Journal of Management & Public Policy,
Vol. 14, No. 2, June 2023, Pp. 27-42
ISSN 0976-0148 (Online) 0976-013X (Print)
DOI: https://doi.org/10.47914/jmpp.2023.v14i2.004

Nuances of Supply Chain Paradigms: Evolution and Future Research Scope

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ABSTRACT

Supply chains act as the backbone of the world economy. The ever-increasing challenges and complexities have led to several revolutionary concepts in supply chain practice. This study aims to capture the significant research orientation and practices of supply chains and future alignment with challenges of inexperienced nature. The increasing importance of Hyper-agility, Industry 5.0 considerations and evolving sustainability paradigms have been discussed. This study aims to capture the robustness of current supply chain practices to address future challenges regarding the human-centric Industrial Revolution, extreme time pressure requirements, and incorporating evolving dimensions of sustainable practices in the changing business landscape. Reconfiguration and flexible supply chain strategies have been suggested as the robust platform for future evolving drivers.

Keywords: Flexibility, Reconfiguration, Hyper-agility, Industry 5.0

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INTRODUCTION

The drivers of supply chain practices in the contemporary business world are continuously evolving. As a result, the supply chain is also under continuous improvement to maintain a competitive edge under such diverse market scenarios. Although the practices and policies are market-dependent and intra-dependence between stakeholders involved, optimal alignment of supply chain practices and policies is always open to improvement. The supply chain is a system of systems. It encompasses various activities like procurement, transportation, loading/unloading, manufacturing, storage, inspection, marketing, etc., where the task is to align these activities and resources with the market needs with utmost efficiency and responsiveness. In the present business world, competitive edge depends upon the rivalry of 'supply chain vs supply chain' and the involved efficiency and efficacy.

Today the world has emerged as an intelligent global village wherein a product/service conceived as good at one part may be demanded from anywhere. The fulfilment of such demand requires the involvement of units at geographically dispersed locations and leads to an extended/global/ultimate/long supply chain structure to ensure 7Rs (Garcia and You, 2015). The dynamic and collaborative perspective of supply chain management empowers the utilization of different philosophies and improvement tools of other sectors or industries to address the challenges it faces in the day-to-day operation and long run. One such industry at an arm's length synonymity with the supply chain is the manufacturing industry, and the successfully implemented tools and principles have been of great significance in tangible and observable terms. This relation attracts researchers and academicians from engineering and management backgrounds to foster the qualitative as well as measurable aspects of the field.

Lean, agile, leagile, resilient, sustainable, digital, flexible and reconfiguration paradigms are the most discussed paradigms in supply chain literature, as depicted in Fig. 1. The evolving triggers and challenges of the 21st-century demand supply chain researchers and practitioners of robust, innovative concepts and their applications to maintain a competitive edge. Although the research efforts from both fields are continuously developing, a methodology or tool of universal fit for all the instances and challenges, whether from the theoretical or quantitative aspect, is infeasible.

Failure of supply chains at challenging times has resulted in unfortunate experiences and sufferings for individuals, society, the environment, and the global economy. The transition

from managing individual management silos traditionally to the supply chain aspect emerged as the more holistic and practical approach. And presently, supply chains, especially global ones, are responsible for the worldwide availability of products and services. The supply chain has always been challenging as it deals with several conflicts, interests, regulations, and targets. Supply chain models are need-oriented and require tuning to improve performance from whatever aspect is demanded or conceived as prime importance. Innovation, real-time decision-making, sustainability orientation, and human-centric are the critical ingredients identified to gain a competitive edge for supply chains in future (Turner, 2023). Supply chains are continuously evolving to attain a competitive edge, and this study aims to cover the practices that are present in practice and explores suitability towards future challenges.

