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Original Article

Strategizing Smart Supply Chain Adoption: An Integrated Framework for Industry 4.0 Transformation in the Automotive Industries, Kerala

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Abstract - *This research investigated which strategic factors determine the implementation of Smart Supply Chain (SSC) systems in the automotive sector, while the research specifically examined how Strategic Digital Alignment (SDA) functions as a mediating variable. The research developed an integrated strategic framework that consists of nine organizational strategies that explain Dynamic Capability Theory and Resource-Based View. The researchers employed a mixed-method research design, which combined survey data from managerial professionals in automotive firms in Kerala with qualitative interviews. The results from Structural Equation Modeling (AMOS) analysis demonstrated that all strategic dimensions produced strong positive effects on SDA, while SDA demonstrated a significant impact on SSC adoption ($\beta = 0.65$, $p < 0.001$), which accounted for 61% of the SSC adoption variance. The strategies showed that data-driven decision-making and digital culture were the strongest predictors of SDA, with respective β values of 0.26 and 0.24. The analysis of mediation showed that SDA functioned as a partial mediator between organizational strategies and SSC adoption. The qualitative research demonstrated that leadership-driven vision, organizational readiness, strategic alignment, and continuous learning served as essential factors that enabled SSC implementation. The results demonstrate that SSC implementation functions as a transformation process that businesses execute through strategic development and alignment with their organizational goals rather than through technological advancements.*

Keywords - *Smart Supply Chain Adoption, Strategic Digital Alignment, Digital transformation strategy, Dynamic Capabilities, Automotive industry.*

1. Introduction

The advent of Industry 4.0 innovations has resulted in a complete overhaul of the basic tenets of supply chain management practices, thereby giving rise to the concept of the Smart Supply Chain (SSC), which refers to a digitally integrated framework of organizational processes, stakeholders, and decision-making capabilities (Yadav et al., 2024; Mustafeez You're (Rehman et al., 2025). Unlike traditional supply chains, which mainly focus on operational efficiency, cost reduction, and linear process optimization, the SSC focuses on real-time visibility, smart coordination, responsiveness, and organizational learning within the interconnected network (Mathivathanan and Kirubanandan, 2024; Mubarik and Khan, 2024). The need for adopting SSC has become especially critical in industries such as automobiles, which operate under highly complex production processes, including multi-level supplier networks, wide geographic distribution, demand uncertainty, stringent quality control requirements, and a 'just-in-time' manufacturing environment (Yeung, 2023; Dakic et al., 2024). Thus, SSCs can be seen not only as a technological innovation but also as a key element of strategic planning in these industries (Chichi & Mamad, 2025; Singh et al., 2023).

The majority of previous SSCs literature has focused on the technologies underlying the digital transformation of the supply chain, such as IoT, artificial intelligence, blockchain, cyber-physical systems, cloud computing, and big data analysis (Cortes-Murcia et al., 2022; Lazaroiu et al., 2022). Even though these papers provide profound insights into technology-related aspects and benefits, the current literature is not yet well-integrated because the concept of SSCs has mainly been perceived as technology-focused (Ferreira and Janssen, 2023). However, there are a growing number of papers that argue that the implementation of SSCs involves many other important factors apart from technological capability, including strategic alignment, organizational readiness, dynamic capabilities, digital culture, and

collaborative ecosystems (Ozbiltekin-Pala et al., 2024; Kumar and Sharma, 2025; Vo et al., 2025). Previous studies have highlighted the significance of organization preparedness, strategic alignment, and capacity building for successfully achieving digital transformation (Hautala-Kankaanpaa, 2022; Bhatti et al., 2025). Likewise, literature related to supply chain integration and information communication technology alignment indicates that digital strategies can produce positive performance results only if they are strategically aligned with the organization's processes and those of the supply chain (Oubrahim et al., 2023; Zhu et al., 2022). However, despite the above contribution by various scholars, the existing body of literature focuses on studying different factors separately in isolation, including digital readiness, analytics capability, platform adoption, innovation, or supply chain integration (Munir et al., 2023; Mao et al., 2025).

The presence of such a gap shows that the process of SSC adoption cannot be explained on the basis of technology itself. The process calls for a comprehensive strategic thinking approach to include organizational resources, managerial competencies, strategic orientation, corporate governance, digital culture, business collaboration, and workforce readiness in a systematic SSC adoption strategy (Li et al., 2022; Schoggl et al., 2024; Mutambik, 2024). At the same time, the lack of empirical studies has hindered the identification of strategic digital alignment as an intermediary construct to explain how organizational strategy translates into SSC adoption (Tran et al., 2025; Lerman et al., 2022). In addition, while empirical data has mostly been gathered from developed economies and multinational firms, there has been little research done concerning emerging industrial ecosystems where differences in institutional context, management, and digital maturity levels play a role (Kumar and Sharma, 2025; Mutambik, 2024). Consequently, a significant knowledge gap is observed regarding the nature of the multidimensional strategic capability-building process associated with SSC adoption.

What is unique about the current research is its attempt at moving away from the traditional perspective of understanding SSC adoption toward a more contemporary view that emphasizes strategic digital alignment within organizations. The existing literature is mostly characterized by studies that have attempted to explore issues relating to specific technological enablers, operational challenges, digital readiness, analysis capability, innovations, and integration in supply chains separately (Cortes-Murcia et al., 2022; Lazaroiu et al., 2022; Oubrahim et al., 2023). The current research attempts to develop a strategic digital alignment model that incorporates nine strategic aspects: commitment from strategic leaders, organizational readiness, digital culture, integration of processes, making decisions based on data, collaborative ecosystem development, building workforce skills, governance, and policy alignment, as well as continuous innovation. This stands out in that, compared to earlier research that has focused on single strategic variables or direct effects of technologies, the current research considers the concept of strategic digital alignment to be the key mediator of organizational strategy in relation to SSC adoption (Bhatti et al., 2025; Zhu et al., 2022; Munir et al., 2023).

The automotive industry in Kerala, India, serves as an essential empirical context for analyzing this question. The state of Kerala has experienced progressive development in automotive manufacturing and component manufacturing facilitated by industrial clusters, logistic connections, a qualified labor pool, and connectivity to national and international supply chains. Despite that, significant heterogeneity is observed with regard to digital maturity, technology readiness, and strategic orientation towards implementing SSC practices. While some firms develop digitalization initiatives at the high-end level, others still operate in a conventional way, relying upon the traditional supply chain approach. Such differentiation serves as a basis for exploring the effect of organizational strategic characteristics on SSC practices and the role of digital alignment in mediating it. Moreover, studies analyzing SSC practices are mostly focused on developed countries like North America, Europe, and East Asia. In contrast, empirical evidence regarding developing nations is rather scarce (Kumar and Sharma, 2025; Mutambik, 2024). Through exploring SSC practices in the automotive industry of an emerging economy, this paper seeks to fill this geographical and context-related gap.

The current study makes three main contributions to the existing body of literature. Firstly, it adds to the theory of the topic by offering an idea of how SSC can be adopted as a strategy for developing organizational capabilities. Secondly, it makes an empirical contribution by analyzing the topic within the framework of an emerging economy, thus overcoming the contextual limitations associated with the previous SSC literature focusing on advanced economies. Finally, the current study suggests a strategic model to guide decision makers to adopt SSC in ways beyond technology implementation towards organizational alignment, integration of governance, and capability development. It is safe to say that the success of SSC in the future will depend not only on the adoption of technology but also on how organizations will align themselves to realize competitive advantage from their investments.

2. Literature Review

Research in SSC has gradually moved beyond a technological angle to focus on a much broader one that is strategic and organizationally transformation-oriented. While previous works focused largely on technological innovations such as IoT, AI, Blockchain, analytics, and CPS as key enablers of SSC modernization, contemporary scholars have

come to realize that technology-driven innovation alone is inadequate to secure SSC success without strategic and organizational orientation. Along this line, Ozbiltekin-Pala et al. (2024) found that operations excellence approaches and Industry 4.0 innovations created value when aligned with organizational strategy, infrastructural preparedness, and investment orientation. Further, their comparative analysis in three sectors – automotive, food, and textile showed that the automotive industry was better aligned with strategic configurations necessary for digital transformation success. In a similar fashion, Kumar and Sharma (2025) developed an organizational digital readiness maturity model for small and medium enterprises and found that the success of digital transformation initiatives required greater organizational preparedness and strategic capability.

