Singine, A. C., Yüksel, H. / Journal of Yasar University, 2026, 21/82, 287-311

Critical Enablers for Successful Supply Chain 4.0 Adoption: Enhancing Supply Chain Visibility and Efficiency[1]

Başarılı Tedarik Zinciri 4.0 Uyumu için Kritik Kolaylaştırıcılar: Tedarik Zinciri Görünürlüğünü ve Etkinliğini Artırma

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Abstract: This study investigates the influence of the critical organisational factors on Supply Chain 4.0 (SC4.0) adoption and how SC4.0 impacts supply chain visibility and efficiency. Although Industry 4.0 has gained increasing interest, there is little empirical research on SC4.0 and its impacts on operational performance, particularly in emerging economies. Drawing on the Resource-based view (RBV) and Dynamic capability theory (DCT), we assessed the influence of Industry 4.0 strategy, supply chain integration (SCI), production system automation (PSA), and lean practices (LP) on SC4.0 adoption and ultimately the impact of SC4.0 on performance. PLS-SEM was used to analyse data from Turkish manufacturing firms. This was also supported by bibliometric analysis. The findings reveal that the I4.0 strategy, SCI, and PSA significantly influence SC4.0 adoption, while LP does not. SC4.0 improves visibility, which leads to improvements in efficiency. This makes visibility an important mediating capability in digital supply chains. This study is one of the first to directly position SC visibility as a critical dynamic capability within SC4.0. The findings also challenge traditional assumptions about LP, which shows that there is a need to build digital lean strategies. Our study contributes to supply chain theory by emphasising the important role of dynamic capabilities in digital transformation. It also offers managerial guidance on how they can use I4.0 strategies, integration and automation to support SC4.0 and ultimately enhance visibility. Managers should also explore new enablers to advance SC4.0 adoption.

Keywords: Supply Chain 4.0, Digital Transformation, Enablers, Visibility, Efficiency

JEL Classification: M11, L23, O33, O14, L25

Öz: Bu çalışma, kritik organizasyonel faktörlerin Tedarik Zinciri 4.0 (SC4.0) benimsenmesi üzerindeki etkisini ve SC4.0'ın tedarik zinciri görünürlüğü ve verimliliğini nasıl etkilediğini incelemektedir. Endüstri 4.0 giderek artan bir ilgi kazansa da, SC4.0 ve özellikle gelişmekte olan ekonomilerde operasyonel performans üzerindeki etkileri hakkında çok az ampirik araştırma bulunmaktadır. Kaynak tabanlı görüş (RBV) ve Dinamik yetenek teorisinden (DCT) yararlanarak, Endüstri 4.0 stratejisinin, tedarik zinciri entegrasyonunun (SCI), üretim sistemi otomasyonunun (PSA) ve yalın uygulamaların (LP) SC4.0 benimsenmesi üzerindeki etkisini ve nihayetinde SC4.0'ın performans üzerindeki etkisini değerlendirdik. Türk üretim firmalarından gelen verileri analiz etmek için PLS-SEM kullanıldı. Bu, bibliyometrik analizle de desteklendi. Bulgular, I4.0 stratejisinin, SCI'nın ve PSA'nın SC4.0 benimsenmesini önemli ölçüde etkilediğini, LP'nin ise etkilemediğini ortaya koymaktadır. SC4.0, görünürlüğü artırarak verimlilikte iyileşmelere yol açar. Bu da görünürlüğü dijital tedarik zincirlerinde önemli bir aracı yetenek haline getirir. Bu çalışma, SC görünürlüğünü SC4.0 kapsamında kritik bir dinamik yetenek olarak doğrudan konumlandıran ilk çalışmalardan biridir. Bulgular ayrıca, LP hakkındaki geleneksel varsayımlara da meydan okuyarak, dijital yalın stratejiler oluşturulması gerektiğini göstermektedir. Çalışmamız, dijital dönüşümde dinamik

[1] Bu çalışma Dokuz Eylül Üniversitesi Sosyal Bilimler Enstitüsü İşletme Anabilim Dalı İşletme Doktora programında hazırlanmakta olan "Sürdürülebilir Tedarik Zinciri Performansı için Döngüsellik Ve Endüstri 4.0 Entegrasyonundan Yararlanma: Kavramsal Ve Ampirik Bir Analiz " başlıklı doktora tezi kapsamında üretilmiştir.

Makale Geçmişi / Article History

Başvuru Tarihi / Date of Application : 31 Ekim / October 2025

Kabul Tarihi / Acceptance Date : 9 Mart / March 2026

yeteneklerin önemli rolünü vurgulayarak tedarik zinciri teorisine katkıda bulunmaktadır. Ayrıca, yönetimlere SC4.0'ı desteklemek ve nihayetinde görünürlüğü artırmak için I4.0 stratejilerini, entegrasyonu ve otomasyonu nasıl kullanabilecekleri konusunda rehberlik sunmaktadır. Yöneticiler ayrıca SC4.0 benimsenmesini ilerletmek için yeni kolaylaştırıcıları da araştırmalıdır.

Anahtar Kelime: Tedarik Zinciri 4.0, Dijital Dönüşüm, Kolaylaştırıcılar, Görünürlük, Etkinlik

JEL Sınıflandırması: M11, L23, O33, O14, L25

1. Introduction

The Covid-19 crisis exposed the limitations of traditional manufacturing and supply chain (SC) operations, which have become more apparent in this digital age. Consequently, Supply Chain 4.0 (SC4.0) attempts to develop sustainable manufacturing and logistics solutions through Industry 4.0 (I4.0). Scopus data on SC4.0 as of January 2025 demonstrates that over 6000 I4.0 related materials were published, suggesting a growing interest in this area. Overall, these publications relate to I4.0 implementations in manufacturing and SCs as an attempt to enhance sustainable performance. While I4.0 denotes a new era of industrial transformation that is involves the integration of digital technologies into operations systems and manufacturing, SC4.0 involves applying I4.0 to SC operations. SC4.0 represents the digital transformation of SC processes and manufacturing operations through the adoption of I4.0. Rossini et al. (2019) noted that decentralisation and digitisation of production processes support interconnected and autonomous production systems within the SC.

Since the emergence of I4.0, critical I4.0 technologies (I4T), such as simulation, big data (BDA), cloud computing, 3D printing, the internet of things, and AI, have been argued to transform traditional SCs. Choi et al. (2022), argued that I4.0 creates opportunities for improving visibility, efficiency, and agility all of which are very important for building more resilient and sustainable SCs. Notwithstanding theoretical discussions on the influence of I4.0 on various aspects of SCM (Ivanov et al., 2019), there still remains a need to establish and empirically investigate critical enablers that drive successful SC4.0 implementation. This is because most literature on SC4.0 and performance mainly focused on the theoretical and conceptual influence of SC4.0 in developed economies. Thus, leaving the question of whether SC4.0 can be successfully adopted to enhance the performance of firms in emerging economies unanswered. Also, what critical factors and capabilities are necessary for SC4.0 adoption in firms? According to Frederico et al. (2020), SC4.0 refers to how I4.0 concepts and technologies are integrated and implemented within the SC. By integrating enablers such as supply chain integration (SCI), production system automation (PSA), lean techniques (LP) and I4.0 strategy firms can leverage the potential of SC4.0 and improve SC visibility and operational efficiency. If firms can successfully adopt SC4.0, it can become a fundamental to sustainable supply chain (SSC) performance.

Despite several review studies discussing the potential of SC4.0 (Ghadge et al., 2020; Cugno et al., 2021; Khin and Hung, 2022), there is little empirical research addressing how the successful adoption of SC4.0 can improve visibility and efficiency in SC. Particularly, the benefits and impact of SC4.0 on SSC performance in developing economies requires investigation. We believe that understanding these relationships is critical especially for firms seeking to leverage I4T for operational and SSC performance.