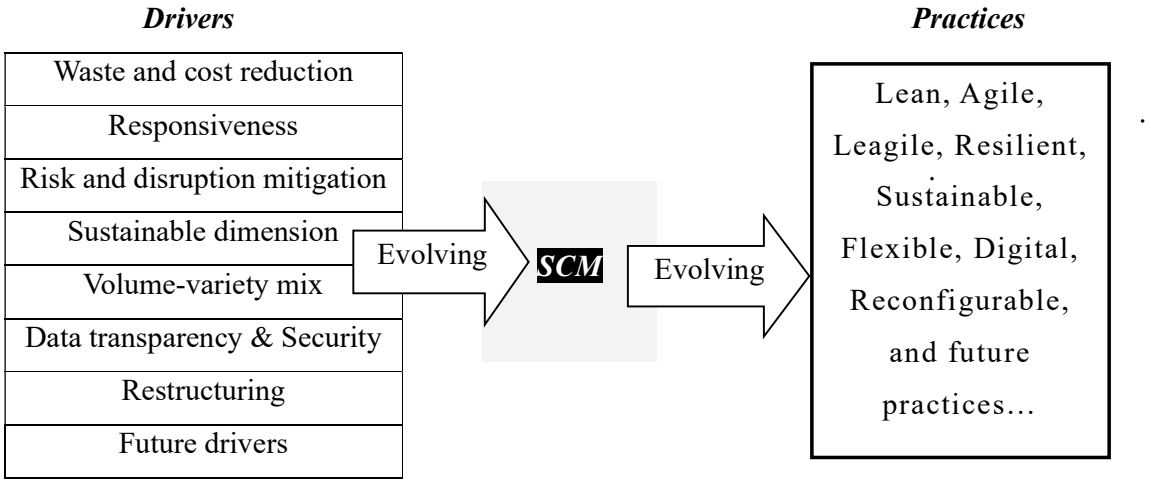

Fig 1. Drivers and supply chain major research practices

BACKGROUND AND RESEARCH MOTIVATION

The academic records illustrating applications and conceptual demonstrations of different SCM (Supply Chain Management) practices were identified and subsequently categorized based on their period of introduction in SCM research.

Lean, Agile and Leagile Concepts

The research developments in lean concepts can be traced back to TPS, by Womack et al. (1990) popularised lean in the book 'The Machine that Changed the World'. Lean practices focus on developing a value stream for eliminating muda, doing more with less, cost reductions, volume-centric production and working well in a stable and predictable demand. Agile, on the other hand, as a bearer of competitive advantage, focus on responsiveness and

the ability to respond rapidly against uncertainty and is suitable for high-end innovative technological products with shortened life-cycle (Yusuf et al., 2004; Aggarwal et al., 2006 & Singh and Pandey, 2015). Two critical lessons were identified in a review by Hoek (2001), carrying the past decade of academic literature as streamlining the operations and achieving an agile supply chain. Although the two practices, lean and agile paradigms, seem similar, but are different and have some overlapping concepts. The study by Narasimhan et al. (2006) concluded that the quest for agility might include lean as a precedence practice but not necessary in the case of pursuing leanness.

Similarly, regarding performance measures/metrics improvement, delivery speed and reliability act as the overlapping concept between the two paradigms. The literature on lean and agile concepts indicates chronological developments in critical attributes and overlapping/dual aspects between the two paradigms. It has been suggested that leanness acts as a foundation for agility (McCullen & Towill, 2001), or in other terms, agility as a precursor to leanness (Hormozi, 2001).

The two paradigms were combined to form the so-called leagile paradigm with the positioning of the de-coupling point. To qualify as successful leagile, lean and agile cannot be applied at the same point and lean should be applied upstream and agile downstream about the de-coupling point (Pattanaik,2021). While adopting lean, inventory levels need to be reduced, but from an agility view, customers are supplied with what they need at the right time, even with high inventory. Thus, a balance between cost reduction and responsiveness maximisation is desired; the portion of lean and agile in total SC might change dynamically and seldom encounters pure leanness, and pure agility may be observed in real business practices. Hence supply chain approach can be changed according to circumstances. It is not suitable to declare that one is better and the other is worst. Instead, they complement each other, and the combination depends upon market conditions (Kisperska & Haan, 2011).

Resilient and Sustainable Concepts

Resiliency has been applied in several scientific fields like engineering, sociology, ecology, economics, psychology, and organization management with different perspectives. Supply chain resilience utilizes the aspect of flexibility, dynamic capacity, and adaptability approach towards negative as well as positive influences of the environment (Ponomarov & Holcomb, 2009). It was identified as one of the critical components of Supply Chain Risk Management

(SCRM), with overlapping concepts of organizational agility under dynamic competition, i.e., the ability to cope with unexpected challenges, survival under threats, and exploit challenges to take advantage of opportunities (Sharifi & Zhang, 2009). Parallel developments in resilience concepts, i.e., restoration or rebound aspect (fail-safe design from an engineering perspective) and beyond restoration towards further development (safe-fail design from ecological perspective) of novel capabilities with better strength can be identified in various interpretations of literary study (Coutu, 2002; Fiksel, 2006 & Vogus and Sutcliffe, 2007). The most grounded enablers of resiliency in the supply chain have been suggested in the review work carried out by Ponis and Koronis (2012), such as agility, flexibility, velocity, visibility, availability, redundancy, mobilization of resources, collaboration, and supply chain structure knowledge. Significant overlaps have been identified in literary studies dealing with resilience definition and capabilities and a better perspective considering resilience as an adoptive and evolving nature guiding supply chains to consider sense, respond, control, recover and evolve to a more robust state, thus, gaining competitive advantage.

In the review by Carter and Rogers (2008), several potential intersections with social/environmental/economic aspects have been identified, and a broader framework of sustainable supply chain management has been presented, which includes risk management, transparency, strategy, and culture towards triple bottom-line goals for the supply chain. The research development aspects of sustainability have undergone objections, often identified as costly undertakings by the company to achieve a win-win situation, and were considered low-hanging fruit. Ideal sustainability occurs at the intersection of social, environmental, and economic goals in strategic vision, and aggregated network effort comprehensively orients towards these goals.

