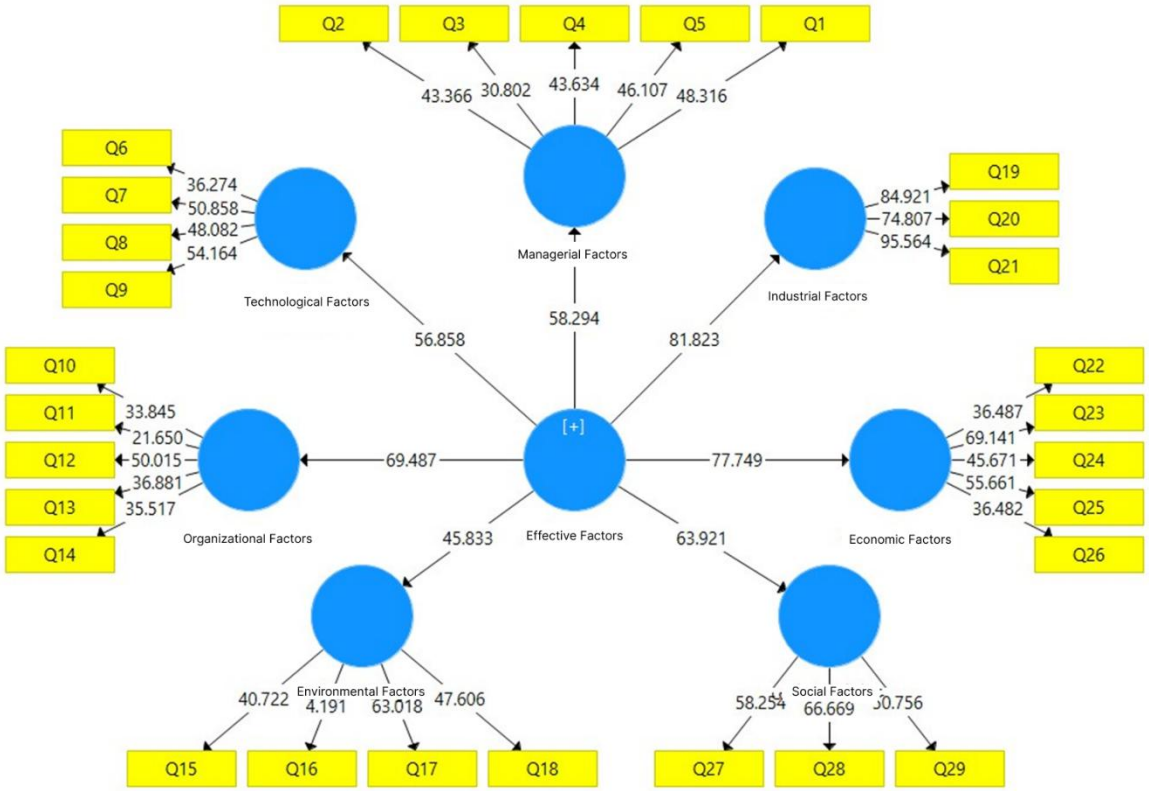

Figure 2. Model of Components and Indicators Influencing the Digital Supply Chain in the Food Retail Industry – Significance of Coefficients

Figure 2 presents the research model in terms of the absolute significance of coefficients (t-values). According to this model, all t-statistic values exceed 1.96. The results confirm that all factor loadings are statistically significant at a 95% confidence level.

Table 3. Validity and Reliability Indices of the Final Model Influencing the Digital Supply Chain in the Food Retail Industry

Latent Variables	AVE	CR	R^2	Cronbach's Alpha	GOF
Managerial Factors	0.655	0.905	0.762	0.868	0.737
Technological Factors	0.728	0.914	0.755	0.875	
Organizational Factors	0.644	0.900	0.774	0.862	
Environmental Factors	0.622	0.866	0.738	0.794	
Industrial Factors	0.814	0.929	0.803	0.886	
Economic Factors	0.714	0.926	0.820	0.899	
Social Factors	0.761	0.905	0.760	0.843	
Causal Factors	0.539	0.971		0.969	

Table 3 presents the validity and reliability indices for all research variables. The study also considers discriminant validity, meaning that the indicators of each construct ultimately provide a distinct measurement compared to other constructs in the model. Simply put, each indicator should measure only its intended construct, and the combination of indicators should ensure that all constructs are well distinguished from one another. The average variance extracted (AVE) confirmed that all constructs under study had an AVE greater than 0.5.

4. Discussion and Conclusion

By examining the research questions aimed at identifying the components and indicators influencing the digital supply chain in the food retail industry, the findings revealed that among the 29 identified indicators, seven main components

could be recognized. The results indicate that the influencing factors include economic factors, social factors, technological factors, environmental factors, managerial factors, organizational factors, and industrial factors.

A key aspect of the profound transformations within the Fourth Industrial Revolution is the transparency and efficiency of industrial operations in a supply chain. The fact that manufacturers source their raw materials and deliver their final products is recorded transparently within a system, allowing real-time reporting at any stage. By sharing certain production data with suppliers, manufacturers can better plan deliveries [1, 17]. For example, if an assembly line experiences a disruption, delivery routes can be adjusted or postponed immediately to minimize costs in subsequent stages [5, 13].

