
Driving logistics and supply chain agility through supply chain digital transformation strategy implementation with the moderating role of pharmaceutical supply chains internationalization

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Abstract: The purpose of this research paper is to study the impact of implementing supply chain digital transformation strategy (SCDTSI) on fostering the logistics and supply chain agility (LSCA). It investigates the moderating effect of logistics and supply chain internationalization (LSCI) on the SCDTSI-LSCA relationship across the global pharmaceutical supply chains in Egypt. After conducting a bibliometric thematic analysis, the authors detected and bridged theoretically three active literature research themes on logistics and supply chain digital transformation, agility, and internationalization. A research model was generated and tested empirically using 250 questionnaires answered by logistics and supply chain managers at 50 international, digital, and agile pharmaceutical supply chains operating in Egypt and globally. Quantitative data were analyzed using structural equation modeling by SmartPLS-v4. Results indicated that SCDTSI has a significant positive impact on LSCA, and LSCI was found to be a significant moderator in the SCDTSI-LSCA relationship. Adopting a mixed methods approach, the authors started with exploratory then explanatory qualitative interviews with logistics and supply chain experts to obtain a comprehensive analysis of this technologically-evolving industry. The authors contributed graphically by illustrating a supply chain map of these internationally-oriented digitally-transformed agile pharmaceutical networks in Egypt. This study presented practical and social implications to logistics and supply chain professionals and policy makers on implementing supply chain digital transformation strategies with the aid of creating global partnerships and strategic alliances to reinforce a digitally-driven logistics and supply chain agility within this vital pharmaceutical industry, which will then have an ecofriendly contribution to the society.

Keywords: Logistics and supply chain agility, Supply chain digital transformation strategy implementation, Supply chain internationalization, Global logistics, Pharmaceutical industry supply chain map.

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Introduction and Mapping the Pharmaceutical Supply Chain in Egypt

Today's technologically-evolving and digitally-transforming business environment is driving supply chains to quickly and continuously enhance their agile logistics and supply chain capabilities through developing and implementing effective and efficient supply chain management (SCM) strategies, which are using advanced systems and cutting-edge technologies in order to rapidly cope with the ever-changing supply chain stakeholders' demands (Dubey *et al.*, 2024; Jafari *et al.*, 2026). Logistics and supply chain agility or an agile supply chain is conceptualized as the supply chain that has the capability of responding promptly and flexibly towards the changes in technology, stakeholders' demands, and rivals' competitive strategies (Abdelilah *et al.*, 2023; Adel, 2015; Jafari *et al.*, 2026; Piprani *et al.*, 2024). Empirically, logistics and supply chain agility is measured in the literature (Adel, 2015; Li *et al.*, 2025) in terms of three dimensions, which are the flexibility, responsiveness, and speed of the organization's logistics and supply chain management system. Breakthrough technologies can unlock the way, optimize new opportunities and overcome the challenges of sustaining agile supply chains (Choudhury *et al.*, 2021). Specifically, logistics and supply chain digital transformation is the strategy of transforming the traditional logistics and supply chain management (LSCM) practices into digitally-oriented LSCM practices through using a wide range of emerging technologies (e.g., artificial intelligence, big data analytics, and blockchain technology) (Dubey *et al.*, 2024; Jafari *et al.*, 2026; Mutambik, 2024; Rana *et al.*, 2025; Wu *et al.*, 2024; Younis and Adel, 2020). At the same time, conducting supply chain internationalization, which implies the international expansion of the logistics and supply chain management operations globally, can provide their supply chains with international partners and upstream and downstream stakeholders, who can support and encourage the usage of these modern technologies for better agile performance (Nguyen *et al.*, 2025). Yet, despite the availability of active literature research trends on logistics and supply chain digital transformation (Abdul Rahman *et al.*, 2026), logistics and supply chain agility (Zhang *et al.*, 2025), and logistics and supply chain internationalization (Nguyen *et al.*, 2025), till now their related literature remains fragmented and lacks an integrated SCM lens that investigates the relationship between digital transformation strategy execution, agility and internationalization from a logistics and supply chain management perspective especially in a vital industry like the pharmaceutical industry whether globally or within emerging markets and Arab countries. Therefore, this empirical article will investigate the impact of implementing supply chain digital transformation strategy (SCDTSI) on fostering logistics and supply

chain agility (LSCA) with the moderating effect of logistics and supply chain internationalization (LSCI) on the SCDTSI-LSCA relationship across the global pharmaceutical supply chains in Egypt. Thus, as communicated in Figure 1, this study integrates, through using a SCM lens, conceptually and empirically the active research clusters that are evolving in the SCM literature in relation to digital transformation, agility and internationalization.

As for the chosen sector for this empirical research, the pharmaceutical industry supply chain was selected by the authors due to its attractive hierarchical supply chain nature as a dynamic complex network, which encompasses multiple layers of nodes of local and global stakeholders including the suppliers of suppliers, suppliers of pharmaceutical raw materials, producers and manufacturers that convert raw chemical ingredients into medicines, as well as distributors, wholesalers, retailers, and customers (e.g., hospitals, pharmacies, and patients) (Boualam and El Farouk, 2025; Ciceri *et al.*, 2025; Goswami *et al.*, 2024; Kotwani and Joshi, 2021; Nguyen *et al.*, 2022). All these pharmaceutical supply chain nodes are working in a harmony while synchronizing their coordinated efforts with their internal and external stakeholders to ensure a smooth supply chain flows of information, cash, people, components, and products across the whole global value chain (Boualam and El Farouk, 2025; Ciceri *et al.*, 2025; Goswami *et al.*, 2024; Kotwani and Joshi, 2021; Nguyen *et al.*, 2022). In Egypt, the pharmaceutical industry is the largest in North Africa and the 9th in the region because of its huge production base, digitally-transformed logistics and agile supply chain management systems, and its upstream and downstream expansion into the international market, which contribute to the sustainable development of the Egyptian economy and the improvement of the Egyptian public health especially after its digital transformation strategy implementation that is supported by the Egyptian policy makers and aligned with the United Nations sustainable development goals and Egypt's vision of 2030 (American Chamber of Commerce, 2026). Thus, mapping a horizontally and vertically integrated globally-oriented pharmaceutical supply chain in the Egyptian dynamic healthcare industry is a challenging yet a crucial task in order to identify its main stakeholders and nodes to reduce the potential risks of the pharmaceutical supply chain bullwhip effect and ensure agile logistics and supply chain management of the needed medicines to save patients' lives in Egypt (Boualam and El Farouk, 2025; Goswami *et al.*, 2024). After thoroughly reviewing the relevant literature (Adel, 2021; Boualam and El Farouk, 2025; Goswami *et al.*, 2024), the authors illustrated graphically the long hierarchical

supply chain map of the globally-oriented pharmaceutical multi-layered networks in Egypt (as drawn in Figure 2).