Notwithstanding the growing attention given to digital SCs, SC4.0 and its impact are less studied in existing literature. Research is lacking in this area, especially in determining critical factors for successful SC4.0 and how to implement it to optimise SC performance. Although literature makes clear the relevance of I4.0 in SCM (Srivastava et al., 2022; Lin et al., 2023), we believe there is a need to assess the impact of SC4.0 as how it is influenced by organisational enablers. Our study seeks to assess the influence of critical enablers such as I4.0 strategies, supply SCI, PSA, and LP on SC4.0 adoption, as well as the impact of SC4.0 on SC visibility and efficiency. Therefore, the paper is concerned with addressing the following questions that focuses on these issues.

RQ1.How do organisational enablers influence the adoption of SC4.0?

RQ2. What impact does SC4.0 adoption have on SC visibility and efficiency?

RQ3. What is role of SC visibility in the relationship between SC4.0 and efficiency?

2. Literature Review

We combined traditional literature review (LR) with bibliometric analysis (BA) in order to provide richer and relevant LR. BA was conducted using Scopus and VOSviewer to identify important themes and concepts around SC4.0 and I4.0. LR provides insights into key technologies and applications.

2.1. Bibliometric Review

A systematic literature search was conducted to support both the bibliometric analysis and the traditional literature review. The search was carried out using the Scopus database, a widely recognised source of peer-reviewed academic literature in supply chain and operations management. Our bibliometric analysis involved studies from 2019 to 2024 to capture key themes, and significant contributions to SC4.0 research. The keywords search included “Supply Chain 4.0,” “Industry 4.0,” “digital supply chain”, and “Supply Chain”. We obtained initial 2995 publications using Boolean AND/OR notations on Scopus. The results reveal a growing interest in digital supply chains and transformation, with 175 publications directly mentioning supply chain 4.0 and 2995 focusing on I4.0 and SC. Duplicate records were first removed before title and abstract screening was conducted. This allowed us to exclude studies that were not directly related to Supply Chain 4.0. We further excluded Conference papers, book chapters, non-English publications, and all studies that were not focused on supply chain. After this process and a thorough screening of the articles, 175 peer-reviewed articles were retained for bibliometric analysis.

2.1.1. Key Contributions to SC4.0 Research

While the works by Kagermann et al. (2013) and Ivanov et al. (2019) are popular among the early citations on SC4.0, some more recent articles (Tjahjono et al.,2017; Ivanov et al., 2019; Frederico et al. 2020; Liu et al. 2021; Queiroz et al., 2022; Mubarik et al., 2021; Chauhan et al., 2021; Marinagi et al.,2023; Surucu-Balci et al., 2024) have gained prominence. This reflects the growing importance of SC4.0 as a crucial area of study that can leverage digital transformation and I4.0-related technologies for optimised SC operations.

2.1.2 Contributing Regions

Bibliometric findings identify a growing global significance of SC4.0 research with an increasing trend toward emerging economies. Among other emerging countries like, China, Italy, Brazil, and Turkey, India has the highest number of publications. The diverse regional contribution to the topic indicates that SC4.0 is an important field that needs further empirical evaluation. Therefore, our study seeks to contribute to the growing relevance of SC4.0 in modern SCM.

2.1.3. Network Analysis of Supply Chain 4.0 and Related Research

Figure 1 below is VOSviewer generated network map (NM) which provides five main clusters that are foundational to the conceptual understanding of SC4.0. The red cluster represents digital transformation (DT) and I4.0 as core SC4.0 concepts, which include decision-making, AI, big data, sustainable development, and supply chain. It illustrates how the concept of I4.0 and DT influences SC decision-making and sustainability goals. The successful implementation of SC4.0 can contribute to the sustainable development goals SDG 9 and SDG 12, whose aims are industry innovation, responsible consumption and production. The green cluster, represents SCM and logistics as an important aspect of SC4.0. It links keywords like SC resilience, SC integration, risk assessment, SC efficiency, visibility, competitiveness, and agility. This cluster not only highlights the linkage between SC4.0 and performance improvements, but it also associates some critical capabilities and enablers with SC4.0. The blue cluster, represents the smartness and automation aspect of SC4.0 which links cyber-physical systems (CPS), production systems, smart manufacturing, automation, industrial IoT and interoperability. Not only does this highlight the potential for improving the smartness of SCs through SC4.0 adoption, but it also links PSA to SC4.0 adoption. While the purple cluster represents data analytics and AI as essential for real-time decision making and SC efficiency, the yellow cluster represents emerging technologies in SC. Blockchain, 3D printing, and cybersecurity are some of the keywords associated with security and SC visibility among emerging technologies. Overall, the NM reveals that SC4.0 is a holistic construct which involves strategic, technological, operational, and sustainability that can be leveraged to develop responsive, resilient, data driven and sustainable SCs.