Organizational readiness and strategic capability building were again emphasized by Vo et al. (2025) when their research found that organizational readiness had a positive effect on innovation and digital transformation, where innovation served as a mediator between organizational readiness and digital transformation. The findings of their research revealed that digital transformation served as a strategic capability-building tool rather than an output of technology implementation. Further corroborating the above finding, Hautala-Kankaanpaa (2022) concluded that digital platforms had an indirect effect on performance through the development of capabilities in the supply chain, where digital culture played a moderating role. Bhatti et al. (2025) noted that digital strategy improved business performance through the mediation of digital platform capability and digital culture. These findings implied that strategic alignment, organizational readiness, and digital culture served as important factors in determining the success of SSC, other than technology.

In another strand of studies, the importance of integration and alignment was emphasized in facilitating the digital transformation of supply chains. According to Oubrahim et al. (2023), digital transformation positively contributed to the sustainability performance of supply chains due to supply chain integration. Thus, it can be concluded that strategic integration mechanisms are crucial for achieving the advantages of digital transformation. Likewise, according to Zhu et al. (2022), ICT alignment had no direct impact on the performance of the supply chain; however, it had a powerful indirect effect through the mechanism of supply chain integration. In other words, these studies indicate that organization's alignment and integration act as intermediation mechanisms in terms of achieving digital outcomes. Moreover, from the viewpoint of Dynamic Capabilities Theory, Munir et al. (2023) showed that the supply chain analytics capability acts as a partial mediator in the link between ambidexterity and sustainability performance. Digital transformation is also viewed strategically in such terms when Mao et al. (2025) revealed its positive impact on customer stability via enhanced competitiveness and information transparency. The development of collaborative ecosystems and interorganizational relations also appeared to be relevant strategic constructs in SSC. Specifically, Li et al. (2022) revealed that stakeholder collaboration networks facilitated risk prevention performance and contended that collaboration was a strategic resource but not just a managerial one. Similarly, Schoggl et al. (2024) showed that collaboration between organizations positively affected sustainable and circular economy performance, whereas the role of digital technologies remained purely instrumental in terms of enabling collaboration.

Tran et al. (2025) showed that absorptive capacity acted as a mediator in the relationship between social innovation and business performance, which implied that learning capabilities were indispensable for translating innovative ideas into the effects of digital transformation. Moreover, Lerman et al. (2022) indicated that smart supply chain strategies could improve green performance via integrated governance and organizational mechanisms. Finally, Mutambik (2024) singled out leadership, technological culture, inter-business coordination, and recruitment management as the key enablers of supply chain digital transformation and resilience.

Nevertheless, despite the above substantial contributions, there are several theoretical and methodological lacunae in the extant body of knowledge on SSC adoption since very few studies have attempted to develop a coherent strategic framework for adopting SSCs. While previous studies have identified various mediators of SSC adoption, the strategic digital alignment construct has seldom been considered an important mediator connecting organizational strategy and the results of SSC adoption. In addition, many of the empirical studies that have been undertaken have been done mainly in developed nations and multinational corporations, and not much attention has been paid to emerging countries with different institutional environments and managerial practices, such as India. Hence, the current study aims at addressing the above lacunae by constructing a comprehensive SSC adoption model involving nine strategic dimensions moderated through strategic digital alignment in the automobile sector of Kerala, India.

2.1. Theoretical Framework and Hypotheses Development

The theoretical framework of the proposed work is based on the combination of the Resource-Based View (RBV) theory (Barney, 1991) and Dynamic Capabilities Theory (DCT) (Teece et al., 1997), which, respectively, justify a strong theoretical framework of how organizational strategies facilitate the adoption of Smart Supply Chain (SSC) systems in the environment of Industry 4.0. Whereas RBV explains the role of internal strategic resources in providing sustained competitive advantage, DCT builds upon this line of thinking

by focusing on how firms restructure and redesign their resources to meet disrupted and digitally disrupted environments. A combination of these two theories enables this research to transcend technological determinism and rather the adoption of SSC is a strategic, capability-based process of organizational change.

The Resource-Based View entails that companies attain outstanding performance when they have desirable, rare, inimitable, and non-substitutable (VRIN) resources, which are entrenched in company processes, leadership frameworks, and management approaches (Zvarimwa and Zimuto, 2022). When considering the resources needed to adopt SSC, it is important to note that they are not constrained to physical technologies and digital infrastructures, but rather to strategic leadership will, organizational preparedness, digital culture, and governance mechanisms that influence how companies adopt and use smart systems (Das, 2024).

One example is Strategic Leadership Commitment, which indicates the attention of managers, resource allocation, and strategic intent as the key intangible resources that are related to firm-level performance (Shafique et al., 2021). The commitment of the leadership allows the firms to mobilise internal resources and ensure the focus of the strategic agenda on SSC initiatives, thus improving Strategic Digital Alignment. According to the RBV, strategic orientation has been considered a fundamental organizational potential, which is promoted through leadership and facilitates digital alignment and SSC adoption (Cui, 2024), thus resulting in Hypothesis 1.

Organizational Readiness Strategy is also an association of internal capabilities, including structural flexibility, financial preparedness, and institutional preparedness towards digital transformation (Wang et al., 2025). According to RBV, companies vary in their resource endowments and absorptive capacity, which determines the variability of strategic performance (Lubis, 2022). Companies that are better equipped have better organizational resources that enable them to stitch together digital efforts and supply chain purposes in a more efficient manner. Such preparedness turns into a strategic resource that facilitates Strategic Digital Alignment by allowing the seamless alignment of SSC programs with the current operation frameworks (Rocha et al., 2025), hence explaining Hypothesis 2.

Digital Culture Strategy is also related to the focus of RBV on intangible resources like organisational culture, norms, and values. Experimentation, learning, and innovation are promoted by digital culture, making a firm capable of exploiting digital opportunities in a strategic way (Wang et al., 2022). A robust digital culture (in SSCs) becomes a tool based on knowledge and helps in aligning digital initiatives with business objectives, which results in Hypothesis 3.

Whereas RBV describes strategies of possessing strategic resources, the Dynamic Capabilities Theory describes how companies restructure such resources in a continuous manner in response to environmental changes, especially in situations of a high rate of technological disruption (Konlechner et al., 2018). The environments in Industry 4.0 are volatile, uncertain, and complex digitally, which means that the situation has not sustain a viable advantage with traditional resource ownership. DC has three fundamental processes, which include sensing opportunities, seizing opportunities, and transforming organizational structures (Malakar et al., 2025). Process Integration Strategy indicates that the firm has altered and re-engineered internal operations in reaction to the digital opportunities. In DCT terms, cross-functional process integration helps companies to re-adapt operations dynamically to digital goals and improve Strategic Digital Alignment (Yeow et al., 2018). This helps to confirm Hypothesis 4, which advances a positive correlation between process integration and strategic digital alignment.

Another primary form of dynamism capabilities is the Data-Driven Decision Strategy. DCT claims that data analytics and real-time information processing help firms to feel market shifts and a strategic opportunity (Gupta et al., 2019). The strategies based on data are used in SSC to make the firm more able to dynamically change the supply chain decisions, to align digital investment with strategic priorities, and to keep on optimizing performance. Such dynamic utilisation of data emerges as a strategic ability that enhances Strategic Digital Alignment, which results in Hypothesis 5.

The concept of Collaborative Ecosystem Strategy is another manifestation of dynamic relational capabilities, as companies go beyond their scopes and establish inter-organisational networks to create value together (Jucevicius and Juceviciene, 2022). As DCT emphasizes, to succeed in a complex digital ecosystem, businesses need to acquire external integration capacities. The interaction with suppliers, logistic partners, and customers allows common learning, co-innovation, and strategic alignment, which promotes the increase of alignment between digital efforts and SSC goals. This is the theoretical reasoning that justifies Hypothesis 6.