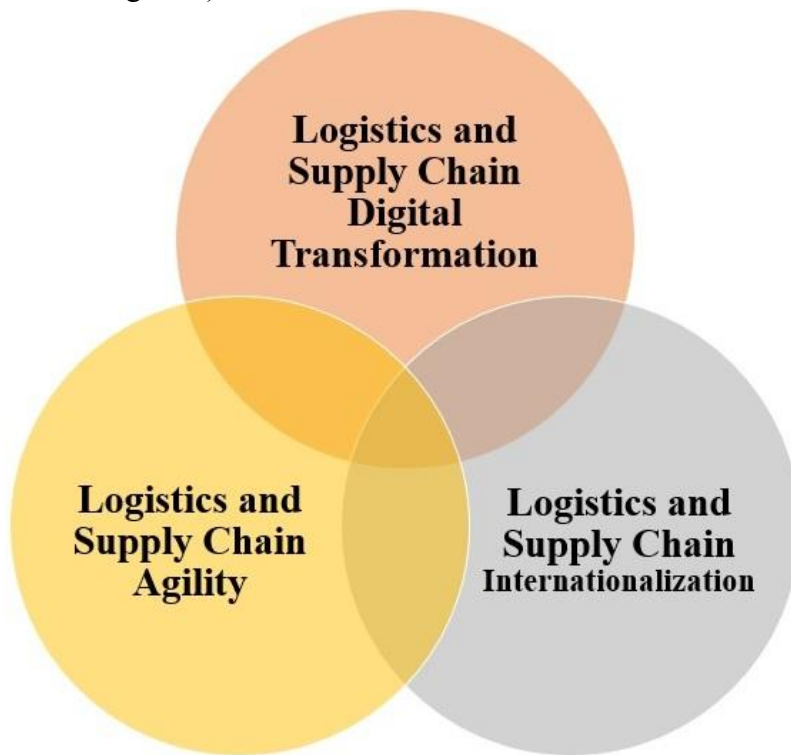


Figure 1. The Active Literature Research Themes of Logistics and Supply Chain Management integrated in this study
Source: The authors' own work

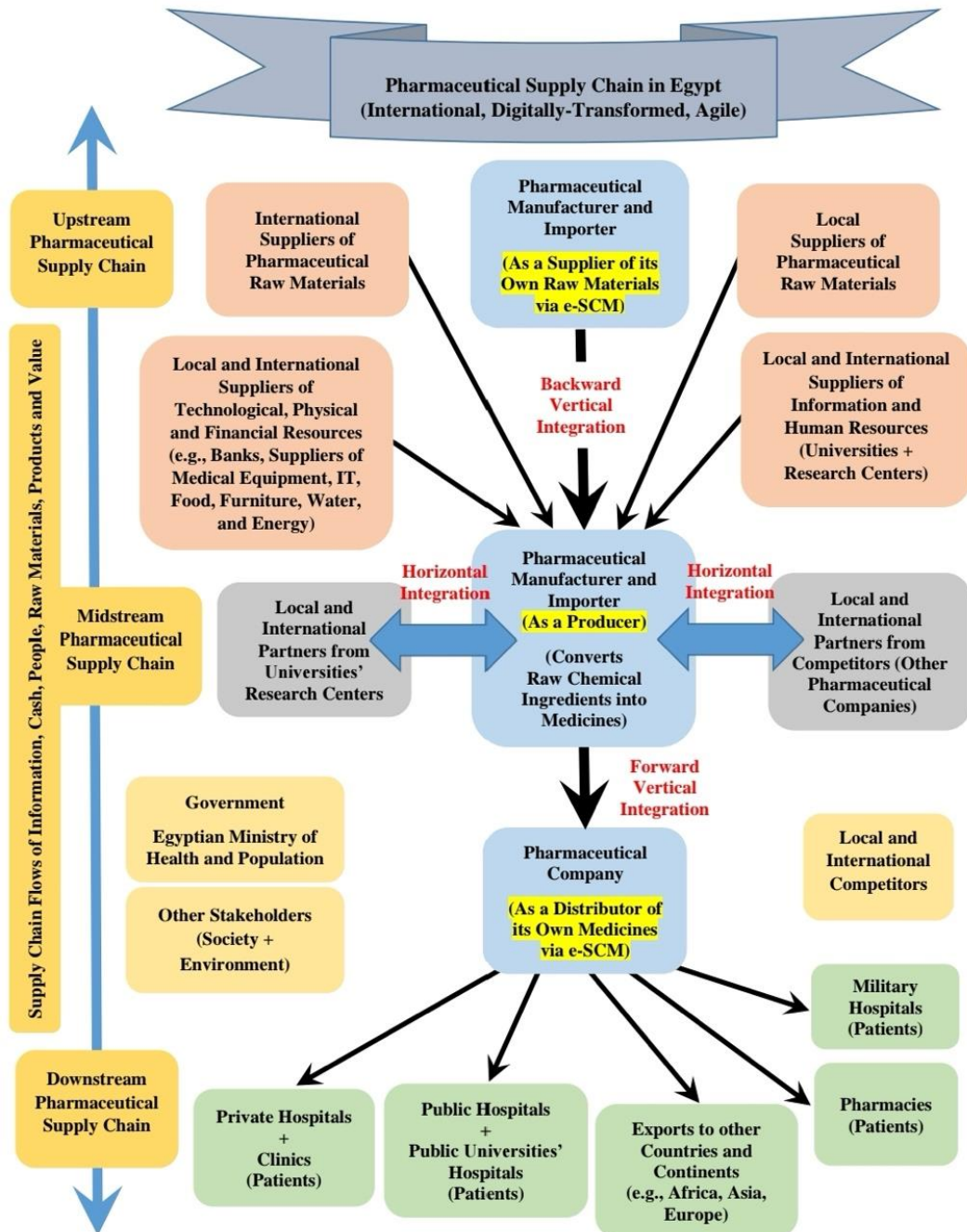


Figure 2. The Pharmaceutical Industry Supply Chain Map in Egypt depicted by the authors
Source: The authors' own work

Literature Review and Hypotheses Development

Bibliometric Thematic Analysis and Research Gap

The authors conducted a bibliometric thematic analysis, through which three active literature research themes were detected, which are the logistics and supply chain digital transformation, logistics and supply chain agility, and logistics and supply chain internationalization. The authors undertook a Boolean query within the Scopus Database, through which total publications of 334 were found to have been published during the period from 2020 to 2026 in English language under the following keywords: ((“Agile Supply Chain” OR “Supply Chain Agility” OR “Agile Logistics”) AND (“Supply Chain Internationalization” OR “International Supply Chains” OR “Global Partnerships” OR “Strategic Alliances”) AND (“Digital Transformation” OR “Digital Transformation Strategy” OR “Supply Chain Digital Transformation” OR “Digital Logistics”)). Those keywords are relevant to the three aforementioned active literature research themes/areas, which shaped the purpose of the current study and directed the present research conceptual model. Figure 3, which was generated using the VOSviewer software version 1.6.20, maps the following co-occurrence network chart that shows those active literature research themes related to logistics and supply chain management (i.e., logistics and supply chain digital transformation, logistics and supply chain agility, and logistics and supply chain internationalization). Each of these research themes or clusters is represented by a different color on the map and is connected by a line with another research trend or theme.