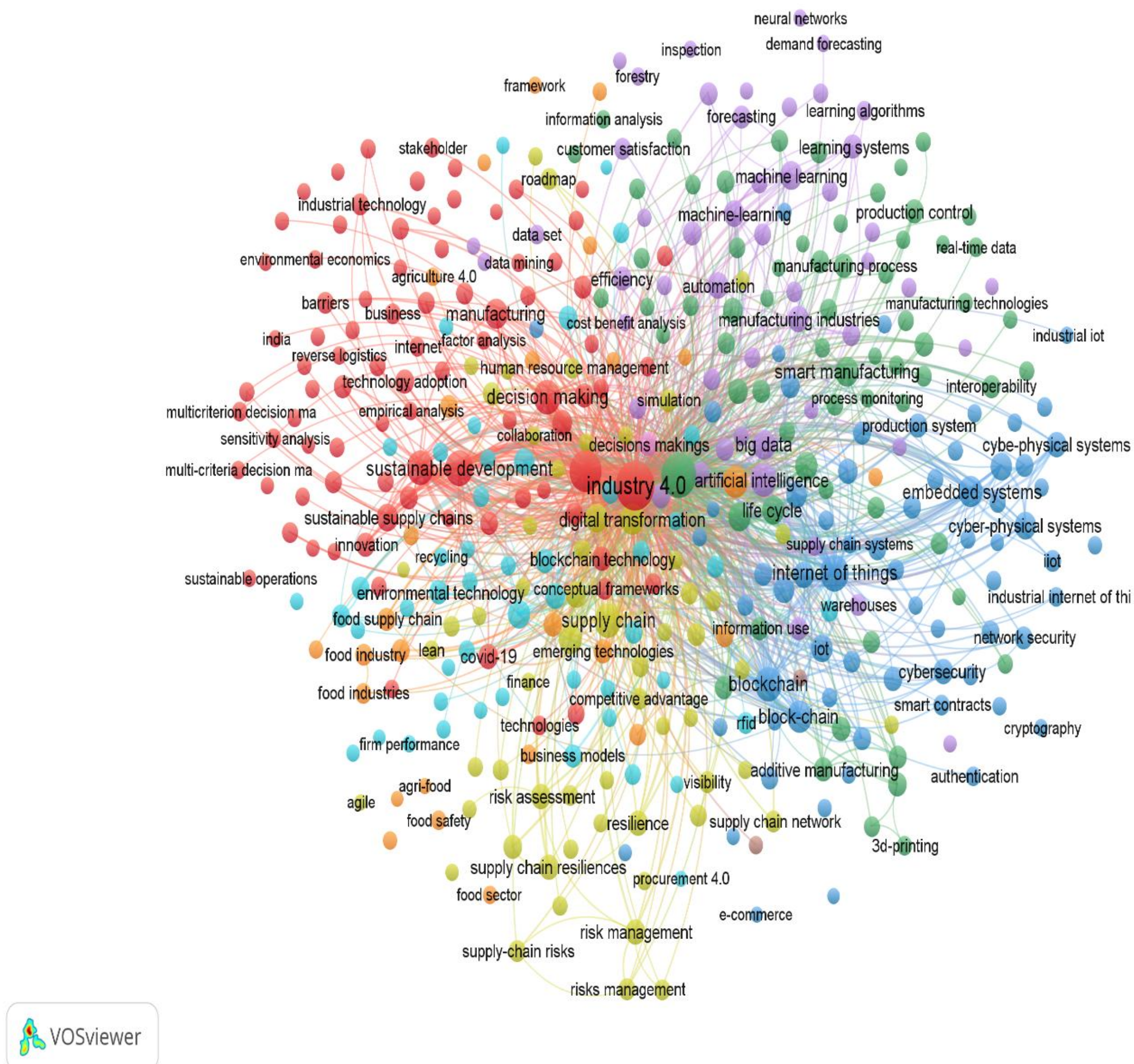

Figure 1. Network map (NM) of SC4.0

Despite an increasing focus on sustainability and industry 4.0 technology I4T, the network analysis indicates limited attention on critical enablers of SC4.0 and as well as the influence of

SC4.0 on performance. Although studies on SC4.0 have moved past the integration of I4T with SCs to focus on SC sustainability and issues to do with security, there is little research on SC4.0 enablers such as I4.0 strategies, lean technologies, SC integration, and automation.

2.2. Industry 4.0

Industry 4.0 entails the fourth industrial stage in manufacturing and operations systems that integrates digital technologies into the entire SC to add value and enhance SC sustainability. I4.0 seeks to enhance operations of SC via improved visibility, which is enabled through the intelligent integration of SC processes, technology, and people (García-Reyes et al., 2022). Technologies like IoT, AI, blockchain, CPS, and BDA enable the development of smart, sustainable, and self-optimising SCs. The transition increases SC decentralisation and digitalisation environment, which makes the production and SC operations elements more autonomous (Dalenogare et al., 2018; Tortorella et al., 2019). It also enhances interconnectivity and interactions among systems, people, and machines, which enables interconnectedness, flexibility, transparent and autonomous manufacturing systems.

Foundational to I4.0 are advanced digital technologies as indicated by the NM. CPS is the amalgamation of physical manufacturing processes with digital systems technologies to enable smart manufacturing (Ryalat et al., 2023). Xu et al. (2018) noted that IoT improves visibility and production efficiency, while BDA optimises production planning and logistics (Witkowski, 2017). AI enables advanced analytics and automation, leading to enhanced agility and risk assessment.

Digital transformation (DT), is central to I4.0 as indicated in the NM. DT involves automation and the integration of advanced technologies across the value chain. DT, through improved decision making, process automation and customer satisfaction leads to better quality, efficiency and productivity (Tao et al.,2018). It also promotes integration, real-time tracking and SC visibility.

Kazançoğlu et al. (2023), noted that the principles of I4.0 do not only enhance monitoring, visibility, and efficiency in supply chain processes, but they also help in enabling circular economy models. This leads to greater SC responsiveness and resilience. I4T like IoT, digital twins and AI-driven systems help in anticipating risks and minimising SC disruptions.

2.3. Supply Chain 4.0

SC4.0 represents the integration of digital technologies to strengthen the connectivity, improve the agility and efficiency of SCs. It seeks to support sustainability and resilience goals by optimising SC operations and performance. According to Derakhti et al. (2023), I4T enables interconnected SCs with the capability to adapt to change as the NM suggests. Overall, I4Ts provide SCs with integration, real-time data, analytics and robust forecasting capabilities that they need.

SC4.0 promotes connectivity, interoperability, integration and collaboration within SCs (Zekhnini et al., 2021). While connectivity links production and SC functions for better visualisation (Frazzon et al. 2019 Chauhan), digitalisation facilitates decentralised and autonomous systems (Tortorella et al. 2019). SC4.0 provides firms with necessary capabilities needed to deal with SC disruptions. It also has the ability to allow for efficient use of resources, and promote SSC goals. Thus, SC4.0 can be regarded as modern SC integration that brings SC partners together and facilitates cooperation across the value chain.

SC4.0 has the potential to improve SC visibility. Tjahjono et al. (2017) indicated that SC4.0 can increase transparency across the SC. Attaran (2020), further noted that SC4.0 enables SC cooperation which shortens response times. SC4.0 through I4Ts streamlines and integrates downstream and upstream SC operations and processes, which are crucial for enhancing SC efficiency and performance. Ageron et al. (2020) argue that I4.0 enhances information sharing and cooperation among SC participants, which is essential for better SC visibility. It is crucial for achieving operational goals. According to Sobb et al. (2020) SC4.0 will bring about improvements in many areas of the SC. Some of the improvements SC4.0 is expected to bring, include improved interoperability, collaboration, transparency, integration, flexibility, responsiveness, efficiency, and leaner operations. All of these improvements are very important for smart manufacturing and circular economy principles, which are key to SSC.

2.4. Enablers of Supply Chain 4.0

Literature review and bibliometric analysis above suggest that successful adoption of SC4.0 depends on a number of key enablers. Since SC4.0 builds on the principles of I4.0, we believe both SC4.0 and I4.0 share common enabling factors. These enablers can be categorised into organisational, technological, and environmental factors (Sony and Naik 2020). The network map (NM) identified some technological enablers of SC4.0 which include digital twins, BDA, IoT, AI, machine learning, blockchain, and cybersecurity. However, we do not focus on technological enablers because they are well established in I4.0 literature (Liu et al., 2021; Govindan et al., 2022; Marinagi et al., 2023). On the contrary, our interest is on organisational enablers which include integration, automation, lean practices, digital transformation, and strategic alignment (Mubarik et al., 2021; Surucu Balci et al., 2024). Though not the focus of this study some important environment enablers which include market dynamism, customer expectations, sustainability, and regulatory pressures were identified. However, our study is interested in determining how organisational enablers as strategic resources and critical capabilities affect the adoption of SC4.0.

2.4.1 Supply Chain Integration

SCI is crucial for effective coordination, information sharing and decision making within SC because it helps in building trust and collaboration (Flynn et al., 2010; Jajja et al., 2018; Surucu-Balci et al., 2024). Agility and SC performance can be improved when strong collaboration and relationships exist among SC partners. SCI can also help in synchronising SC processes and operations, which is an important SC4.0 capability.

H1. Supply chain integration positively influences Supply Chain 4.0 adoption.

2.4.2 Industry 4.0 Strategies

A clear DT strategy is needed to successfully implement SC4.0 in firms. This is supported by Ivanov and Dolgui (2021) who noted that an I4.0 strategy can lead to DT and improvements in SC operations. Therefore, strategic alignment (SA) in SC4.0 can help organisations to have managerial skills, technology, and direction or goals needed to adopt SC4.0. Sony and Naik (2020) also argued that SA, especially one which includes strategic planning, leadership support, and training, can overcome most barriers associated with I4.0 implementation. Equally, Queiroz et al. (2022) pointed out the need for clear SC objectives that align with I4.0. Therefore, we argue that successful SC4.0 adoption requires DT strategies that incorporate clear I4.0 and SC objectives. Without a clear strategy all efforts to implement I4.0 may prove futile. A good I4.0 strategy can provide firms with the ability to sense and seize opportunities presented by digital technologies. I4.0 can allow firms to leverage digital technologies to enhance SC operations (Richnak & Fidlerova, 2022).

H2. Industry 4.0 strategy significantly influences the adoption of Supply chain 4.0.