The RBV and DCT revolve around the Workforce Skill Development Strategy. In the RBV perspective, employee skills and knowledge are critical human capital resources that are hard to replicate and hence the source of competitive advantage (Gerhart and Feng, 2021). In terms of DCT, continuous skill development is the ability of the firm to reorganize human resources to meet the changing digital requirements (Chavarnakul et al., 2025). In the case of SSC adoption, competent staff members have helped companies to transform digital strategies into operational reality by connecting the technological efforts with organizational

objectives. In this way, workforce capabilities have been dynamic capabilities to improve Strategic Digital Alignment, and the result is Hypothesis 7. The Strategic Approach of Governance and Policy Alignment also demonstrates a dynamic structural capability because DCT places a lot of importance on organizational routines, governance mechanisms, and institutional arrangements in facilitating strategic transformation (Justice Mutua and Amenya, 2024). Good governance has made sure that digital efforts are systemically correlated with SSC goals, minimize strategic uncertainty, and allow departments to coordinate their decisions. Hypothesis 8 follows this ability of dynamic governance.

Continuous Innovation Strategy is the direct implementation of the transformation aspect of DCT. The innovation skills have made the firms constantly experimenting, learning, and adapting to technological change. In the case of SSC, the continuous innovation enables organizations to improve digital strategies, identify new business models, and maintain the strategic alignment in the long term (Florek-Paszkowska and Ujwary-Gil, 2025). According to DCT, the companies that are highly innovative are more likely to be in a better position to sustain the consistency between digital programs and supply chain strategy (Li et al., 2024), which explains Hypothesis 9. Collectively, these 9 strategic dimensions constitute a portfolio of strategic resources (RBV) and Dynamic Capabilities (DCT), which all combine to define the firm in terms of Strategic Digital Alignment.

The mediating construct in this research is Strategic Digital Alignment, which is both theoretically based on RBV and DCT. In the RBV, alignment is the orchestration of the strategic resources, and it means that digital investments are utilized in a manner that they generate value in the supply chain (Willie, 2025). In a DCT sense, alignment indicates how the firm is able to dynamically integrate, build, and reorganize internal and external competencies in reaction to digital opportunities (Yeow et al., 2018). Strategic Digital Alignment thus serves as a process of implementing strategic intent in the form of operational transformation. Companies with high alignment are more likely to incorporate digital efforts into the supply chain operations, institutionalise smart practices, and have adopted SSCs sustainably. Hypothesis 10, derived through this theoretical rationale, is that Strategic Digital Alignment and SSC adoption have a positive relationship.

Moreover, Strategic Digital Alignment is used as a mediating variable by RBV and DCT. According to RBV, strategy resources by themselves are not necessarily able to achieve performance results unless they are implemented and coordinated with organizational goals. This is extended by DCT, according to which alignment processes that are dynamic are required to convert resources into actionable capabilities. Strategic leadership, readiness, culture, integration, and innovation have only affected the outcomes of adoption in SSC adoption when they are strategically aligned with the digital transformation objectives. Strategic Digital Alignment consequently acts as the mediator in the relationship between the nine strategic dimensions and SSC adoption by being the dynamic process through which strategic resources in turn become the actual organizational capabilities. This theoretical rationale underpins the mediation hypotheses (H11a-H11i), which hold that Strategic Digital Alignment moderately mediates the association between each of the strategic dimensions and the adoption of SSC.

In this regard, the current study contributes to existing SSC literature by going further than previous approaches that apply the Resource-Based View (RBV) and Dynamic Capabilities Theory (DCT) individually as theories that explain SSC adoption. This research attempts to integrate RBV and DCT through SDA theory to analyze SSC adoption as a multivariate process of strategic transformation. Previous literature on SSC adoption has been focused on studying various dimensions of organizations, such as digital readiness, analytics capability, innovation, platform adoption, and supply chain integration individually without considering the interaction between all of these dimensions that leads to SSC adoption outcomes (Kumar and Sharma, 2025; Munir et al., 2023; Oubrahim et al., 2023). Furthermore, previous literature has considered technological and operational integration without addressing the strategic alignment process through which resources and capabilities within organizations become digitally aligned (Ozbiltekin-Pala et al., 2024; Zhu et al., 2022). On the other hand, the current study proposes a holistic framework that integrates both theories of RBV and DCT through the concept of SDA as a mediator that explains the transformation process from strategic dimensions to digitally aligned operational capabilities (Bhatti et al., 2025; Mao et al., 2025).

It further differs from previous studies by taking all nine strategic dimensions under consideration in a single SSC adoption framework, unlike the previous frameworks that focused on just one or two organizational variables. While prior research explored organizational readiness, innovation capabilities, digital culture, collaborative ecosystems, analytics capability, and strategic partnership as independent variables influencing digital transformation and supply chain performance, they failed to develop a strategic framework that integrated these variables in the form of a SSC adoption framework mediated by strategic digital alignment (Vo et al., 2025; Hautala-Kankaanpaa, 2022; Li et al., 2022; Mutambik, 2024). In contrast, the current study has made a significant contribution by proving that the adoption of SSCs is driven by more than technology, that is, the interplay of leadership commitment, governance alignment, workforce capability, collaborative ecosystem, innovation orientation, and process

integration (Schoggl et al., 2024; Tran et al., 2025). The application of this conceptual framework in the context of the Indian automotive industry is another contribution of this study, as most research contributions in the field of SSCs have come from the developed countries (Lerman et al., 2022; Ozbiltekin-Pala et al., 2024).

Figure 1 shows the Conceptual framework diagram.

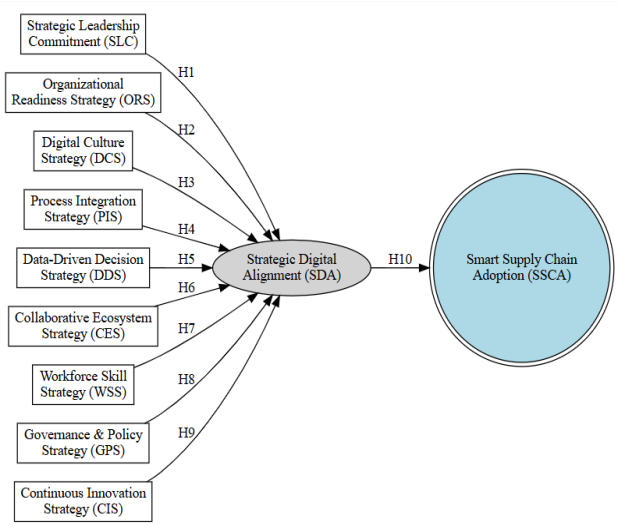

Fig. 1 Conceptual framework diagram

3. Research Methodology

The current study is based on the mixed-method explanatory sequential research design to establish and confirm a better strategic framework of Smart Supply Chain (SSC) systems consolidation in the automotive sector within the Industry 4.0 framework. The essence of the research is to outline empirically-based and practically viable measures that have helped organizations to successfully implement SSC practices.

The study combines quantitative and qualitative studies to enable the researcher to not only identify statistically significant associations between the strategic constructs but also gain in-depth managerial information on how these strategies are perceived, adopted, and institutionalized in actual organizational settings. The research lies in a paradigm of positivism-interpretivism, in which quantitative approaches determine generalisable trends and qualitative approaches include varied context and exposition.

3.1. Study Area and Sample Population

The research is performed in the auto industry in Kerala, India, and comprises automobile manufacturing companies, auto-component companies, Tier 1 and Tier 2 suppliers, auto-logistics and auto-warehousing companies, and auto-service companies, which are interlinked with both national and international supply chains. Kerala offers a suitable empirical location with regard to its expanding industrial zones, policy focus on digital manufacturing, and a general rise in the involvement of car manufacturers in Industry 4.0 programs.

The target group is the managerial and supervisory professionals directly related to supply chain management, operations, production planning, logistics, digital transformation, and strategic decision-making. They are the supply chain managers, operations managers, plant heads, IT managers, production managers, logistics managers, and the leads of digital transformation. The unit of analysis is the organization, whereas the unit of observation is individual managers with at least five years of work experience in professional positions related to the supply chain or any other operation-related activities.