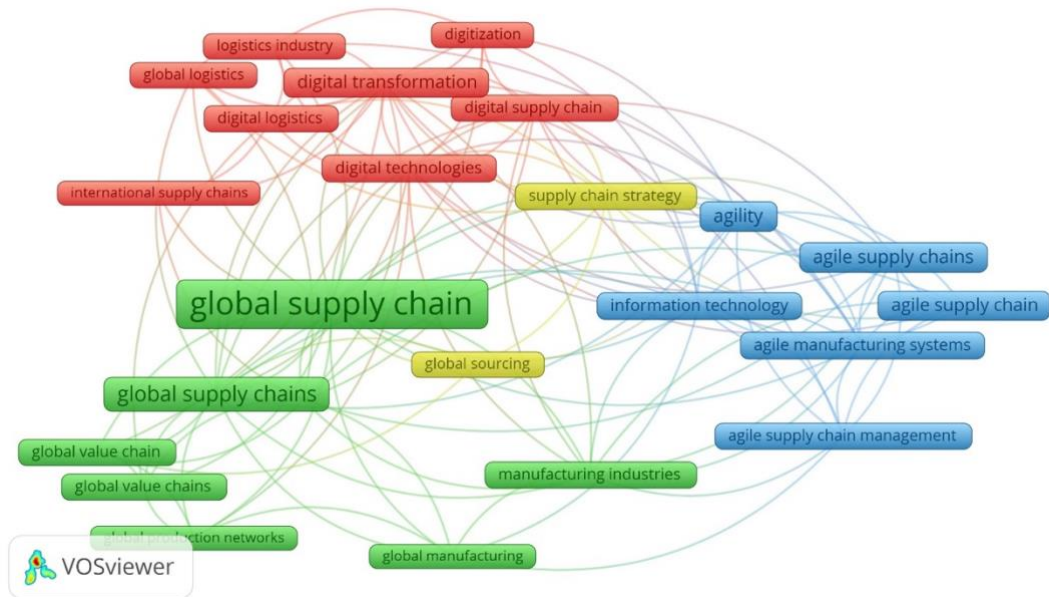


Figure 3. The VOSviewer Co-Occurrence Network Chart showing the Active SCM Literature Research Themes
Source: The authors' own work

Furthermore, Figure 4, which was drawn by using the WordArt tool 2026, highlights the high-interest research themes that are brought to the fore in the supply chain management literature and are given in this diagram a larger size than other emerging research variables that call for more research attention due to their importance to vital contexts and dynamic research areas. For example, as depicted in Figure 4, “digital transformation” without being linked to the strategic supply chain context is given more attention in the literature than the “supply chain digital transformation” and the “supply chain digital transformation strategy”, *which both represent a research gap that need to be filled through more research attention to be provided by the academics due to their importance to the dynamic research context of strategic supply chain management especially in the vital pharmaceutical industry and the promising emerging markets like Egypt.*



Figure 4. A Word Cloud highlighting the SCM Literature Research Trends
Source: The authors' own work

Supply Chain Digital Transformation Strategy, Logistics and Supply Chain Agility and Internationalization

Digital transformation, agility and internationalization were investigated separately within the interdisciplinary literature of different research areas and contexts. A limited number of empirical publications have studied only two of these three research themes together without studying the three research constructs in one conceptual model and also without investigating them from a logistics and supply chain management perspective. Only few studies have tested the direct and indirect relationships between these three research variables (digital transformation strategy, agility and internationalization) through an integrated lens from a logistics and supply chain management perspective. For example, Mutambik (2024) examined the impact of digital transformation and strategic partnerships on logistics and supply chain agility and adaptability in the Saudi Arabian companies of food and beverages, electronics and textiles. Similarly, Dubey *et al.* (2024) tested the effect of digital transformation and the capability of alliance management in terms of inter-organizational relationships and collaborations of Indian manufacturing companies (e.g., automobile, steel and cement industries) on the supply chain agility and adaptability. As for the direct digital-agile supply chain relationship without considering the internationalization factor, Elmouhib and Idrissi (2025) investigated the impact of digital logistics and supply chain practices on the supply chain agility and innovation within a number of Moroccan industries (e.g.,

aerospace, textile, automotive, agricultural and food products). From a different perspective, Ma and Chang (2025) studied the opposite relationship between agility and digital transformation through measuring the effect of maintaining the automotive supply chain agility on facilitating the digital supply chain transformation within the Chinese auto manufacturers. Through the lens of strategic supply chain management, Fang *et al.* (2023) found out a positive significant effect of digital transformation strategy on the strategic agility also within the Chinese food, textile and electronics industries.

As demonstrated by this profound literature review and clearly shown in the bibliometric thematic analysis, despite the availability of active research trends on the logistics and supply chain digital transformation, logistics and supply chain agility, and logistics and supply chain internationalization, till now their related literature remains fragmented and lacks an integrated supply chain management lens that investigates the relationship between digital transformation strategy, agility and internationalization from a logistics and supply chain management perspective especially in a vital yet under-investigated industry like the pharmaceutical industry whether globally or within the emerging markets and Arab countries. Therefore, this empirical article will investigate the impact of implementing supply chain digital transformation strategy (SCDTSI) on fostering the logistics and supply chain agility (LSCA) with measuring the moderating effect of logistics and supply chain internationalization (LSCI) on the SCDTSI-LSCA relationship across the global pharmaceutical supply chains in Egypt. Thus, the following hypotheses were suggested to close these empirical and contextual research gaps:

H1: SCDTSI impacts LSCA positively and significantly

H2: LSCI moderates significantly the SCDTSI-LSCA relationship

Research Methodology

The purpose of this research paper is to study the impact of implementing supply chain digital transformation strategy (SCDTSI) on fostering the logistics and supply chain agility (LSCA). In addition, it investigates the moderating effect of logistics and supply chain internationalization (LSCI) on the relationship between supply chain digital transformation strategy implementation and logistics and supply chain agility across the global pharmaceutical supply chains in Egypt. After conducting a bibliometric thematic analysis, the authors detected and bridged theoretically three active literature research

themes, which are the logistics and supply chain digital transformation, agility, and internationalization. Building on these extracted active interrelated literature themes, a research model (as exhibited in Figure 5) was generated and tested empirically using 250 questionnaires, which were answered by logistics and supply chain managers at 50 internationally-oriented, digitally-transformed, and agile pharmaceutical supply chains operating in Egypt and globally.