2.4.3 Lean Techniques

Integrating lean techniques with Industry 4.0 enables automation and digitalisation (Kolberg 2015). Lean techniques (LP) through I4T can enable real-time visibility and synchronisation of SC operations. Sony and Naik (2020) argued that digital lean practices can facilitate smart manufacturing through cyber-physical production systems (CPPS). McDermott et al. (2024) highlight the complementary effect between lean and I4.0, arguing that lean is a prerequisite to digitalisation in SCs. Integrating AI and related digital technologies into lean practices, can help in providing better resource utilisation and flexibility. Ali and Aboelmaged (2022) also argued that LP can promote the implementation of I4.0. Not only does integrating of lean with I4.0 not have the potential to improve efficiency, but it can also increase the adaptability and resilience of SCs.

H3. LP has a significant impact on the adoption of SC4.0.

2.4.4 Production System Automation

The NM links automation related I4Ts such as cyber-physical systems and autonomous warehouses to SC4.0, which suggests that PSA is essential for successful SC4.0 adoption. This argument is well supported by Yuan and Xue (2023), who noted that automation technologies and systems such as robotics, CPS, and autonomous warehouses are crucial for optimising operational costs and production processes. Similarly, Baryannis et al. (2019) noted that modern automation systems, such as digital twins, AI, and advanced robotics, enable tracking, which is crucial for reducing SC errors and optimising resources as well as improving responsiveness. Automation systems such as CPPS and robotics enhance flexibility, production efficiency and the resilience of SCs.

H4. PSA has a significant influence on the adoption of SC4.0.

2.5. Impact of Supply Chain 4.0 on Firms

Different studies have argued that the adoption of SC4.0 can bring about significant improvements to firms. For instance, Yüksel (2022) argues that I4T have the potential to significantly improve production processes, manufacturing systems, as well as SCs. Chauhan et al. (2021) also argued that I4.0 can help in building SC competency and operational performance. All this suggests that firms that adopt S4.0 would likely improve their SCs and performance. Choi et al. (2022) argued that I4T can significantly enhance visibility, and efficiency within SCs. Liu et al. (2021) also associated the integration of I4.0 with enhanced visibility. Better SC visibility can lead to improved coordination, shorter lead times, and increased agility with the SC. Kazançoğlu et al. (2022), also noted that I4.0 can provide the visibility that is required to close loops in SCs and improve resilience of SCs. Similarly, Frederico et al. (2023) demonstrated that I4.0 increases transparency which in turn improves the inventory management and SC resilience with more accurate demand forecast.

SC efficiency implies providing what is needed to the right location at the right time with the minimum cost. The NM also linked AI, big data, and automation with visibility and efficiency. SC4.0 can also streamline logistics operations and improve the performance of SC networks (Singh et al., 2023). Govindan et al. (2022) suggests that organisations that implement digitalised SC models experience improvements in productivity, cost, and customer responsiveness. Similarly, Yuan and Xue (2023) noted how automation and digital integration optimise SC operations, minimise costs and enhance customer service levels.

H5. SC4.0 adoption has a positive significant influence on SC efficiency.

H6. SC4.0 adoption has a positive impact on SC visibility.

H7. SC visibility has a positive influence on SC efficiency.

2.6. Theoretical Foundation

Adoption of SC4.0 is a strategic transformation to SC operations that requires a strong theoretical background. This paper incorporates the resource based view (RBV) and dynamic capabilities theory (DCT) to demonstrate how firms use strategic resources and dynamic capabilities to enhance visibility and efficiency. RBV posits that organisations attain a competitive advantage by acquiring and implementing resources or strategies that are valuable, rare, inimitable, and non-substitutable. In the context of SC4.0 adoption, organisational enablers such as I4.0 strategy, SCI, PSA, and LP represent critical resources that can enhance SC visibility and efficiency. However, given the dynamic and evolving nature of digital technologies as well as the SC environment as a whole, Firms must develop dynamic capabilities to reconfigure and adapt to change. Thus, this study argues that firms must possess both strategic resources and dynamic capabilities to leverage the benefits of SC4.0. By combining RBV and DCT, the study forms a stronger basis for the proposed hypotheses in figure 2.

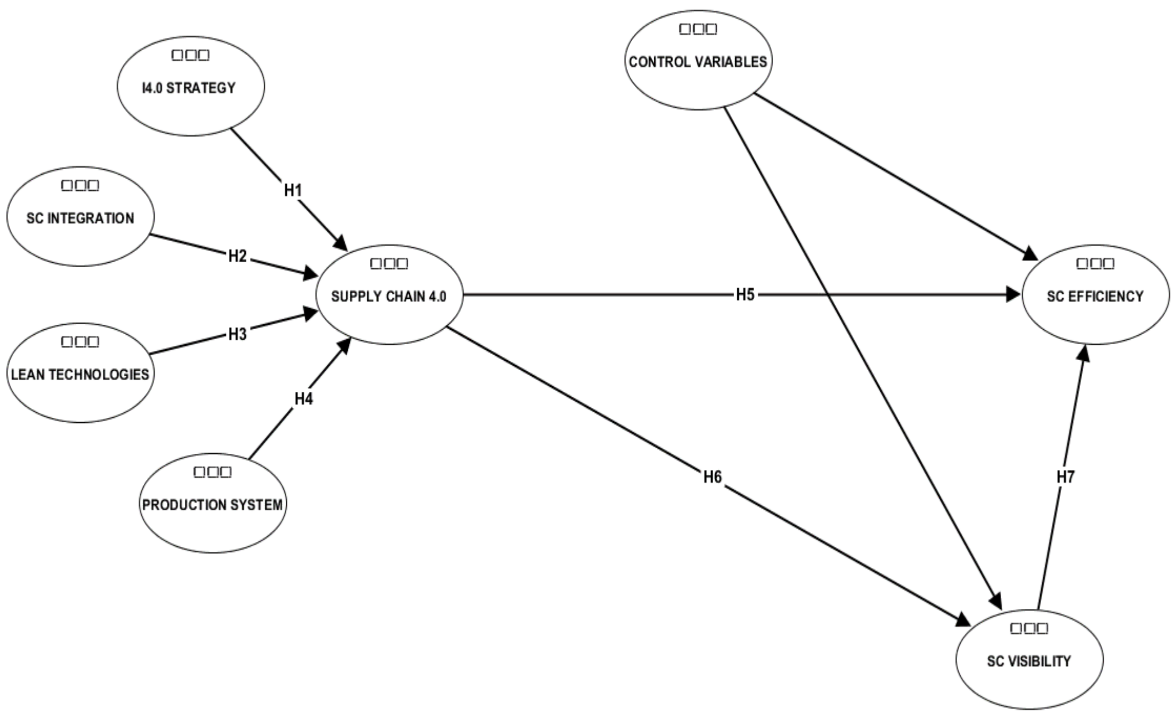

Figure 2. Conceptual relationships and hypotheses

3. Methodology

3.1. Measurement Items and Questionnaire Design

The article adopted constructs and measurement items based on their validity from previous relevant studies to ensure consistency and objectivity. For instance, the SC4.0 measurement items were based on (Liu et al., 2021; Choi et al., 2022; Roldán et al., 2023). The rest of the constructs and their relevant sources are provided in Table 1. Figure 2 above is a representation of the conceptual framework of the study and the relationships between its constructs and their variables. All measurement items are based on a five-point Likert scale. Respondents who are acquainted with SC and I4.0 advances from Turkish Manufacturing were asked to participate in a questionnaire-based survey. They were requested to indicate their level of disagreement or agreement with several statements on these constructs. Table 1 gives a summary of the scales used to measure these items. Several control variables, such as firm size, organisational flexibility, and ERP level, were also included in the questionnaire to test whether certain variables may influence our performance outcomes.