3.2. Sampling Method and Sample Size (Quantitative Phase)

The research uses purposive stratified sampling to conduct its quantitative research. The study uses purposive sampling to select participants who possess the required expertise, while the study uses stratification to select participants from different categories of automotive companies, which include vehicle manufacturers, component manufacturers, logistics providers, and ancillary units. The sample size is determined based on Structural Equation Modeling (SEM) requirements.

The model contains nine strategic constructs and one mediating construct, which uses four indicators for measuring their respective elements that total 40 observed variables. The study needs at least 400 participants because it requires 10 respondents for each observed variable according to SEM guidelines. The study team distributed 420 questionnaires to participants, and the data screening process resulted in 387 valid responses, which provide sufficient statistical power to conduct Confirmatory Factor Analysis (CFA) and SEM.

3.3. Measurement Variables and Research Constructs

The study conceptualizes SSC adoption as the dependent construct and operationalizes it through a strategic framework consisting of nine key strategic dimensions. The study defines SSC adoption as its dependent variable, which it measures through nine essential strategic elements that include (1) Strategic Leadership Commitment (SLC), adapted from leadership and digital transformation capability scales developed by Kane et al. (2015) and Queiroz et al. (2021); (2) Organizational Readiness Strategy (ORS), adapted from organizational readiness and digital transformation readiness measures proposed by Lokuge et al. (2019) and Srinivasan and Swink (2018); (3) Digital Culture Development Strategy (DCS), adapted from digital culture and innovation orientation scales used by Martínez-Caro et al. (2020) and Bhatti et al. (2025); (4) Process Integration Strategy (PIS), adapted from supply chain integration and process coordination measures developed by Flynn et al.

(2010) and Oubrahim et al. (2023); (5) Data-Driven Decision Strategy (DDS), adapted from analytics capability and data-driven decision-making scales proposed by Dubey et al. (2019) and Munir et al. (2023); (6) Collaborative Ecosystem Strategy (CES), adapted from interorganizational collaboration and digital ecosystem capability scales developed by Li et al. (2022) and Schöggl et al. (2024); (7) Workforce Skill Development Strategy (WSS), adapted from workforce digital competency and human capability development measures proposed by Tortorella et al. (2020) and Mutambik (2024); (8) Governance and Policy Alignment Strategy (GPS), adapted from ICT alignment and governance capability measures used by Zhu et al. (2022) and Tallon et al. (2019); and (9) Continuous Innovation Strategy (CIS), adapted from innovation capability and strategic renewal scales proposed by Vo et al. (2025) and Wang and Ahmed (2004).

Strategic Digital Alignment (SDA) is introduced in this research as a mediating concept to measure the extent to which the digital strategy aligns with the supply chain objectives within the organization. The scale for SDA measurement has been developed using the conceptual framework on strategic alignment and digital alignment by Chan et al. (2006), Coltman et al. (2015), and Zhu et al. (2022). The SSC Adoption (SSCA) scale was measured based on strategic outcomes such as the institutionalization of smart practice, strategic integration of digital technologies, agility, responsiveness of the supply chain, and competitive position. These measures have been derived from SSC adoption and Industry 4.0 adoption scales by Queiroz et al. (2021), Lerman et al. (2022), and Frederico et al. (2020).

The selection of the study constructs and indicators is underpinned by theoretical considerations based on the RBV, DCT, and current research on SSC, all of which agree on the notion that for effective SSC implementation, there should be alignment between organizational capabilities, digital resources, and management. The nine strategic constructs are selected because they have been repeatedly identified as key factors in earlier empirical studies as determinants of digital transformation, supply chain integration, innovation capacity, organizational readiness, and operational agility. On the other hand, the indicators within the constructs are adapted from validated measures used in previous studies in relation to SSCs, Industry 4.0, and digital transformation.

All variables were quantified on a Likert scale of one to five, with one indicating “Strongly Disagree” and five indicating “Strongly Agree”. Expert validation on the instrument involved validation through five academicians specializing in the field of supply chain management and digital transformation, and three experts from the automobile industry. A pilot study was carried out with thirty participants in order to gauge the comprehensibility of the items, reliability of measures, and overall reliability of constructs.

Constructs’ reliability was gauged using Cronbach’s Alpha and Composite Reliability (CR), while the construct validity of all constructs was determined using standardized factor loading and average variance extracted, following the standards set forth by Hair et al. (2021) and Fornell & Larcker (1981). Discriminant validity for constructs was established through application of the Fornell–Larcker Criterion and HTMT Ratio, as recommended by Henseler et al. (2015).

3.4. Quantitative Data Collection

The study used a structured questionnaire to gather quantitative data. The pilot study tested content validity, clarity, and reliability of the research through its 30 respondents who participated in the testing.

The research team completed their main data collection after making small changes to their project. The researchers conducted online and offline tests of the final questionnaire.

Online surveys were distributed through professional networks, industrial organizations, and corporate connections, while offline surveys were conducted through direct visits to industrial sites.

The research team maintained strict compliance with ethical standards, which included procedures for informed consent and the protection of participant identities and the right to choose their involvement in the study.

3.5. Quantitative Data Analysis and Model Estimation

This research applied SPSS 26 and AMOS 24 software to conduct its quantitative data analysis. The analysis began with descriptive statistics and reliability analysis, which used Cronbach's alpha and Composite Reliability (CR) as its evaluation methods. The researchers conducted Confirmatory Factor Analysis (CFA) to test the validity of their measurement model. The CFA equations are represented as:

$$X = \Lambda_x \xi + \delta$$
$$Y = \Lambda_y \eta + \varepsilon$$

The model includes observed variables X and Y and exogenous latent constructs, which exist as ξ, and endogenous latent constructs, which exist as η and their factor loadings, which are represented by Λ, and the error terms, which appear as δ and ε. The researchers used SEM to evaluate the structural relationships between their variables.:

$$\eta = B\eta + \Gamma\xi + \zeta$$

The matrix represents the endogenous relationship matrix B, while the matrix represents the exogenous relationship matrix Γ, and the structural error term is represented by the term ζ.

3.6. Mediation Analysis

Mediation was performed with 5,000 cases of bootstrapping. Indirect influence was:

$$Indirect\ Effect = a \times b$$

where $a$is the effect of strategies on SDA, and b is the effect of SDA on SSCA. The total effect is:

$$Total\ Effect = c' + (a \times b)$$

The indirect effect is adequate if it meets the following criteria: if it is statistically significant in the current model, if the bootstrap confidence interval does not span zero, and if the direction is appropriate.

3.7. Qualitative Phase: Design and Sampling

The qualitative phase follows the quantitative analysis and is designed to explain, enrich, and contextualize the statistical findings. The researchers used a semi-structured interview method to gather managerial perceptions, strategic reasoning, and experiential insights about SSC adoption. The researchers selected 20 senior managers from the quantitative sample who showed high digital transformation dedication through purposive sampling. The group consists of plant heads, supply chain directors, IT strategy managers, and operations leaders. The sample size of 20 is considered sufficient to achieve theoretical saturation in qualitative research. Coding reliability and consistency were ensured by having two separate coders code each interview transcript using the NVivo 12 program independently of one another. Intercoder reliability was tested using Cohen's kappa statistic, and its value was above the threshold of 0.80, thus indicating good consistency in coding. Any discrepancies were settled through discussions and the refining of categories.

3.8. Qualitative Data Collection

The research team gathered data through in-depth semi-structured interviews, which lasted between 45 and 60 minutes. The interview protocol was created to investigate themes about SSC strategic vision, leadership functions, strategic alignment processes organizational readiness, digital culture, collaboration methods, and upcoming strategic objectives. The researchers obtained participant approval to record all interviews, which they later transcribed word-for-word to conduct their analytical work.

3.9. Qualitative Data Analysis

The research used thematic analysis to study qualitative data following Braun and Clarke's six-step framework. The researchers used NVivo 12 software to help them with coding and organizing their themes. The researchers used inductive coding to allow themes from the data to develop without interference. The researchers discovered six major themes, which included strategic leadership vision, digital alignment mechanisms, cultural transformation, collaborative ecosystems, and continuous innovation pathways, and they mapped those themes to the quantitative constructs.