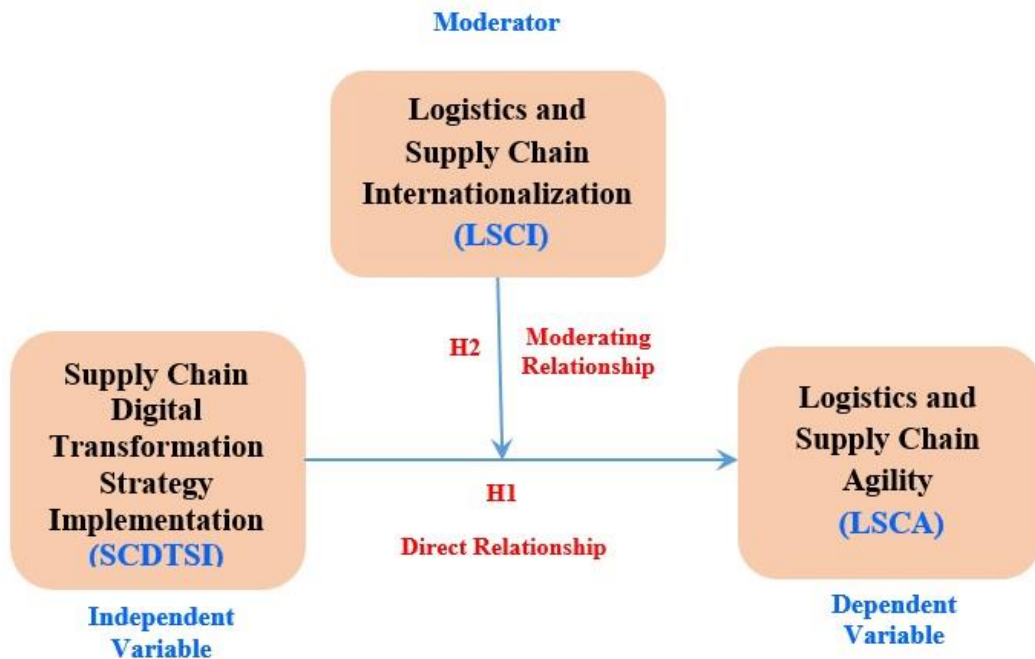


Figure 5. Research Model
Source: The authors' own work

As for the operationalization of the conceptual model's research constructs (as clarified in Figure 5), the authors of the current article adapted the measurement items and scales used in the relevant literature (as displayed in the Appendix Table A1). The independent variable, the supply chain digital transformation strategy implementation (SCDTSI), was measured by the adapted statements of Teng *et al.* (2022). The dependent variable, the logistics and supply chain agility (LSCA), was evaluated in terms of three dimensions that assess the supply chain flexibility, responsiveness, and speed by using the adapted scale of Li *et al.* (2025). In regard to the moderator, the respondents were asked to choose whether their pharmaceutical supply chain is operating in the international or the local market in order to test the moderating effect of logistics and

supply chain internationalization (LSCI) on the relationship between supply chain digital transformation strategy implementation and logistics and supply chain agility across the global pharmaceutical supply chains in Egypt.

The authors in this research undertook a mixed methods approach and followed its corresponding methodological steps (as illustrated thoroughly in Figure 6), which are suggested in the relevant literature of mixed methods management research (e.g., Adel and Younis, 2023; Creswell and Creswell, 2023; Nagy and Adel, 2026; Sahab and Oulfarsi, 2026; Schindler, 2022). Accordingly, the authors incorporated and interwove together quantitative and qualitative data to obtain an in-depth comprehensive analysis of this attractive technologically-evolving, yet under-investigated, pharmaceutical industry and its hierarchical supply chains that are flowing within Egypt and expanding worldwide. *First*, the authors started with 20 exploratory qualitative interviews and 2 focus groups, with logistics and supply chain academics and professionals in order to: (a) explore the unique characteristics of these internationally-oriented digitally-transformed agile pharmaceutical value chains in Egypt, (b) illustrate graphically the long hierarchical supply chain map of these globally-oriented pharmaceutical multi-layered networks in Egypt, and (c) confirm the face and content validity of the adapted survey's measurement items as advised by Hair *et al.* (2019a). *Second*, in this case of the absence of a published list of the digitally-transformed pharmaceutical supply chains operating in Egypt, the quantitative sample in this study was gathered using the snowball sampling technique as advocated by Schindler (2022) and followed by similar e-supply chain management studies (Adel *et al.*, 2024; Adel and Allam, 2014; Rajab *et al.*, 2025). Hence, the authors started with choosing a number of internationally-oriented digitally-transformed agile pharmaceutical networks in Egypt, in which the target respondents of their logistics and supply chain managers suggested further potential participants from other similar pharmaceutical value chains. As a result, 250 questionnaires were collected by the authors after being filled by the logistics and supply chain managers working at 50 pharmaceutical supply chains that are operating inside Egypt and extending across the globe. Those 250 surveys are greater than 70 participants, which are calculated via multiplying 10 by 7 (i.e., the maximum value of items that assess a variable in this study) according to the 10 times rule as suggested by Hair *et al.* (2019a) for the minimum sample size. *Third*, after analyzing the quantitative data, the authors carried out 20 additional qualitative explanatory interviews with logistics and supply chain experts to reflect on and further explain the quantitative statistical findings. As explained by Creswell and Creswell (2023) and followed in the

literature (e.g., Adel and Mahrous, 2018), the authors adopted the saturation principle while collecting the qualitative data in this research through ending the data collection process when they realized that no further information can add additional value.