Table 1. Summary of constructs and measurement items

Construct/ Indicator	Code	Mean	STD	FL	α	ρ	AVE
1. Supply Chain Integration					0.767	0.769	0.532
Communication among members of the supply chain	SCI1	3.243	1.287	0.572			
Integration among SC partners, operations and warehouses	SCI2	2.806	1.442	0.750			
Level of integration between units or departments	SCI3	3.408	1.240	0.840			
2. Production System Automation					1.000	1.000	
Level of production system automation	PSA	3.068	1.301	1.000			
3. Lean techniques					1.000	1.000	
Applications and level of LP	LP	2.932	1.223	1.000			
4. I4.0 Strategy					1.000	1.000	
Availability and implementation of industry 4.0 strategies	ISL	2.204	1.562	1.000			
5. Supply Chain 4.0					0.843	0.882	0.516
Incorporation of internet of things into SCs	SCA1	2.544	1.679	0.692			
Application of big data in logistic or SCs	SCA2	1.505	1.137	0.676			
The use of cloud technology in SCs	SCA3	2.796	1.574	0.746			
The use of augmented reality related systems	SCA4	1.670	1.224	0.657			
Implementation of cyber security systems in SCs	SCA5	1.631	1.245	0.700			
Additive manufacturing (3DP) or rapid prototyping	SCA6	2.097	1.411	0.785			
Adoption of artificial intelligence in SC operations	SCA7	1.680	1.300	0.762			
6. Supply Chain Visibility					0.871	0.921	0.796
Traceability of the production process	SCV1	3.806	1.276	0.932			
Real time tracking of data and decision making	SCV2	3.350	1.412	0.878			
Traceability of supply chain	SCV3	3.505	1.267	0.865			
7. Supply Chain Efficiency					0.656	0.814	0.587
Flexibility of supply chains	SCF1	3.223	1.244	0.831			
Improved stock levels	SCF2	2.971	1.339	0.577			
Level of Production efficiency	SCF3	3.437	1.160	0.864			

Note: FL = factor loading; SD = standard deviation; AVE = average variance extracted; α = Cronbach's Alpha; ρc = composite reliability.

3.2. Sampling and Data Collection

Pretesting of the questionnaire was conducted with experts and academicians for clarity and content validity. Feedback was obtained from five companies to validate the instrument. The final questionnaire was distributed to 500 Turkish manufacturing firms. The survey generated 108 responses, 103 were retained for final analysis after screening. We used simple random sampling to ensure equal representativeness of the sample. Our final sample consists of 54.6% large companies, 32% medium firms, and 13.6% small firms**.** 82.5% of the respondents had adopted SC4.0, while 17.5% were in the adoption stage. Our final sample represents a response rate of 20.6%, which exceeds the required minimum of 92 cases to run the analysis. The required minimum was determined through the G*Power calculator (effect size = 0.15, significance = 0.05, power = 0.80). Not only does our sample exceed the minimum required response, it is also sufficient to perform PLS-SEM in both WarpPLS 7.0 and ADANCO 2.4.

3.3. Data Analysis

Our study is exploratory and involves several latent constructs. This compelled us to employ partial least squares structural equation modelling (PLS-SEM) as the most appropriate method for analysis. PLS-SEM was chosen after considering several important issues. For instance, (Mehmetoglu & Venturini, 2021; Henseler, 2021) argue that PLS-SEM is very useful when estimating complex models or when the focus is on prediction rather than testing theory. It is also useful when the field of study is still in its early or exploratory stage. PLS-SEM neither requires strict normality conditions, nor does it discriminate against small samples like the one in our study. Furthermore, PLS-SEM gives room for models with various research objectives to be assessed simultaneously. All of these attributes rendered PLS-SEM the most appropriate method for analysing data in this research.

The simultaneous use of WarpPLS 7.0 and ADANCO 2.4 software is complementary. For instance, ADANCO 2.4 provides a better evaluation of construct reliability and validity. It provides both HTMT and HTMT2 discriminant validity results. Additionally, it generates bootstrap results which provide more robust and accurate mediation and path analysis. WarpPLS can identify and model nonlinear relationships. It provides more robust predictive power and nonlinear model fit metrics. WarpPLS also provides both the Average Block VIF (AVIF) and Average Full Collinearity VIF (AFVIF) metrics, which are very useful in assessing multicollinearity across the entire model. The advantages of both software are inexhaustible.

4. Results and Analysis

4.1. Common Method Variance Assessment

Common method variance assessment was conducted. CMV is a type of measurement error that can occur when the data for different variables in a study is obtained using the same method or from the same source. The consequence of CMV is usually inflated relationships that may appear to be related when they are not. Harman's single-factor test was performed as a preliminary CMV assessment test. Results reveal that the first factor only accounts for 39.03% of the total variance (see Appendix 1), indicating that CMV is not a major concern in our data. We also confirmed this with a full collinearity test. According to Kock (2017), average full collinearity VIF (AFVIF) is one of the suitable ways to assess CMV and collinearity in PLS-SEM. The AFVIF value of 2.130 in Table 3 is less than the threshold of 3.3. Thus, showing that CMV does not affect the results of the study.

Lastly, a comparison of the means and standard deviations allowed us to also examine whether there is extreme variability among variables that may affect our results. Table 1 shows that on a 5-point Likert scale, there is no indicator with a standard deviation value greater than 2. Equally, no indicator has a mean value that was more than twice the value of the standard deviation. Thus, showing that there is no extreme variability and the relationships among variables are asymmetric. Thus, implying that the distribution of responses is reasonable.

4.2. Measurement Model Evaluation

PLS-SEM analysis involves two main stages: measurement and structural model assessment. Thus, our model assessment begins with measurement model evaluation, performed to determine the reliability and validity of constructs. The criteria for assessing construct reliability, convergent validity and discriminant validity are derived from recommendations by many authors (Henseler, 2021; Hair & Alamer, 2022). For convergent validity to be established, the average variance extracted (AVE) should be greater than 0.5, and the factor loading for each indicator must be greater than 0.6. Our results in table 1 above shows that all AVE values are greater than 0.5, and their corresponding factors are equally greater than 0.6. This shows that convergent validity is established in our study constructs. In other words, the variables measure what they are supposed to measure.

Construct reliability, which confirms whether indicators consistently represent the constructs, was determined using Cronbach's Alpha (α) and composite reliability (ρc). Table 1 shows that all values except SC efficiency ($\alpha = 0.656$) meet the criteria for construct reliability ($\alpha > 0.7$; $\rho c > 0.7$). Notwithstanding, Hair *et al*. (2010) suggested that 0.6 could be used as a threshold for α, especially when dealing with exploratory studies and complex models with small samples.

Although SC efficiency's α is lower than 0.7, it is higher than 0.6 and has ρc, which is greater than 0.7. Thus, we conclude that construct reliability exists among our study variables.

Discriminant validity, which measures the extent to which a construct in a model differs from other constructs, was assessed using Heterotrait-Monotrait ratios (HTMT) and HTMT2. The results in Table 2 were obtained using ADANCO 2.4. Henseler (2021), argues that these modern approaches provide far better discriminant results than the Fornell-Larcker criterion and cross-loading approaches. HTMT values below the 0.85 threshold are indicative of conceptually distinct constructs. Both HTMT and HTMT2 are below the threshold of 0.85, which is indicative that the constructs in the model are conceptually distinct. Since two tests are similar, we conclude that discriminant validity is established in our study.