3.10. Integration of Quantitative and Qualitative Findings

The final stage of the research works to combine quantitative findings with qualitative results through a triangulation method. The study identified strategic relationships through quantitative results, which reached statistical significance, while qualitative results provided explanations about the operational aspects of these strategies. The integrated system improves construct validity, increases practical value, and creates a complete strategic framework that adapts to different contexts for SSC adoption.

3.11. Methodological Contribution

The mixed-methods approach achieves methodological accuracy through its combination of SEM-based quantitative modeling and detailed qualitative thematic analysis, which produces both theoretical depth and practical business value. The methodology creates an SSC adoption strategic roadmap that combines empirical evidence with real-world application for the automotive sector, making it appropriate for doctoral research and high-impact journal articles.

4. Results

4.1. Survey Findings

The findings of this research are empirical confirmation of the strategic framework to be used in adopting Smart Supply Chain (SSC) in the automotive sector, as they offer a holistic insight into the role played by organizational strategies mediated by Strategic Digital Alignment (SDA) in the adoption of SSC. Table 1 gives the demographic picture of the respondents, which shows that the sample was well spread and very relevant because of the key management positions in the automotive industry in Kerala. The gender aspect is equally represented, as there are 55.3% and 44.7% men and women, respectively, indicating a sufficient gender diversity in the field of management, in terms of the supply chain and digital transformation. The age distribution indicates that most of the respondents are within the age range of 30 39 (45.0%), 40 49 (35.1%), and 50 + (19.9%), which comprises a workforce with a lot of mid-career professionals having extensive managerial experience and decision-making roles. This age group is specifically apt for the study, because SSC adoption needs a combination of both strategic thinking and operational knowledge. Moreover, the label profile implies that the respondents are in strategic and functional positions, such as Supply Chain Managers (28.9%), Operations Managers (26.9%), Plant Managers (22.2%), and IT/Digital Leads (22.0%), thus making sure that the information were gathered among those who have direct access to the strategic and operational side of supply chain management. The experience profile also maintains the trustworthiness of the data, with 39.8 % of the population possessing 5-10 years of experience, 35.4 % having 11-15

years, and 24.8 % having over 16 years of experience, which proves that the sample is composed of informed professionals who have given informed perceptions concerning SSC strategies. Moreover, the distribution of firm type represents the representation of Vehicle Manufacturers (36.7%), Auto Component Manufacturers (40.3%), and Logistics Providers (23.0%), which increases the applicability of the results to various segments of the automotive supply chain system.

Table 1. Demographic profile of respondents (N = 387)

Variable	Category	Frequency	Percentage
Gender	Male	214	55.3%
	Female	173	44.7%
Age Group	30–39 years	174	45.0%
	40–49 years	136	35.1%
	50+ years	77	19.9%
Designation	Supply Chain Manager	112	28.9%
	Operations Manager	104	26.9%
	Plant Manager	86	22.2%
	IT/Digital Lead	85	22.0%
Experience	5–10 years	154	39.8%
	11–15 years	137	35.4%
	16+ years	96	24.8%
Firm Type	Vehicle Manufacturer	142	36.7%
	Auto Component Manufacturer	156	40.3%
	Logistics Provider	89	23.0%

Descriptive statistics and reliability analysis are provided in Table 2, and they show that the measurement instrument has high psychometric properties. The average of all constructs is between 3.76 and 4.01, which means that the respondents are mostly in agreement with the strategic dimensions and SSC adoption items.

This implies that the engaged companies view themselves as moderately to highly invested in strategic efforts involving SSC adoption. It is worth noting that SSC Adoption (SSCA) has the greatest mean value (4.01), which means that firms have appreciated the strategic role of Smart Supply Chain Adoption. Strategic Digital Alignment (SDA) also has a high mean (3.95) as evidence of the fact that companies are becoming more and more ambitious to align their digital activities with the goals of the supply chain.

The reliability analysis also supports the internal consistency of all the constructs because the value of Cronbach's alpha is higher than the recommended value of 0.70, with a range of 0.85 to 0.93. These large reliability coefficients suggest that measurement items are always able to measure the underlying strategic constructs. All constructs also have Composite Reliability (CR) values greater than 0.87, which once again confirms the healthiness of the measurement model.

In addition, the values of the Average Variance Extracted (AVE) are 0.61 to 0.76, which exceed the required minimal level of 0.50, thus proving the high level of convergent validity. These findings, in unanimity, indicate that the measurement model is reliable and valid and has been further subjected to structural analysis. Figure 2 shows the Mean scores.

Table 2. Descriptive statistics and reliability

Construct	Mean	SD	Cronbach's α	Composite Reliability	AVE
Strategic Leadership Commitment (SLC)	3.94	0.61	0.89	0.91	0.68
Organizational Readiness Strategy (ORS)	3.87	0.58	0.88	0.90	0.65
Digital Culture Strategy (DCS)	3.91	0.63	0.90	0.92	0.70
Process Integration Strategy (PIS)	3.85	0.60	0.87	0.89	0.64
Data-Driven Decision Strategy (DDS)	3.97	0.59	0.91	0.93	0.72
Collaborative Ecosystem Strategy (CES)	3.89	0.62	0.88	0.90	0.66
Workforce Skill Strategy (WSS)	3.83	0.65	0.86	0.88	0.63
Governance Policy Strategy (GPS)	3.76	0.67	0.85	0.87	0.61
Continuous Innovation Strategy (CIS)	3.92	0.61	0.89	0.91	0.69
Strategic Digital Alignment (SDA)	3.95	0.58	0.92	0.94	0.74
SSC Adoption (SSCA)	4.01	0.55	0.93	0.95	0.76