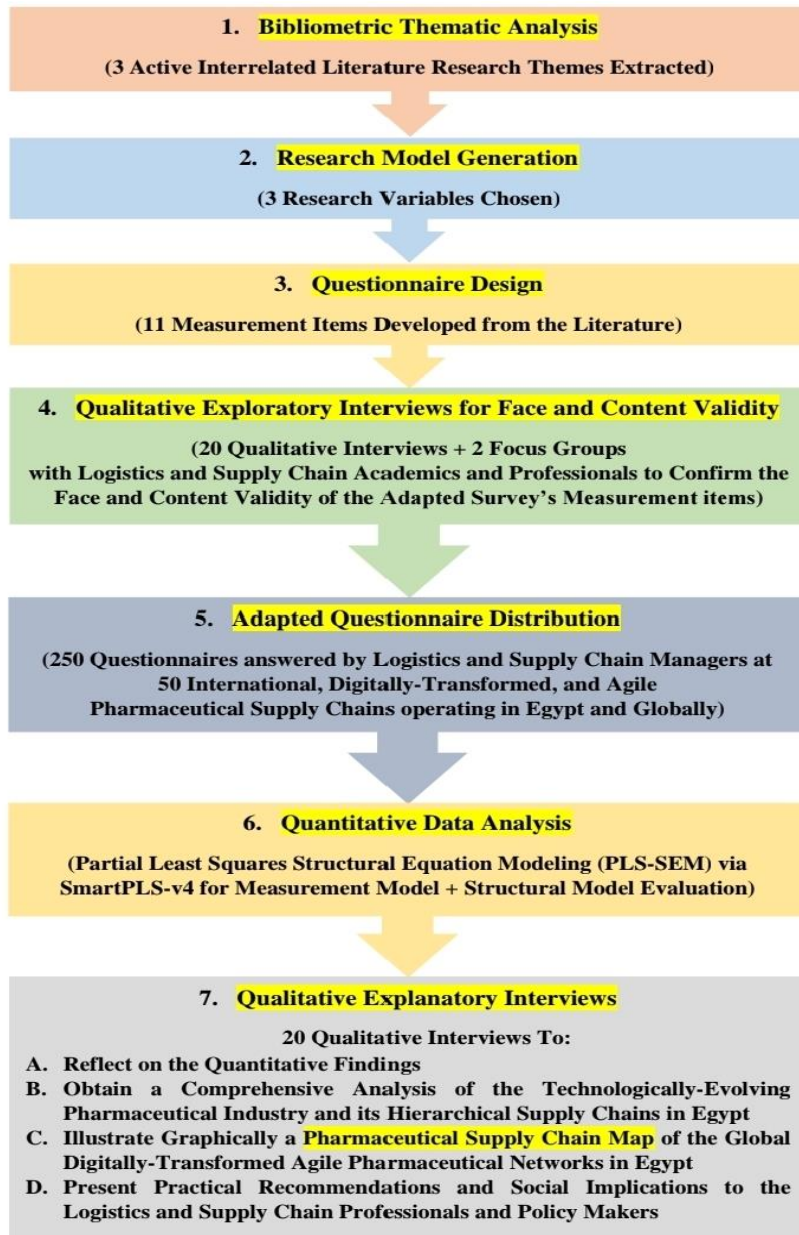


Figure 6. The Mixed Methods Approach and Methodological Steps undertaken by the authors
Source: The authors' own work

Data Analysis and Results

This empirical article undertook a partial least squares—structural equation modeling (PLS–SEM) via SmartPLS-v4, following a number of relevant studies in the literature of statistics and logistics and supply chain management (Adel *et al.* 2024; Hair *et al.*, 2019a, 2019b; Mutambik, 2024; Sarstedt *et al.* 2023; Osman *et al.*, 2025), because of its powerful analytical capabilities especially when testing indirect moderating relationships. A two-step approach via PLS–SEM was carried out in this study, as advocated in the literature (Sarstedt *et al.* 2024; Hair *et al.*, 2019a, 2019b), to evaluate the measurement model through undertaking the confirmatory composite analysis (CCA) and afterwards to test the structural model’s direct and moderating relationships between SCDTSI, LSCI, and LSCA. According to the shared results of variance inflation factors (VIFs) in Table 1, the VIF values in this research were reported to be lower than 3.3, which provide a good evidence for the lack of common method bias (CMB) and the multicollinearity problem, as advised by Le *et al.* (2025) and Kock (2015).

Table 1. Full Collinearity Evaluation

Independent variable	Dependent variable		
	SCDTSI	LSCA	LSCI
SCDTSI	-	3.102	3.210
LSCA	3.102	-	2.21
LSCI	3.210	2.21	-

All the research factors’ *validity and reliability* were measured and established (as reported in Table 2) based on the recommended evaluation metrics of Hair *et al.* (2019a, 2019b). The reliability of all the questionnaire’s statements were verified because the lowest value, as shown in Table 2, is 0.812 (more than the 0.708 threshold value). Moreover, as presented in Table 2, the reliability of all the variables (independent, dependent, and moderator) were checked and supported since the lowest value of the Cronbach’s Alpha was found to be 0.848 along with the lowest value of the CR that was found to be 0.879, which are greater than the 0.7 threshold value (Hair *et al.*, 2019a, 2019b). Additionally, the average variance extracted (AVE) resulted in a lowest value of 0.653 for all the variables (more than the 0.5 threshold value), which confirm the *convergent validity*. Further, the authors established the *discriminant validity* because the calculated values of the HTMT, that are displayed in Table 2, were all reported to be less than the recommended 0.85 threshold value in the literature (Henseler *et al.*,

2015), and also according to the Fornell-Larcker Criterion, the $\sqrt{\text{AVE}}$ of every construct, after being calculated, produced a value that is more than its correlation among all constructs. As aforementioned in the methodology section, the authors conducted the qualitative interviews with logistics and supply chain academics and professionals to confirm the *face and content validity* of the adapted survey's measurement items as advised by Hair *et al.* (2019a). Finally, as supported by Lim (2024) and discussed by Hair *et al.* (2019a), the *nomological validity* was also established because the statistical results were concluded to be aligned and in agreement with the hypothesized relationships suggested in the current research according to the reviewed literature.