Smart factories have the capability to produce customized goods that better address the specific needs of individual customers. In many industrial sectors, manufacturers aim to achieve product customization in a more cost-effective manner. Utilizing advanced simulation software, new materials, and technologies such as 3D printing, manufacturers can easily produce small batches of specialized items for specific customers. While the First Industrial Revolution was characterized by mass production, Industry 4.0 focuses on mass customization. Additionally, by analyzing weather conditions, transportation logistics, and retail data, companies can use predictive shipping to ensure that final goods are delivered at the right time, aligning with consumer demand.

Based on the research findings and the path coefficients derived from the model, the factors influencing the digital supply chain in the online food retail industry are ranked as follows: economic factors (0.905), industrial factors (0.896), organizational factors (0.880), managerial factors (0.873), social factors (0.872), technological factors (0.869), and environmental factors (0.859). This demonstrates the rapid pace of technological evolution, implying that marketers and business owners must constantly stay informed about emerging changes and advancements and be prepared to implement them at any moment.

Smart industries refer to the technological transformation from embedded systems to cyber-physical systems. In simpler terms, the Fourth Industrial Revolution represents a shift toward the Internet of Things, big data, and service networks. The decentralization initiative aids in creating a network of smart production, where independent management of production projects fosters constructive interactions between the real and virtual worlds, leading to remarkable advancements in manufacturing processes. In the context of the Fourth Industrial Revolution, which exemplifies the transition from centralized to decentralized production, technological advancements have enabled the transformation of traditional manufacturing methods. More specifically, future advanced production lines will no longer be simple processing units but will instead interact with all elements of the production line, providing precise instructions on what needs to be done. The Fourth Industrial Revolution integrates embedded system manufacturing technology with smart product processing, driving a new technological era that rapidly transforms industries, product value chains, and business models. In general, smart manufacturing is analyzed through the following concepts.

With the continuous advancement of science and technology, the methods for managing production activities have evolved, emphasizing the importance of using various techniques, models, and practical methods for planning and controlling the production process of goods and services. Since production is a segment of the organization responsible for converting inputs into outputs (products) while maintaining a desired quality level, production control involves planning, organizing, directing, and overseeing production processes to deliver goods and services at minimal costs. Nearly a century has passed since the introduction of production control knowledge in organizations, during which industrial production systems have seen significant growth in agility and efficiency. By employing production control, all production activities—from initial manufacturing to the final product leaving the warehouse—remain under supervision, ensuring that the quantity of raw materials and finished goods in each production unit and warehouse is accurately tracked [11, 18, 19]. Production personnel can record real-time data on material consumption, actual production volumes, waste, and labor time spent on tasks. If production processes are not well-managed, they can lead to increased manufacturing and storage costs, ultimately resulting in financial losses for the production facility. Therefore, supervisory systems for production processes can assist managers in making informed decisions.

From a theoretical perspective, production control encompasses methods and concepts used to establish manufacturing plans, issue execution directives, and collect and record control data related to production compliance with manufacturing plans. In essence, this system provides managers with comprehensive and real-time information about production performance, comparing it with

engineering standards and the status of work-in-progress inventory. Alongside material planning and production planning systems, this system ensures complete control over the entire production process. Each stage of the supply chain requires the use of smart tools.

Based on the obtained results, the following recommendations are proposed:

- The correct use of customer relationship management (CRM) software and the adoption of marketing strategies comprehensively reflect the organizational culture. By leveraging customer data for sales and marketing, businesses can design targeted marketing strategies aimed at high-value customers.
- It is recommended that supply chain automation and improved smart communication be prioritized to enhance the resilience of the online supermarket supply chain.
- Sensors can be used to track inventory locations as they move through the warehouse. This not only reduces the time and effort required by warehouse personnel but also eliminates the likelihood of errors and mistakes.
- Businesses should be prepared to adapt to changes driven by dynamic environmental factors such as technological advancements and regulatory or political pressures. These factors require seamless integration within supply chain processes so that each member can effectively fulfill their role in response to these influences.
- The use of assistant robots, also known as cobots, has proven highly effective in modern warehouses. These robots collaborate with human workers in warehouse operations and can efficiently perform complex tasks such as order picking and processing. Cobots operate continuously, reducing redundant and unnecessary tasks to a minimum.
- Increasing specialized knowledge at the university level is essential. Alongside training specialized personnel to advance smart supply chain initiatives, it is also necessary to enhance general awareness of digital transformation among employees within organizations. This will improve organizational readiness for adopting new technologies and foster trust in integrating these innovations into industrial processes.
- Cloud-based software and digital devices can significantly boost productivity. Additionally, investing in technology can enhance operational efficiency, such as using sensors to monitor and track warehouse activities. Businesses should also implement digital inventory management software to facilitate inventory tracking and optimize transportation scheduling.

Future researchers are encouraged to conduct similar studies in other industries and compare their findings with the present research. Additionally, it is suggested that this study be extended to the service industry, as enabling factors differ significantly between service and manufacturing sectors. Practical dimensions and components can be identified through expert interviews in the service sector to develop a tailored framework.

Authors' Contributions

Authors equally contributed to this article.

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Declaration of Interest

The authors report no conflict of interest.

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Ethical Considerations

All procedures performed in this study were under the ethical standards.

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