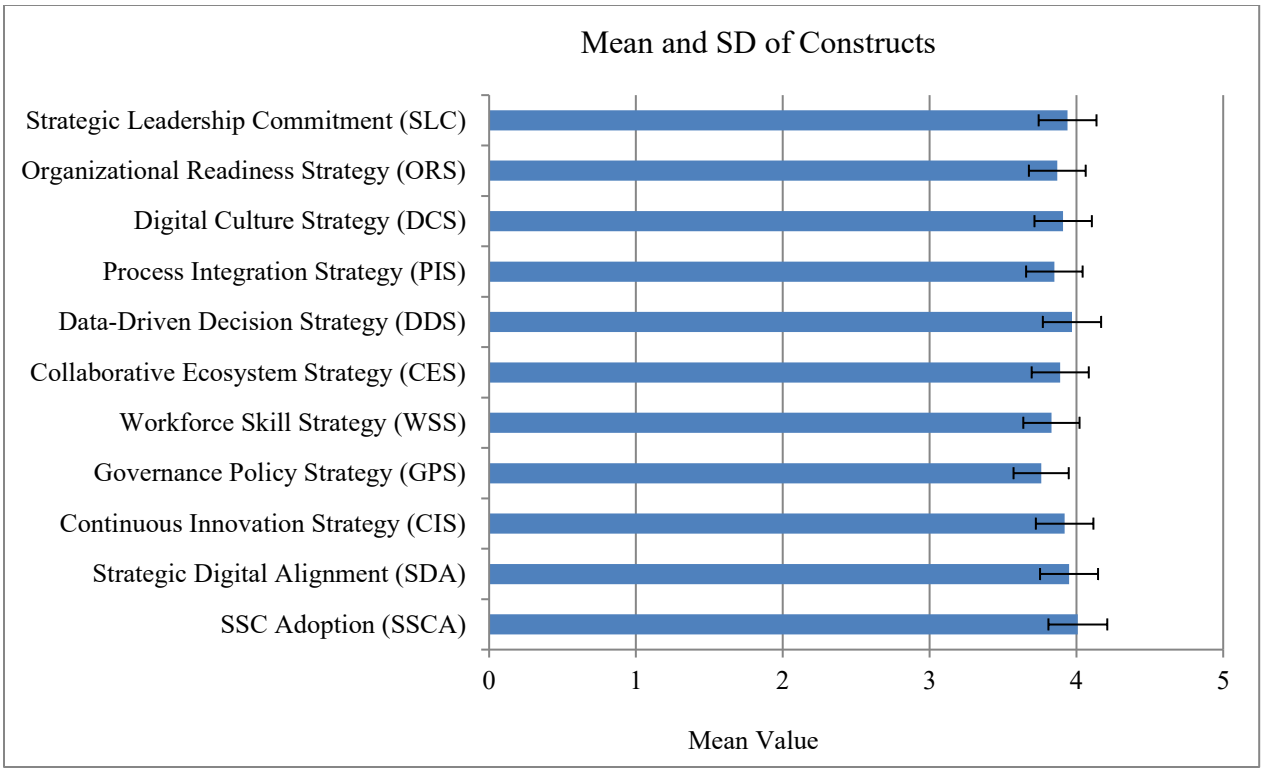

Fig. 2 Mean scores

The findings of Table 3 of the discriminant validity results, which was calculated using the Fornell-Larcker criterion, are additional indicators of construct distinctiveness. The diagonal values, which are the square root of AVE, are always high compared to the inter-construct correlations, which show that each construct has more variance with its indicators than with other constructs. As an example, an SDA square root of AVE is 0.86, which is higher than its correlation with all other constructs, such as SSCA (0.78). In the same way, the AVE square root of SSCA is 0.87, which is higher than its correlation with all the strategic constructs. The results support the hypothesis that the constructs are empirically different and do not have a problem of multicollinearity because the structural relationships have been interpreted meaningfully. Theoretical coherence is also implied by the moderate and positive correlation between constructs since all strategic dimensions are conceptually related to the SSC adoption, but with sufficient discriminant separation. Figure 3 shows the Correlation heatmap.

Table 3. Discriminant validity (Fornell–Larcker)

Construct	SLC	ORS	DCS	PIS	DDS	CES	WSS	GPS	CIS	SDA	SSCA
SLC	**0.82**										
ORS	0.61	**0.81**									
DCS	0.64	0.59	**0.84**								
PIS	0.58	0.63	0.62	**0.80**							
DDS	0.66	0.61	0.68	0.64	**0.85**						
CES	0.57	0.60	0.59	0.62	0.63	**0.81**					
WSS	0.55	0.58	0.60	0.57	0.59	0.61	**0.79**				
GPS	0.52	0.56	0.55	0.58	0.57	0.59	0.60	**0.78**			
CIS	0.63	0.60	0.65	0.61	0.67	0.62	0.59	0.56	**0.83**		
SDA	0.71	0.69	0.72	0.68	0.74	0.70	0.67	0.64	0.73	**0.86**	
SSCA	0.68	0.66	0.70	0.65	0.72	0.69	0.66	0.63	0.71	0.78	**0.87**

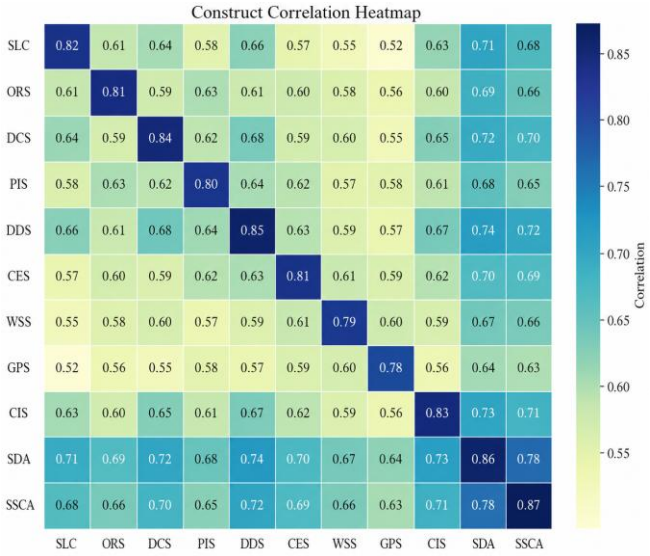

Fig. 3 Correlation heatmap

The results of the structural model are presented in Table 4, and they are obtained using AMOS, which directly empirically supports the proposed hypotheses. All nine paths between the nine strategic dimensions and Strategic Digital Alignment are statistically significant and positive, which proves that the organizational strategies are vital in determining digital alignment. Among them, Data-Driven Decision Strategy (DDS → SDA) is the most impactful (0.26), which means that data-driven practices are the most potent force of strategic digital alignment in the automotive environment. This observation identifies that analytics and evidence-based decision-making are the keys to digital transformation. Digital Culture Strategy (β = 0.24) and Continuous Innovation Strategy (β = 0.23) are also very significant, implying that cultural orientation and innovation capabilities are very critical in aligning digital initiatives to the supply chain objectives. Strategic Leadership Commitment (β = 0.21) and Collaborative Ecosystem Strategy (β = 0.19) also help to underline the role of leadership and external collaboration in creating alignment. The comparatively smaller coefficients like Governance Policy Strategy (β = 0.14) are statistically significant, which means that formal governance mechanisms add value to strategic alignment. The values of the effect size (f^2) show that most of the strategies have a small to moderate effect, but the relationship between SDA and SSCA shows a large effect size ($f^2 = 0.42$), which indicates the central role of strategic use of digital alignment in the adoption of SSC.

The results of the effect size analysis make the proposed model more convincing by showing the magnitude of the practical significance each of the strategic variables contributes to SDA and SSCA. Based on Cohen's rules for interpreting effect sizes, the measured effect sizes (f^2) show that Data-driven decision strategy, Digital culture strategy, and Continuous innovation strategy all have a moderately significant impact on SDA, whereas the impact of governance and policy alignment is smaller but still significant. Most importantly, the strong effect size of the relationship between SDA and SSCA ($f^2 = 0.42$) proves the role of SDA as the primary mechanism of SSC adoption. The present study's multidimensional SDA model proves to be significantly more predictive than other technology-focused SSC models found in previous literature.

The value of 2.18 of the χ^2/df ratio is within the acceptable range, which implies that the model fits the observed data well. Both CFI (0.94) and TLI (0.93) are greater than the desired threshold of 0.90, and the RMSEA value of 0.054 is less than the critical value of 0.08 of the model as a whole, indicating that the model fits the data very well. These findings indicate that the strategic framework suggested gives a statistically valid and theoretically significant explanation of the dynamics of SSC adoption in the automotive industry. Figure 4 shows the Pathway diagram.

Table 4. Structural model results (AMOS Regression)

Hypothesis	Path	Std. β	SE	CR (t)	p-value	95% CI (Lower–Upper)	f^2
H1	SLC → SDA	0.21	0.043	4.82	***	0.13 – 0.29	0.07
H2	ORS → SSDA	0.18	0.041	4.36	***	0.10 – 0.26	0.06
H3	DCS → SDA	0.24	0.044	5.41	***	0.16 – 0.32	0.09
H4	PIS → SDA	0.17	0.043	3.98	***	0.09 – 0.25	0.05
H5	DDS → SDA	0.26	0.044	5.93	***	0.18 – 0.34	0.11
H6	CES → SDA	0.19	0.045	4.25	***	0.11 – 0.27	0.07
H7	WSS → SDA	0.16	0.043	3.71	***	0.08 – 0.24	0.05
H8	GPS → SDA	0.14	0.043	3.28	**	0.06 – 0.22	0.04
H9	CIS → SDA	0.23	0.045	5.12	***	0.15 – 0.31	0.08
H10	SDA → SSCA	0.61	0.049	12.47	***	0.52 – 0.70	0.42

Model Fit Indices:

$\chi^2/df = 2.18$
CFI = 0.94
TLI = 0.93
RMSEA = 0.054

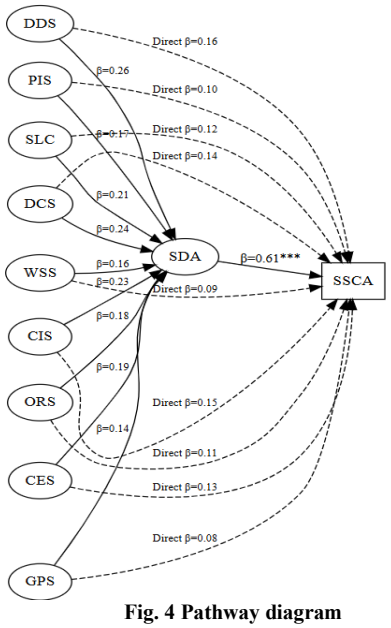

Fig. 4 Pathway diagram

The results of the mediation analysis provided in Table 5 provide more in-depth information about the mechanism by which organizational strategies affect the adoption of SSC. None of the indirect effects through Strategic Digital Alignment are statistically insignificant, and the confidence intervals containing zero are not within the values of each other, validating the mediating position of SDA.