Table 2. Measurement and Establishment of the Validity and Reliability

Measurement Item	SCDTSI	LSCA	LSCI
SCDTSI ₁	0.812		
SCDTSI ₂	0.862		
SCDTSI ₃	0.872		
SCDTSI ₄	0.853		
SCDTSI ₅	0.893		
SCDTSI ₆	0.871		
SCDTSI ₇	0.849		
LSCA ₁		0.876	
LSCA ₂		0.898	
LSCA ₃		0.913	
	SCDTSI	LSCA	LSCI
Cronbach's Alpha	0.902	0.877	0.848
Composite Reliability (CR)	0.934	0.879	0.895
Convergent Validity (AVE)	0.653	0.803	0.681
HTMT Ratio of Correlations	SCDTSI	LSCA	LSCI
SCDTSI	-		
LSCA	0.434	-	
LSCI	0.156	0.130	-
Fornell-Larcker Criterion	SCDTSI	LSCA	LSCI
SCDTSI	0.808		
LSCA	0.408	0.896	
LSCI	0.043	0.121	0.825

Subsequently, following Hair *et al.* (2019b), the authors measured the structural model through running the SmartPLS-v4 to assess the direct and moderating relationships

between the supply chain digital transformation strategy implementation (SCDTSI), logistics and supply chain internationalization (LSCI), and logistics and supply chain agility (LSCA). As a result, according to what is being displayed in Table 3, both hypotheses were accepted. H1 is supported because the direct effect of SCDTSI on LSCA ($\beta = 0.160$, $p = 0.053$) was found to be positive and significant at the 10% level. In addition, the moderating effect of LSCI on the SCDTSI-LSCA relationship was reported to be positive and statistically significant ($\beta = 0.360$, $p = 0.001$), indicating that LSCI significantly strengthens the positive relationship between SCDTSI and LSCA. In other words, as the level of the logistics and supply chain internationalization increases, the positive effect of the supply chain digital transformation strategy implementation on the logistics and supply chain agility becomes stronger. Hence, H2 is also accepted, demonstrating that LSCI plays a significant moderating role in the relationship between SCDTSI and LSCA.

Table 3. Direct and Moderated Path Coefficients

Hypothesis	Path	Beta	P-Values	Decision
H1	SCDTSI $\Rightarrow$ LSCA	0.160	0.053	Supported*
H2	LSCI $\times$ SCDTSI $\Rightarrow$ LSCA	0.360	0.001	Supported ***

* Confidence Level 90 %, P-Value < 0.10, and *** Confidence Level 99.9%, P-Value < 0.001

After conducting the needed robustness checks, the authors decided that the structural model of this research is statistically validated and empirically robust. The SRMR value of 0.074 is within the acceptable range of a good model fit because it is less than the 0.08 threshold value. Supply chain digital transformation strategy implementation (SCDTSI) reveals a small-to-moderate effect on logistics and supply chain agility (LSCA), as $f^2 = 0.036$, supporting being a meaningful, though not an exclusive, predictor. Additionally, the $Q^2 = 0.24$ points out a medium predictive power. Thus, these quality indices indicate that this research model has proven a predictive as well as an explanatory adequacy.

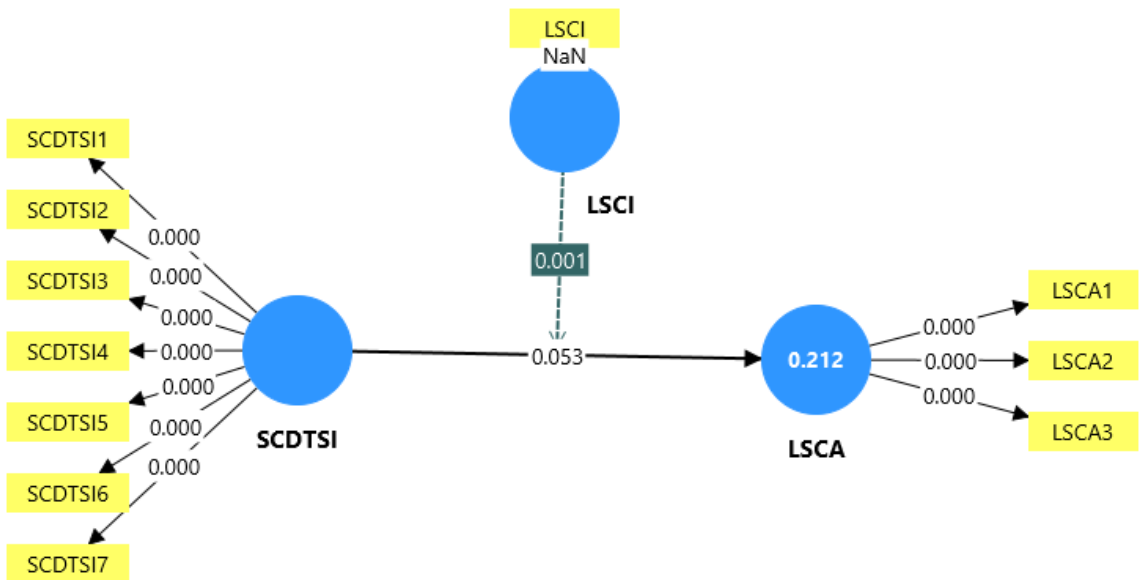


Figure 7. The structural model showing the significant positive relationships between supply chain digital transformation strategy implementation, agility, and internationalization
Source: The authors' own work

Conclusions, Discussion, Limitations, Practical Recommendations, and Research and Social Implications to the Logistics and Supply Chain Academics, Professionals and Policy Makers

The purpose of this conceptual-empirical research is to study the effect of conducting supply chain digital transformation strategy implementation (SCDTSI) on promoting the logistics and supply chain agility (LSCA). In addition, it investigates the moderating effect of logistics and supply chain internationalization (LSCI) on the relationship between supply chain digital transformation strategy implementation and logistics and supply chain agility across the global pharmaceutical supply chains in Egypt. Building on a bibliometric analysis and a thematic literature review, a research model (as exhibited in Figure 5) was generated and tested empirically using 250 questionnaires, which were answered by logistics and supply chain managers at 50 internationally-oriented, digitally-transformed, and agile pharmaceutical supply chains that are operating in Egypt and expanding globally both upstream and downstream across the pharmaceutical supply networks. For the purpose of adopting a mixed methods approach, in addition to the quantitative distributed questionnaires, the authors started with 20 exploratory qualitative interviews, with logistics and supply chain academics

and professionals, which were followed by further 20 explanatory interviews to reflect on the quantitative findings and obtain a comprehensive analysis of this technologically-evolving vital pharmaceutical industry and its hierarchical supply chains.