Table 2. Discriminant validity results

Construct	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1.Supply Chain 4.0							
2. SC Visibility	0.475						
3. I4.0 Strategy	0.614	0.386					
4. Production System	0.538	0.416	0.408				
5. Lean Technology	0.378	0.338	0.228	0.428			
6. SC Efficiency	0.339	0.587	0.163	0.263	0.210		
7. SC Integration	0.472	0.725	0.194	0.339	0.267	0.830	
1							
2	0.468						
3	0.597	0.371					
4	0.531	0.416	0.408				
5	0.367	0.337	0.228	0.428			
6	0.329	0.586	0.163	0.263	0.210		
7	0.449	0.708	0.156	0.338	0.220	0.828	

Note: All ratios of correlations are below 0.850

4.3. Structural Model Evaluation

Table 3 presents statistical measures for overall model quality, validity and reliability assessment. The significant average path coefficient (APC = 0.285, $p = 0.010$), average R^2 (ARS = 0.474, $p < 0.001$), and adjusted R^2 (AARS = 0.451, $p < 0.001$) represent relatively strong explanatory power, where approximately 47.4% of the variations in the dependent variables are explained by the independent variables in our model. Similarly, the R^2 Contribution Ratio (RSCR = 0.970 > 0.7) shows that the independent variables in the model contribute significantly to explaining the variance in the dependent variables. The predictive relevance (Q^2) ranges from moderate to strong (i.e. 0.311 to 0.596), indicating significant predictive relevance. Hair et al. (2017), $Q^2 > 0$ indicate significant predictive relevance.

The average block variance inflation factor (AVIF = 1.511) and average full collinearity (AFVIF = 2.130) are below the threshold of 3.3. This implies that multicollinearity is not a major concern in the model. Sympson's paradox ratio (SPR = 0.846 > 0.7) implies that the observed relationships are consistent. Statistical suppression ratio (SSR = 1.000 > 0.7) means that there is no suppression in the model and that our model is stable. Nonlinear bivariate causality direction ratio (NLBCDR = 1.000 > 0.7) implies that all relationships in our model follow a consistent causal direction without ambiguity. Finally, the Tenenhaus Goodness-of-Fit (GoF = 0.617) reflects a large model fit (Wetzels et al., 2009). This confirms that our model is valid with substantial explanatory and predictive power.

Table 3. Model fit and quality indices

Statistical Measure	**Statistic**	***P***	**Threshold**
APC	0.285	0.010	
ARS	0.474	<0.001	
AARS	0.451	<0.001	
RSCR	0.970		acceptable if >= 0.7
AVIF	1.511		acceptable if <= 3.3
AFVIF	2.130		acceptable if <= 3.3
SPR	0.846		acceptable if >= 0.7
SSR	1.000		acceptable if >=0.7
NLBCDR	1.000		acceptable if >= 0.7
Tenenhaus Goodness of Fit (GoF)	0.617		large if >= 0.36
Predictive relevance (Q^2)			
Supply chain 4.0	0.510		acceptable if >= 0
SC visibility	0.311		acceptable if >= 0
SC efficiency	0.596		acceptable if >= 0

Note: *Q^2 around: 0.02= small, 0.15 = moderate, 0.35 = large*

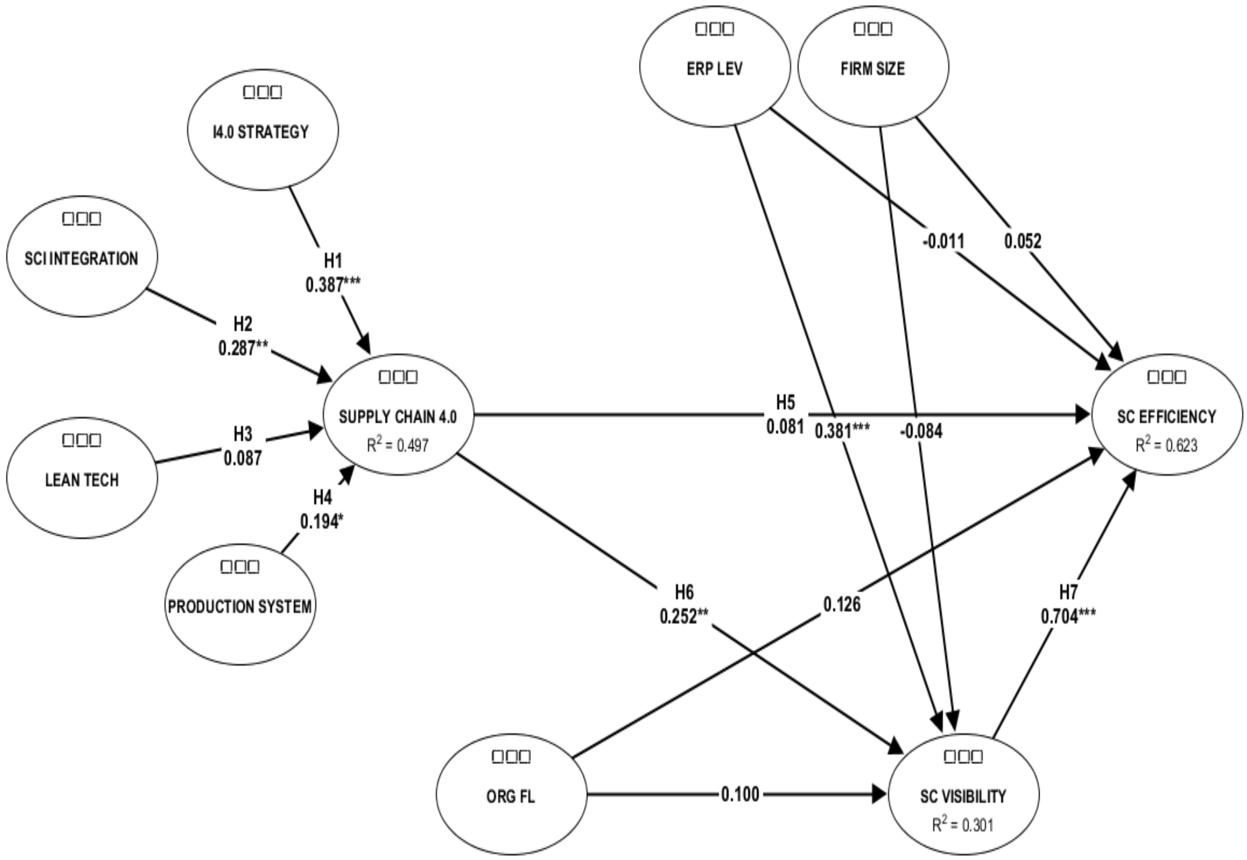

Figure 3. Structural model

Figure 3 is the output of the PLS-SEM model, which indicates construct relationships, coefficient of determination (R^2), path coefficients and their significance. While the asterisks (*****) and (******) denote significance at 5% and 1%, (*******) represents a very high level of statistical significance at 0.1% with p-value < 0.001. Path coefficients without asterisks indicate statistically insignificant effect. For PLS-SEM, R^2 values around 0.25, 0.50, and 0.75 can be interpreted as weak, moderate, and large explanatory power, respectively. In this study, the R^2 values range from 0.301 to 0.623, suggesting moderate to large explanatory power. In particular, supply chain visibility and supply chain efficiency exhibit relatively strong explained variance, indicating that the selected organisational enablers and SC4.0 adoption effectively account for variations in these performance outcomes. In particular, the R^2 values for supply chain visibility and supply chain efficiency are relatively high, indicating that a substantial proportion of variance in these two outcomes is explained by SC4.0 adoption and the associated organisational enablers included in the model.