It is interesting to note that the mediation is partial in all strategic dimensions because it implies that although strategies have direct impacts on the adoption of SSC, much of their impact is passed through strategic digital alignment.

As an illustration, the Data-Driven Decision Strategy has a high indirect effect (0.16) and total effect (0.32) by indicating how important alignment is in turning data-driven practices into actual adoption consequences.

On the same note, Digital Culture Strategy and Continuous Innovation Strategy are high in terms of total effects (0.29), which supports the point that cultural and innovation-based strategies improve SSC adoption mainly through digital alignment. These results support the hypothetical suggestion that alignment is a key integrative process that transforms strategic intent into working reality.

Table 5. Mediation analysis via SDA (Bootstrapping with 95% CI)

Hypothesis	Strategy → SSCA	Direct Effect	Indirect Effect (via SDA)	Total Effect	95% CI (Indirect)	Mediation Type
H11a	SLC	0.12*	0.13***	0.25***	0.08 – 0.19	Partial
H11b	ORS	0.11*	0.11***	0.22***	0.07 – 0.17	Partial
H11c	DCS	0.14**	0.15***	0.29***	0.10 – 0.21	Partial
H11d	PIS	0.10*	0.10***	0.20***	0.06 – 0.15	Partial
H11e	DDS	0.16**	0.16***	0.32***	0.11 – 0.22	Partial
H11f	CES	0.13*	0.12***	0.25***	0.08 – 0.18	Partial
H11g	WSS	0.09*	0.10***	0.19***	0.05 – 0.15	Partial
H11h	GPS	0.08*	0.09**	0.17**	0.04 – 0.14	Partial
H11i	CIS	0.15**	0.14***	0.29***	0.09 – 0.20	Partial

Lastly, Table 6 shows the explained variance and predictive relevance of the model, which further supports the contribution of the study empirically. The Strategic Digital Alignment R^2 equals 0.69, meaning that a significant proportion of the SDA variance is accounted for by the nine strategic dimensions, which is a large level of explanatory force. In the same manner, the value of R^2 of SSC Adoption is 0.61, indicating that the model explains 61 percent of the variation in SSC adoption, which is regarded as significant in behavioral and management studies. The values of predictive relevance (Q^2) of SDA (0.41) and SSCA (0.38) are positive and substantial and indicate that the model has a good predictive strength and real-life applicability. All these findings show that the proposed strategic framework explains a substantial part of SSC adoption behavior as well as provides powerful predictive information, which is why it has been considered an effective tool in managerial decision-making.

Table 6. Explained variance and predictive power

Endogenous Construct	R^2	Q^2
Strategic Digital Alignment (SDA)	0.69	0.41
SSC Adoption (SSCA)	0.61	0.38

4.2. Interview findings.

The qualitative segment of the research was carried out with the aim of getting a more in-depth understanding of how strategic processes influence the adoption of Smart Supply Chain (SSC) systems in the automotive business in Kerala. A semi-structured interview was used to interview 20 senior managers, who were supply chain directors, heads of plants, operations managers, IT strategy leads, and digital

transformation managers. Thematic analysis allowed identifying the four most common and significant themes that have explained the logic of strategy and organization related to the adoption of SSC. They are: (1) Strategic Leadership and Vision Alignment, (2) Organizational Readiness and Cultural Transformation, (3) Strategic Digital Alignment as a Mediating Mechanism, and (4) Continuous Strategic Learning and Innovation. Combinations of these themes introduce the holistic perspective of SSC adoption as a strategic process of organizational transformation instead of a technological initiative.

4.2.1. Theme 1: Strategic Leadership and Vision Alignment.

The first theme that stands out after the interviews is connected with the core place of strategic leadership and vision in the top management, which facilitates the SSC adoption. It was repeatedly noted by the respondents that SSC adoption is inherently a matter of leadership, and the determination, the long-term perspective, and the vision of the top management have a determining role. Managers emphasized that in the absence of overt ownership of leadership, SSC initiatives always remain scattered, pilot-based, or departmentalised. The role of leadership was not seen as a source of financial assistance, but rather as an initiative to influence the strategic direction within an organization, organizational buy-in, and alignment of SSC goals with overall company goals. According to one of the supply chain directors, "*the issue of smart supply chain cannot be left to the IT team by itself. It has to come from the top. People in various departments begin to take it seriously once the leadership makes it clear that it is a long-term business strategy of the business*". On the same note, one of the heads of plant noted, "*Managing director himself drives through digital initiatives on a quarterly basis. That sends a good message that SSC is not optional but one of the strategic priorities*." Some of the respondents indicated that the leadership vision has been used to combat internal resistance and uncertainty about change in the organization. In most companies, staff first viewed SSC programs as disturbing or disruptive to the current practices. Strategic leadership was regarded as a key to change legitimation and positioning SSC adoption as a chance and not a threat. One of the operations managers added that individuals have a fear of change, particularly when digital systems are being put in place. However, the fear subsides gradually as the top management expounds the long-term benefits many times. On the whole, this theme suggests that the adoption of SSC is so embedded in the strategic intent led by leaders and that the alignment of the vision serves as a precondition of successful adoption.

4.2.2. Theme 2: Organization Preparedness and Cultural Change.

The second central theme is the organizational preparedness and the requirement to change its culture in order to adopt SSC. The respondents have stressed that despite having a robust leadership, SSC adoption has not help the organization until the organization has built internal preparedness in terms of attitude, flexibility, and receptiveness to change. Organizational readiness has been defined as a psychological and structural situation within an organization that allows employees to embrace and practice new strategic practices. The traditional manufacturing cultures, which tend to be hierarchical and routine-oriented, were a challenge to SSC adoption, as emphasized by many interviewees. According to one of the senior production managers, "*We have a very traditional manufacturing mentality. Previously, the whole was done by means of manual planning and experience. Going to smart systems involves thinking completely differently*". One of the other respondents remarked that, "*technology is simple to purchase; however, changing the way of thinking of people is extremely hard. SSC must have a culture where individuals believe in data and has benefit by experimenting*." Learning orientation and employee empowerment were also associated with cultural transformation. Some of the managers pointed out that learning had to be promoted, cross-functional work, and sharing of knowledge. One of the logistics managers said that in the past, the operations were in silos. At this point, SSC compels us to cooperate. Procurement, production, logistics, everybody must cooperate. Another response that was made by the respondents was that organizational preparedness entails the redefinition of roles and responsibilities. The more the SSC systems are integrated, the more the decision-making process becomes decentralized and data-driven. One of the IT strategy managers clarified that, "*they do not make decisions anymore based on seniority. Decisions has been made even by junior executives provided they have information. That is a big cultural shift*."

4.2.3. Theme 3: Strategic Digital Alignment as a Mediating Mechanism

The most theoretically important theme is Strategic Digital Alignment, which appeared to be one of the key mediating factors between strategic intentions and real SSC adoption. Throughout their responses, the interviewees always highlighted how a significant number of digital initiatives fail not due to resource shortage, but on how they fail to address business strategy. Strategic digital alignment was defined as the process by which digital initiatives are aligned with organizational objectives, business priorities, and supply chain strategy. One of the digital transformation managers responded, saying that "*the greatest issue is that companies spend on digital tools without clarity. It results in a lot of systems, but not integration*". The other respondent noted that, "*SSC only works when digital systems are in line with the way the business is running. Otherwise, it has been a mere demonstration project. Many interviewees pointed out that strategic digital alignment serves as a connector between the vision of the leaders and operations*." One of the supply chain managers said, "*Top management has a vision, but without conversion into definite digital priorities, SSC has not occur. Digital aligned strategies were also linked to*

interdepartmental coordination and removal of duplication." One of the heads of the plant IT observed that "*in the past, the departments adopted their own digital tools. At this point, we are attempting to make a single digital roadmap*". This theme gives great credence to the mediation aspect as seen in the quantitative model. As a pathway through which strategies affect the results of adoption, strategic digital alignment is a crucial step to convert abstract strategic intentions into SSC practices.