As a result of the following quantitative and qualitative findings, this article contributed to the *logistics and supply chain management literature* by the following means:

1. **Graphically**, after thoroughly reviewing the relevant literature (Adel, 2021; Boualam and El Farouk, 2025; Goswami *et al.*, 2024) and conducting the qualitative interviews with the logistics and supply chain academics and professionals, the authors of this article illustrated graphically the long hierarchical supply chain map of the globally-oriented pharmaceutical multi-layered networks in Egypt (as drawn in Figure 2). Additionally, the authors encapsulated the unique characteristics of these internationally-oriented digitally-transformed agile pharmaceutical supply chains in Egypt (as pointed out in Figure 8).
2. **Theoretically**, after conducting a bibliometric thematic analysis, the authors detected and bridged theoretically three high-interest research themes in the logistics and supply chain management literature, which are the logistics and supply chain digital transformation, agility, and internationalization. Figure 9 depicts and shows the contribution of the present study in using an integrated lens that synthesizes the fragmented logistics and SCM literature.
3. **Empirically**, quantitative data of trending research topics and rapidly growing SCM research areas were gathered, from a vital yet under-investigated pharmaceutical industry and its digitally-transforming supply chains, and analyzed using structural equation modeling by SmartPLS-v4. Consequently, the following findings and conclusions were deduced:
 - 3.1. Supply chain digital transformation strategy implementation was found to have a significant positive impact on logistics and supply chain agility. Hence, H1 was supported. This result contributes and adds to the research work of Li *et al.* (2024), who confirmed the positive significant impact of big data analytics capabilities on the supply chain agility of the manufacturing firms in Pakistan including the pharmaceutical companies. Yet, Li *et al.* (2024) assessed only the big data analytics, as one factor of the digital transformation technologies, and

they didn't measure the comprehensive research construct of the supply chain digital transformation technologies.

- 3.2.** Logistics and supply chain internationalization was found to be a significant moderator in the relationship between supply chain digital transformation strategy implementation and the logistics and supply chain agility. Therefore, H2 was also verified. This quantitative finding adds to the qualitative discussion, from an economic perspective, of Fujita and Hamaguchi (2016) on the importance of adopting supply chain internationalization for rapid growth and productivity. The importance of developing and executing strategies for advanced technology adoption and internationalization within other Egyptian emerging markets (e.g., higher education) was also reported in the literature (e.g., Adel, 2010; Mahrous and Adel, 2017; Adel *et al.*, 2018). Furthermore, this empirical evidence, which supported H2, is in agreement with what Zhu and Tang (2023) and Abougalil *et al.* (2025) have concluded that international partners can help and support their supply chain partners in the emerging markets on applying breakthrough technologies to their logistics and supply chain management practices for better agility. This finding was also confirmed and interpreted by a *Pharmaceutical Logistics and Supply Chain Manager* that was interviewed by the current authors to explain the quantitative findings of this research as they stated: *“Using supply chain internationalization and having global partners especially in the developed markets support and help our pharmaceutical company to enhance their knowledge and skills on how to implement the digital logistics and advanced supply chain management systems through using cutting-edge technologies for more agile and resilient supply chain performance”*.

- 4. Practically**, based on the qualitative and quantitative findings, this study presented the following practical recommendations along with research and social implications to the logistics and supply chain academics, professionals and policy makers on the importance of:

- 4.1.** Formulating and implementing supply chain digital transformation strategies with the aid of creating global partnerships and strategic alliances in order to reinforce a digitally-driven logistics and supply chain agility within this vital pharmaceutical industry in Egypt, which will then have an ecofriendly contribution to the society.

- 4.2. Internationalizing your pharmaceutical supply chain and expanding globally both upstream and downstream across your pharmaceutical value chain so that your global suppliers, partners, and customers especially in the developed markets can support the endeavors of your pharmaceutical company in implementing successful digital supply chain transformation for more responsive and adaptive logistics and supply chain performance.
- 4.3. Linking the fruitful outcomes of implementing pharmaceutical logistics and supply chain digital transformation, internationalization and agility with the achievement of the **17 sustainable development goals (SDGs) of the United Nations and Egypt's vision of 2030 for sustainability**. For example, your pharmaceutical supply chain and the society can benefit from this research through ensuring agile logistics and supply chain management of the needed medicines to save patients' lives in Egypt (**SDG3**), implementing digital transformation technologies will then ensure cleaner energy (**SDG7**) and more innovative and advanced logistics and supply chain management systems across this vital pharmaceutical industry (**SDG9**), more agile and responsive pharmaceutical logistics and supply chain performance can promote better economic growth (**SDG8**), conducting e-supply chain management practices can maintain cleaner and responsible production for more environmentally-friendly community (**SDG11, SDG12**), and finally, creating global partnerships and international strategic alliances (**SDG17**) in order to reinforce digitally-driven logistics and green supply chains will minimize the entire supply chains wastes within this dynamic pharmaceutical industry that will then maintain better sustainable environment both on land and under water (**SDG13, SDG 14, SDG15**).

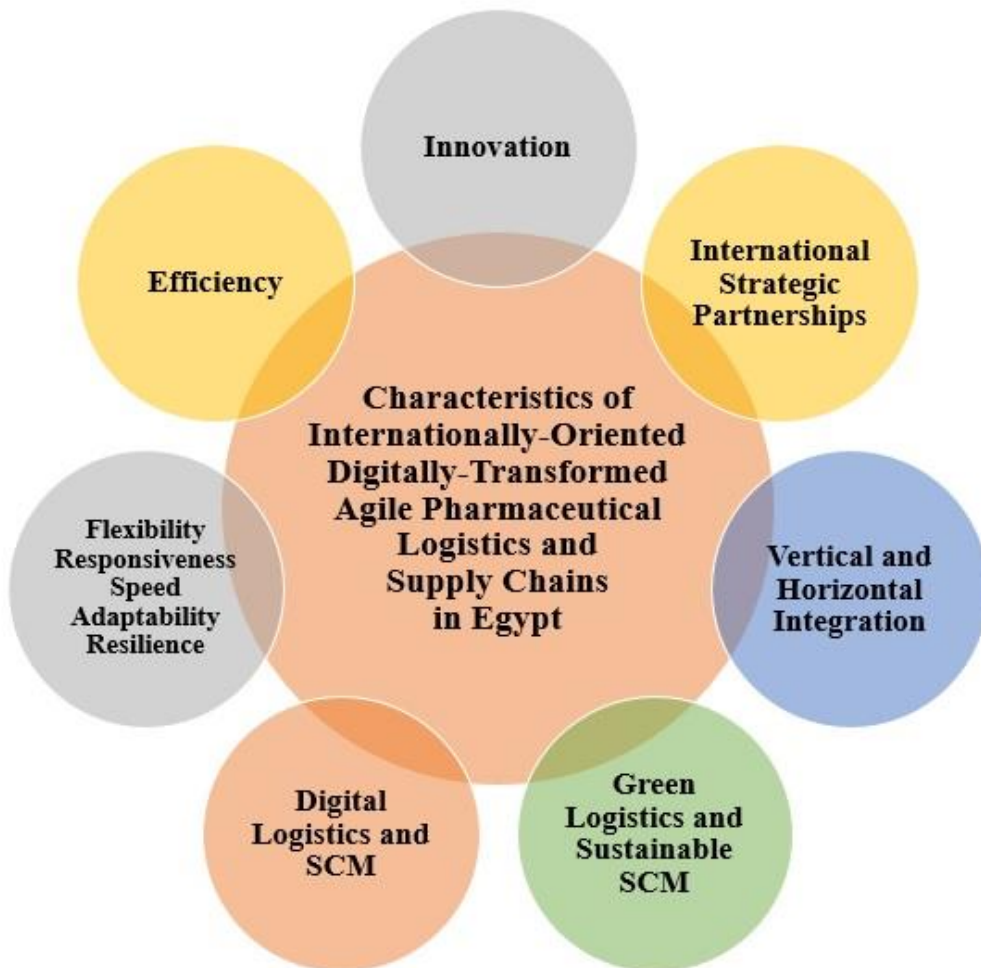


Figure 8: The unique characteristics of the internationally-oriented digitally-transformed agile pharmaceutical networks in Egypt
Source: The authors' own work