The results on effect size in table 4 provide further insights into the importance of these path relationships in the structural model. The effect size (f^2) values of approximately 0.02, 0.15, and

0.35 indicate small, medium, and large effects, respectively. The relationship between SC visibility and SC efficiency exhibits a very large effect ($f^2 = 0.918$), establishing visibility as the dominant capability that enhances efficiency. I4.0 strategy ($f^2 = 0.240$) and SC integration ($f^2 = 0.129$) have medium effects on SC4.0 adoption. This shows that these organisational enablers play important but complementary roles in facilitating digital supply chain transformation. ERP also reveals a medium effect on SC visibility, which shows the importance of integrated information system for achieving visibility. On the contrary, SC4.0 shows a negligible effect on efficiency ($f^2 = 0.013$), which shows that unless mediated SC4.0 does not contribute significantly to SC efficiency. While the effects of production system automation ($f^2 = 0.051$) and SC4.0 adoption on supply chain visibility ($f^2 = 0.072$) are small, the direct effect sizes of SC4.0 on efficiency ($f^2 = 0.013$) and lean practices on SC4.0 adoption ($f^2 = 0.012$) are negligible. Overall, these effect sizes show that SC4.0 is strengthened through certain organisational enablers which in turn indirectly contributes to efficiency.

4.4. Findings and Hypothesis Testing

A bootstrapping approach using ADANCO 2.4 with a sample of 5000 was employed to test the proposed hypotheses and mediation effects. All the estimated path coefficients are evaluated at a 5% level of significance using 95% confidence intervals. Table 4 provides key results, while Table 5 provides a summary of mediation results.

4.4.1. Direct Effects

The hypotheses are tested based on their β-coefficients, t-values, p-values and confidence intervals. H1 in Table 4 confirms that I4.0 strategy significantly influences the adoption of SC4.0 ($\beta = 0.387$, $t = 4.738$, $p = 0.000$). This supports the claims that a good I4.0 strategy positively influences digital supply chains. H2 shows that SCI has a significant positive effect on SC4.0 ($\beta = 0.287$, $t = 3.278$, $p = 0.001$), thereby confirming that integration plays a significant role in supporting digital SC. Interestingly, we found that LP does not have a significant influence on SC4.0 ($\beta = 0.087$, $t = 1.349$, $p = 0.177$, CI [-0.049, 0.209]). On the other hand, H4 was supported ($\beta = 0.194$, $t = 2.358$, $p = 0.018$), which indicates that production system automation (PSA) significantly influences SC4.0 adoption. This confirms that automation is an important factor that supports the implementation of I4.0 in firms.

H5 was not supported by our results (β=0.081, $t = 1.349$, $p = 0.177$, CI ([-0.029, 0.208]), thereby implying that SC4.0 does not have a direct impact on SC efficiency. However, H6 which shows the relationship between SC4.0 and SC visibility is significant ($\beta = 0.252$, $t = 2.834$, $p = 0.005$). This is evidence that SC4.0 positively influences SC visibility. H7 which represents that the relationship between SC visibility and efficiency was confirmed ($\beta = 0.704$, $t = 12.011$, $p = 0.000$). We also found that SC visibility leads to improvement in SC efficiency. This implies that improved SC visibility plays a key role in driving efficiency. It is the path through which SC4.0 enhances SC efficiency.

While examining the control variables, we found that only ERP systems showed a significant association with visibility. firm size (FS) and organisational flexibility (ORGF) did not reveal any association. For example, the paths from FS to SC visibility (β = -0.084, p = 0.385) and SC efficiency (β = 0.052, p = 0.533) were statistically insignificant, suggesting that larger firms do not necessarily outperform smaller firms simply because they are large. Similarly, the insignificant paths from ORGF to visibility (β = 0.100, p = 0.328) and efficiency (β = 0.126, p = 0.108), shows that organisational flexibility alone does not lead to improvements in performance. On the contrary, ERP systems had a significant positive impact on SC visibility (β = 0.381, p = 0.000), thereby implying that ERP capabilities improve transparency across the SC.

Table 4. Hypothesis testing

Structural Path	**β**	**SE**	***t***	***P***	**95% CI**		**f^2**	**Decision**
H1: I4.0 Strategy →SC4.0	0.387	0.082	4.738	0.000	0.223	0.541	0.240	Accept
H2: SCI →SC4.0	0.287	0.087	3.278	0.001	0.119	0.459	0.129	Accept
H3: LP → SC4.0	0.087	0.064	1.349	0.177	-0.049	0.209	0.012	Reject
H4: Production System → SC4.0	0.194	0.082	2.358	0.018	0.034	0.354	0.051	Accept
H5: SC4.0 → efficiency	0.081	0.060	1.349	0.177	-0.029	0.208	0.013	Reject
H6: SC4.0 → visibility	0.252	0.089	2.834	0.005	0.066	0.418	0.072	Accept
H7: SC visibility → SC efficiency	0.704	0.059	12.011	0.000	0.579	0.810	0.918	Accept

Note*: β = beta coefficient; SE = standard error; t = t-value; P = p -value & CI = Confidence intervals;* f^2 = effect size.

4.4.2. Mediation Analysis

Mediation analysis reveals that the influence of SC4.0, I4.0 strategies, and ERP systems on SC efficiency is largely mediated by improvements in visibility. Table 5 illustrates that the total effects for both SC4.0 (β= 0.258, p = 0.001) and ERP systems (β = 0.257, p = 0.018) on efficiency are statistically significant. However, when considering their direct effects in isolation, neither SC4.0 (β = 0.081, p=0.177, CI [-0.029, 0.208]) nor ERP systems (β = -0.011, p = 0.888, CI [-0.163, 0.148]) have a direct influence on SC efficiency. This suggests that their impact is indirect. The indirect effects reveal that SC4.0 (β = 0.177, t = 2.764, p = 0.006) and I4.0 strategy (β = 0.100, p = 0.008) significantly influence SC efficiency through SC visibility. Similarly, ERP systems indicate a significant indirect effect (β = 0.100, t = 2.665, p = 0.008). This shows that the contribution of SC4.0 to efficiency is primarily through improvements in SC visibility.

Table 5. Summary of Bootstrapped indirect, direct and total effect inference results

Path	β	SE	t	P	95% CI	
Total Effect						
SC4.0 → SC efficiency	0.258	0.080	3.228	0.001	0.098	0.417
ERP → SC efficiency	0.257	0.108	2.372	0.018	0.038	0.465
Indirect Effect						
SC4.0 → SC efficiency	0.177	0.064	2.764	0.006	0.045	0.301
ERP → SC efficiency	0.268	0.075	3.577	0.000	0.116	0.417
Direct Effect						
SC4.0 → SC efficiency	0.081	0.060	1.349	0.177	-0.029	0.208
ERP → SC efficiency	-0.011	0.070	-0.141	0.888	-0.163	0.148
ERP→ SC visibility	0.381	0.100	3.812	0.000	0.171	0.568

5. Discussion and Contributions

5.1. Discussion

This study sought to establish organisational enablers of supply chain 4.0 adoption (SC4.0) and the impact of this adoption on supply chain visibility and efficiency. Our hypotheses H1 to H4 are tied to RQ1, while H5 and H6 are associated with RQ2. Ultimately, H7 is associated with RQ3.

Except for lean practices (LP), all the hypothesised enablers were supported. The confirmation of H1 implies that the I4.0 strategy directly influences SC4.0. This aligns with Sony and Naik (2020), who noted that a robust I4.0 strategy facilitates the effective implementation of I4.0 technology (I4T) in SC. Similarly, Kagermann et al. (2015) argued that there must be strategic alignment between I4.0 and transformation efforts for successful I4.0 implementation in SC operations. H2 confirms that supply chain integration (SCI) advances SC4.0. Thus agreeing with the claims of Ivanov et al. (2019) that the integration of data, systems, and processes enables digital SCs. Unsupported H3 suggests that LPs do not significantly impact SC4.0. This result, although not consistent with expectations, still agrees with Kolberg and Zühlke (2015), who noted that in digitised SCs LP may lose their relevance. This outcome reveals that there is a need for firms to modify to new paradigms such as Lean 4.0, which complement SC4.0.