4.2.4. Theme 4: Endless Strategic Learning and Innovation.

The fourth theme is associated with sustained strategic learning and innovation as another mechanism for maintaining SSC adoption. The respondents underlined that "*the adoption of SSC is not a single adoption and is a process of evolution. Organizations need to develop strategies that have constantly been learned, adapted, and fine-tuned in accordance with the fluctuating market conditions, technological advancements, and customer expectations*". The response of a senior operations manager was that "*SSC is not a project that has a time limit. It is a journey. We need to upgrade, modify, and improve every year*". One more respondent said, "*That is what we do today; however, in two years it has been out of fashion. Then, it is highly important that we learn continuously*". Innovation was also observed as a strategic thinking and not a technical affair. Some of the managers underlined the importance of experimentation, pilot testing, and feedback loops. One of the logistical directors added, "*We have small pilot activities and only then increase anything. That is what teaches us how to make mistakes without significant losses*." Another point raised by the respondents was that learning has taken place when there is cooperation with other parties, including suppliers, technology providers, and consultants. According to one of the procurement managers, "*We get a lot to learn with our partners. You cannot develop SSC individually*". Such a theme shows that the adoption of SSCs needs dynamic strategic competencies, whereby organizations are always creating, synthesizing, and using knowledge to optimize their strategic methods.

5. Discussion

The empirical evidence generated from this study provides strong support for the claim that the adoption of SSC in the automobile sector is not just an implementation process but a strategic transformation process. With the use of the SEM approach and management insights, this study reveals that SSC adoption can be accomplished by applying an interplay of organizational strategies through the mediator role played by Strategic Digital Alignment (SDA). These findings are consistent with recent digital transformation theories, which suggest that organizational readiness, strategic alignment, innovation capability, and dynamic capabilities are more important than technology availability to achieve digital success (Vo et al., 2025; Bhatti et al., 2025; Zhu et al., 2022). In effect, this study contributes significantly to SSC theory by suggesting that digital transformation needs to be understood and analyzed in relation to organizational capabilities development. The nine strategic dimensions found empirically to be critical for SSC adoption include strategic leadership commitment, organizational readiness, digital culture development, process integration, data-driven decision making, ecosystem development, workforce development, governance and policies, and innovation capabilities.

While previous studies have explored individual components of analytics capability, digital readiness, or adoption of platform technologies (Hautala-Kankaanpää, 2022; Kumar and Sharma, 2025; Munir et al., 2023), the current research brings all these constructs into one coherent strategic approach. The results clearly confirm the assertion by Ozbiltekin-Pala et al. (2024) that success in the digital transformation process lies mainly in the strategic and organizational alignment of a firm rather than its technical capabilities. The study finds Strategic Digital Alignment to be the most important mediator that connects organizational strategies and SSC adoption outcomes. This finding has strong support within the field of ICT alignment theory and Dynamic Capabilities Theory, according to which organizational alignment mechanisms are essential for translating strategic resources into performance and competitive advantages (Zhu et al., 2022; Munir et al., 2023). Moreover, the mediation results are consistent with the findings of Oubrahim et al. (2023), showing that digital transformation affected SSC performance indirectly through the integration mechanism of the SSC. In addition, Bhatti et al. (2025) found that platform technologies' capabilities and organizational culture act as mediators in the digital strategy-performance relationship.

In this regard, the current research further advances these studies by theoretically demonstrating that the emergence of outcomes from the adoption of SSCs is based not on the implementation of technologies in isolation but on the strategic alignment of the ecosystem of organizations. As for the strategic dimensions, data analytics decision-making, digital culture, constant innovation, and commitment to strategic leadership have been established as the primary drivers of Strategic Digital Alignment. In this respect, the importance of the capabilities of analytics, a culture aimed at learning, innovation, and strategic commitment of executives in digitally transforming supply chains, becomes evident. At the same time, the results of the study correspond with the research of Munir et al. (2023), who proved that analytics capability was a strategic mediator of sustainability and adaptability of supply chains, and Mao et al. (2025), showing that digital transformation was enhanced by information transparency and competitive products. Similar results were obtained by Hautala-Kankaanpää (2022) and Bhatti et al. (2025), who stated that digital culture was critical for improving the efficiency of digital platforms and

transformation strategies. The qualitative analysis further strengthens this perspective through the understanding that the adoption of SSC technology is perceived by managers as a continuous process of transformation led by leaders' visions, organizational learning, and readiness, and not as merely an IT-driven project. Consistently, participants stressed the need for participation from high-level managers and the alignment of such processes with long-term strategic objectives. These insights fully align with the findings by Mutambik (2024), whose research revealed that leadership and a technological culture are key enablers of digital transformation, and by Tran et al. (2025), who established the significance of absorptive capacity and strategic learning for successful digital transformation. According to the qualitative evidence provided, organizations are expected to move from traditional hierarchical decision-making models to collaborative data-informed decision-making processes. This insight coincides with those provided by Kumar and Sharma (2025), who suggested the need for industry-specific organizational preparedness in the context of implementing Industry 4.0 technologies, and by Vo et al. (2025), who found positive correlations between organizational readiness and innovation and digital transformation success. This research adds significant value to its applicability in engineering and industry through introducing a feasible strategic roadmap.

Scalability is exhibited by the framework since its strategic dimensions consist of organizational capabilities rather than technology-driven variables, which can be used across different industries and production types, from manufacturing to logistics, warehousing, and digitally enabled industrial ecosystems. Organizations that produce electronics, pharmaceuticals, heavy machinery, food, and industrial logistics can modify the framework for their benefit in terms of aligning digitally, integrating processes, gaining agility, and improving supply chain responses. An engineering manager's perspective reveals that the framework offers clear strategic ways to integrate Industry 4.0 into the organizational operations and governance structure. The framework can serve as a valuable instrument for policymakers and industrial organizations to develop specific SSC readiness strategies, digital capability evaluations, and strategic transformation strategies among emerging economies where organizations' digital maturity levels vary. Despite its merits, the study has some shortcomings. Firstly, the empirical study was conducted only in the auto industry of Kerala, which might be problematic for generalization to other industries and regions. Secondly, the cross-sectional study design prevents the researcher from examining the dynamic process of SSC implementation and adoption. Potential longitudinal investigations in the future could shed more light on how strategic alignment processes develop in various phases of digital transformation, following Mao et al. (2025). Thirdly, future research might benefit from using objective measures of operational effectiveness, network analysis, and information on interfirm ecosystems, as recommended by Li et al. (2022) and Lerman et al. (2022).

6. Conclusion

This paper concludes that implementing Smart Supply Chain (SSC) systems in the automotive sector is essentially a strategic and organizational change process and not necessarily a technological one. Through the creation and empirical verification of an overall strategic model, the research proves that the adoption of SSC has been explained by a logical network of organizational strategies that act through the central mediating mechanism of Strategic Digital Alignment (SDA). The results substantiate the fact that the strategic leadership commitment, organizational readiness, digital culture, process integration, data-driven decision-making, collaborative ecosystem development, workforce capability development, governance alignment, and ongoing innovation all have an influence on the capacity of firms to implement SSC practices successfully. Among them, SDA has been pointed out as an important integrative process that turns strategic intent into operational results, which puts the emphasis on the importance of the alignment of digital initiatives with business and supply chain goals.

The combination of quantitative and qualitative evidence demonstrates even further that the adoption of SSC is maintained by the leadership-engineered vision, cultural change, and strategic learning by doing, as dynamic capabilities are important in managing digital complexity. The paper also builds upon previous research on the topic of digital transformation and supply chains by shifting out of technology-focused explanations and providing a strategy-based and holistic model of SSC adoption, which takes into account the multidimensional character of SSC adoption. A practical sense of the framework has presented managers and policymakers with actionable insights by highlighting how managers have also invest not only in digital infrastructure but also in organizational capabilities, strategic governance, and collaborative ecosystems. Comprehensively, this study gives a scientifically based and empirically sound roadmap to real-life successful SSC adoption, especially in the emerging industrial environment, and sets a background to further research to involve longitudinal and cross-sectoral dynamics of smart supply chain transformation.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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Not Applicable

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