Regarding the limitations of this article, quantitative and qualitative data were collected from the pharmaceutical industry supply chains in Egypt (i.e., one manufacturing sector only) to study the relationship between supply chain digital transformation strategy implementation, logistics and supply chain agility, and logistics and supply chain internationalization. However, this empirical research distributed and analyzed 250 questionnaires that were answered by logistics and supply chain managers working at 50 internationally-oriented, digitally-transformed, and agile pharmaceutical supply chains, which are operating in Egypt and expanding globally both upstream and downstream across the entire pharmaceutical supply networks worldwide. Besides, this research studied conceptually and empirically the supply chain digital transformation

strategy implementation as one construct with seven measurement items without being measured in terms of a number of factors representing different types of breakthrough technologies (e.g., artificial intelligence, big data analytics, and blockchain technology). Thereby, academics in this dynamic field of logistics and supply chain management are recommended to carry out longitudinal studies instead of using a cross-sectional design, and to undertake further comparative studies in order to test the effect of executing cutting-edge technologies across the supply chains of different markets, industries and economies.

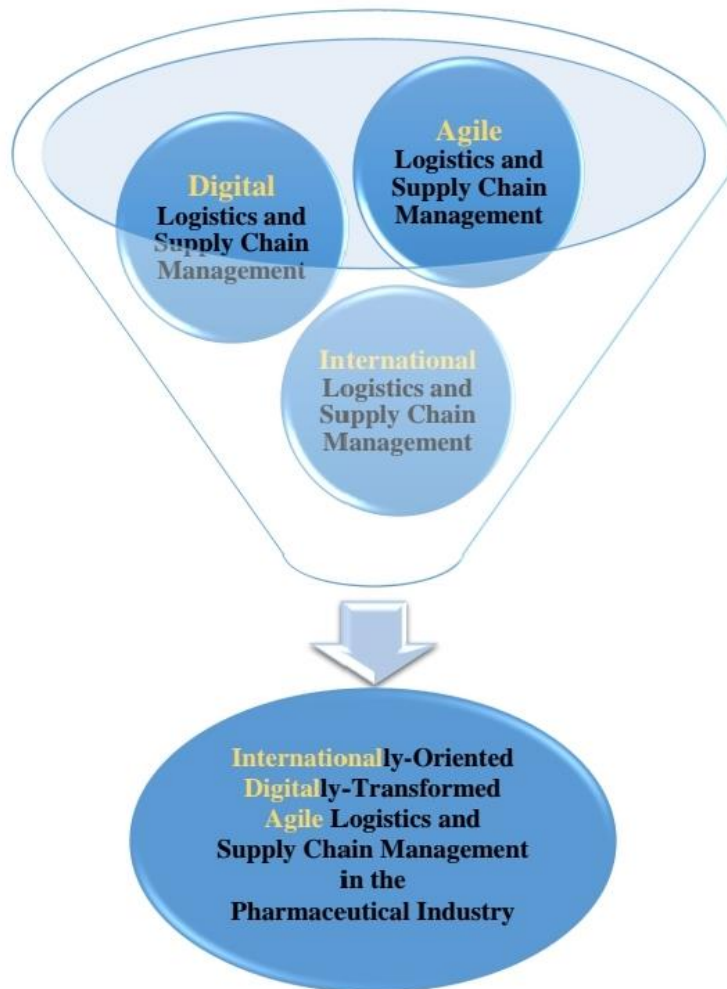


Figure 9. This study's Integrated Lens synthesizing the Fragmented SCM Literature
Source: The authors' own work

Declaration

Ethics approval and consent to participate

The authors confirm that this study posed no potential risks or burdens to participants. Informed consent was obtained from all participants prior to the start of the study. The views and opinions expressed are solely those of the authors and do not necessarily reflect those of their affiliated institutions.

Consent for publication

The authors affirm that this study involved no potential risks or burdens to participants, and consent for publication was obtained prior to conducting the study.

Competing interests

The authors declare no competing interests

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Appendix

Table A1. The measurement items of the questionnaire

Factor	Statement
Supply Chain Digital Transformation Strategy Implementation (SCDTSI) (Adapted from Teng <i>et al.</i>, 2022)	
SCDTSI ₁	Our implemented pharmaceutical logistics and supply chain's digital transformation strategy enhances efficiency.
SCDTSI ₂	Our implemented pharmaceutical logistics and supply chain's digital transformation strategy fundamentally modifies our business processes.
SCDTSI ₃	Our implemented pharmaceutical logistics and supply chain's digital transformation strategy develops our innovation capabilities.
SCDTSI ₄	Our implemented pharmaceutical logistics and supply chain's digital transformation strategy fosters our business decisions.
SCDTSI ₅	Our implemented pharmaceutical logistics and supply chain's digital transformation strategy boosts our competitiveness.
SCDTSI ₆	Our implemented pharmaceutical logistics and supply chain's digital transformation strategy increases our stakeholders' experience and satisfaction.
SCDTSI ₇	Our implemented pharmaceutical logistics and supply chain's digital transformation strategy improves our sales.
Logistics and Supply Chain Agility (LSCA) (Adapted from Li <i>et al.</i>, 2025)	
LSCA ₁	Our pharmaceutical supply chain is capable of quickly changing our products to exceed the expectations of our supply chain stakeholders.
LSCA ₂	The flexible manufacturing and rapid introduction of our new pharmaceutical products and services to the market are within the capability of our logistics and supply chain.
LSCA ₃	Our pharmaceutical logistics and supply chain have the capacity to swiftly respond towards the changes in technology, market, and stakeholders' demands.
Logistics and Supply Chain Internationalization (LSCI)	
LSCI ₁	Does your pharmaceutical supply chain operate in the international or the local market? 1. International Market 2. Local Market