The findings for H4 indicate that automation (PSA) is crucial to implementing SC4.0. This result is similar to the one by Wichmann et al. (2019), who provided evidence that systems like smart manufacturing, robotics and CPPSs play an important role in modern SCs by increasing efficiency, precision and flexibility.

Surprisingly, hypothesis H5 showed that SC4.0 does not have a direct impact on efficiency, which aligns with the findings of Wang et al. (2024). Nonetheless, results show that SC4.0 improves visibility (H6), which then enhances efficiency (H7). In this sense visibility acts as a critical organisational capability through which firms realise operational gains in SCs. Similar conclusions were made by Culot et al. (2020) who emphasised that while I4T may not immediately bring about cost reductions or increased speed, they can enhance transparency and traceability, which ultimately leads to performance improvements. Therefore, coupled with our findings we confirm that visibility is indeed an important capability that firms must possess to translate digital transformation efforts into performance improvements.

Additionally, the significant effect of ERP systems on visibility further supports the crucial role of information transparency and sharing in SC. Firms with good ERP capabilities are better equipped to synchronise data across their SCs. Our evidence also suggests the true value of ERP in digital SC lies in its ability to provide accurate and real time visibility.

In summary, the findings emphasise the significance of organisational enablers in facilitating SC4.0 adoption. But, contrary to expectations, LP did not significantly contribute to SC4.0 adoption. This may imply that in highly automated and data-driven supply chain environments, traditional lean practices lose their relevance unless they evolve toward Lean 4.0. Our study affirms that visibility is indeed a critical capability that mediates the association between SC4.0 and efficiency in SC operations.

5.2 Theoretical Implications

Our study makes important contributions to the development of digital SC theory. It empirically demonstrates that SC visibility is a key dynamic capability of SC4.0 that enhances SC efficiency. Our study also offers empirical support for RBV and DCT theory by establishing capabilities and strategic resources required to successfully adopt SC4.0 in firms.

The study simultaneously establishes visibility as the dynamic capability that promotes SC efficiency and SCI, I4.0 strategy and PSA as strategic organisational resources for successful SC4.0. These enablers provide firms with the necessary sensing, monitoring, and coordination capabilities needed to unlock the full potential of digital SCs. Models on SC digitalisation should incorporate I4.0 strategy, SCI and automation as critical enablers alongside visibility as a central capability. However, LP results challenge existing theory; LP does not automatically translate to an enabler for leveraging SC4.0. Thus, LP must evolve to remain valuable in the digital SC. Scholars must explore this potential gap and establish how lean can be integrated into digital SC frameworks. Both scholars and managers need to recognise that organisational resources must be enhanced to retain their strategic value in a dynamic and digital SC environment.

This study goes further than most to provide empirical evidence that positions visibility as a digital SC capability for better performance. Real-time SC visibility enables firms to leverage I4.0 for better SC performance. The expected benefits of digital SCs are primarily through better visibility capabilities, as confirmed by its mediating role. Thus, digital SC and strategies do not automatically result in operational efficiencies; rather, they result as a consequence of enhanced visibility. In other words, SC4.0 and its enablers are beneficial to performance improvements to the extent that firms can build visibility capabilities that sense, monitor, and coordinate I4.0 technologies and SC operations. Not only does this advance SC theory and emphasise dynamic capabilities, but it also implies that models on digital SCs should include visibility as a central capability for sustainable performance.

5.3 Practical Implications

There are several practical implications that can be derived from this study. Most of these implications have to do with how firms can optimise performance through digital SCs. Firstly, managers must recognise that simply adopting SC4.0 does not guarantee improved SC performance. However, gains in efficiency or SC performance come as a result of enhanced SC visibility through real-time tracking, strategic alignment, integration and automated systems. Therefore, investments in digital SC should prioritise solutions that improve visibility and transparency across the SC. For instance, technologies that promote data synchronisation, tracking, and real time decision making are critical for identifying bottlenecks, mitigating disruptions and coordinating processes. This ultimately leads to improvements in SC performance. Secondly, managers should invest in automation systems that support both operational efficiency and real-time visibility. PSA is another critical enabler that supports the implementation of SC4.0 in manufacturing firms. Through automated systems firms can improve visibility in order fulfilment processes, warehouse operations as well as quality control processes. However, system automation is more valuable when aligned to support operational efficiency.

Equally, we established that SCI is a critical factor for successful adoption of SC4.0 in firms. Consequently, we recommend that managers should focus on systems that strengthen integration like ERP to promote smooth communication and data exchange across SCs which is crucial for SC4.0. Managers should also seek advanced ERP for stronger SCI and improved SC visibility. This is because SCs with stronger SCI can strengthen collaboration and support real-time decision making, which is crucial for optimising SC performance through digital SCs. SCI can further promote interoperability within SCs. Managers should also make sure that there is clear strategic alignment between SC4.0 implementation and their visibility goals for better performance. This implies that they should set clear DT goals that are supported by their resources and they should be actively involved in implementing these goals to accomplish overall SC4.0 objectives.

6. Conclusion

Not only does our study empirically contribute to digital SC research, but it also positions visibility as an essential dynamic capability that supports operational performance in the context of SC4.0. Thus, it extends the DCT perspective by showing that improvements in efficiency not only depend on technology adoption, but also on the capability to achieve SC visibility. Visibility acts as a core capability through which digital SC translates into SC performance gains. Our study also advances the RBV by establishing which strategic resources support the successful adoption of SC4.0 in firms. It provides valuable insight and clear guidance to practitioners on how to leverage strategic alignment, automation, supply chain integration, ERP, SC4.0, and visibility for better SC operations and performance. Leveraging these resources and capabilities would not only enhance SC performance but also help build more resilient SCs. There is also the need for both practitioners and scholars to adapt LP to support digital SC. In their current state LPs may lose their relevance in this digital age. Therefore, future studies should explore hybrid concepts such as Lean 4.0 to determine how LP can be modified to support real time visibility and efficiency.

6.1. Limitations and Future Studies

Notwithstanding the important insights provided by this study, several limitations should be acknowledged. First, the empirical data were collected from Turkish manufacturing firms operating across multiple sectors. While this allows the study to obtain insights from different manufacturing sectors, sectoral heterogeneity may influence how organisational enablers such as supply chain integration, lean practices, and automation contribute to SC4.0 adoption and performance outcomes. Therefore, we suggest that future studies should be conducted to determine whether different sectors and regions would give a different outcome. Second, our study employed a cross-sectional research design, which may limit the ability to observe dynamic changes in SC4.0 adoption, visibility, and efficiency over time. We recommend that longitudinal studies should be conducted to determine how visibility and lean would affect digital SC as digital transformation increases in firms over time. Regardless of these limitations, firms in emerging economies can still take advantage of these critical enablers and SC 4.0 to leverage digital transformation for better operational and sustainable performance. However, the findings also show that the benefits of SC4.0 are primarily realised through enhanced SC visibility, thereby establishing visibility as a critical dynamic capability in digital supply chains.

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APPENDICES

Table 1A. Harman's Single-Factor Test results

Component	Initial Eigenvalues	% of Variance	Cumulative %
1	**8.195**	**39.03%**	**39.03%**
2	3.034	14.45%	53.48%
3	1.280	6.10%	59.57%
4	1.067	5.08%	64.65%
5	0.944	4.49%	69.15%
6	0.894	4.26%	73.40%
7	0.794	3.78%	77.19%
8	0.728	3.47%	80.65%
9	0.700	3.33%	83.98%
10	0.564	2.69%	86.67%

Extraction Method: Principal Component Analysis (PCA)