A coupling of efforts towards the triple bottom-line concepts has been agreed towards several benefits such as cost savings, design for reuse, better working conditions, increased motivation, productivity, less absentee, enhanced reputation, and broader social acceptance, among others. Theoretical developments in the sustainability aspect of the organization utilize concepts from population ecology theory, consideration of energy as the master resource, RBV (Resource-based view), and suggested practices as the run for the acquisition of energy resources at low cost, vertical coordination, contracts, joint ventures, partnership, and alliances and enables accessibility to member's technologies thereby, ensuring effective utilization of resources. Knowledge has also been considered one of the prime resources that

can be utilized to attain a sustainable edge against competitors. Knowledge gained through experiences of sustainable procurement, processing and delivery among stakeholders results in waste and cost reduction goals, responsiveness achieved, and adaptive capacity under risk and uncertainty positively influences trust and other performance measures of stakeholders.

Flexible approaches and increasing accessibility to resources are crucial to sustainability and long-term vitality. Although resilience has not been considered a part of sustainable thinking, overlapping concepts of reducing long-term risks from resource depletion, harm from products such as pollutants and waste, societal safety, food insecurity, climate change, and population growth but proactive management of such risks at an early stage will provide an inimitable edge against competitors in the long run. Within the context of sustainability, risk management focuses on the understanding and control of the risk associated with the triple-bottom-line concept.

The essence of risk management and further transparency on social, economic and environmental issues has been realized as part of the sustainability thinking of organizations for risk assessment of stakeholders and deciding priorities. Organizations mention risks in their sustainability report and continuously examine risks at stakeholders' locations to minimize reputation downfall and facilitate transparency towards sustainable development. Formation of crisis teams and the audit of their contingency plans to ensure adequate response and recovery, sharpen practical skills, coordination improvement, and identification of trouble spots are some of the disruption mitigation plans as a part of sustainable practice before the onset of an emergency.

Flexible and Reconfiguration Concepts

From the manufacturing perspective, internal flexibility traces back to TPS aiming to eliminate waste that does not add any value from the customer's point of view, acts as a predecessor of lean production (Womack et al., 1990), and later externally extended to organizations and finally to supply chains in decades of 21st century (Duclos et al., 2003; More & Babu, 2008). The supply chain flexibility provides options and features on which most of the literature studies agree are the utilization of inter-firm as well as intra-firm flexibilities under risk and uncertainty, focusing on adaptability of linkages between partners and incorporating strategies/structure/network design changes, agility for proactive

responsiveness, flexible robustness in relationship and orientation of entities towards goal attainment.

Flexibility, in general, is a multi-dimensional and complex concept, and the implications associated with supply chain practices are imprecise and inconsistent, ranging from the practices at individual resource, shop floor, plant level, operational and at the system level. The triggers and enablers of flexibility have been identified in a literature review carried out by Tiwari et al. (2015), in which critical flexible practices to mitigate risk and uncertainty are identified as encompassing adaptability, collaboration, integration, transparency and trust, postponement, agility, outsourcing, restructuring, redundancy, and combination with alternative resources and links.

Despite the advances in research angles of lean, agile, resilient, sustainable, and flexible, the search for a versatile integral actor which incorporates and guides research implications from different research aspects has been identified as reconfiguration (Dolgui et al., 2020), with its origin in robotics dealing with the restructuring of modules in space. Reconfiguration has been argued, as the extension of flexible manufacturing aspects emphasizing the aid of self-adjustments and adaptability, for rapid response to changes in a cost-effective manner for companies (Koren et al., 1999).

Traditional literature studies suggest reconfigurability in terms of changeability for quick and cost-efficient addition/removal of resources or products at the equipment, production, and system level, which now has been extended at the supply chain level for design under cost-efficient, responsive, resilient, sustainable manner and can be considered as the prime concept to incorporate viability (Ivanov, 2020). Modularity, integrability, convertibility, scalability, diagnosability and mass customization are the key characteristics of reconfiguration and employing these characteristics, the decision and evaluation of the supply chain capacity to adapt to changes can be performed (Biswas et al., 2019; Zidi et al., 2021a; Zidi et al., 2021b). In scarce studies, quantitative evaluation and optimization aspects of reconfigurable supply chains (Jafarian and Bashiri et al., 2014; Guo et al., 2018 & Pattanaik et al., 2022).

Extracted Motivation

While going through available literature on different supply chain paradigms, the overlapping concepts and interdependence criteria towards a robust practice can be observed. Starting

with the network management (NM) phase, the transition towards a leagile paradigm, leagile SC in resilient paradigm and further extension of these concepts towards performance improvement under TBL (Triple bottom line) aspects of sustainable thinking, a more holistic view of integrated SCM was obtained. The aspects of sustainability and further inclusion of redundancy units and collaboration ability enabled SCF (Supply chain flexibility) and aligned as per the industrial aspects of the present context resulting in RSC (Reconfigurable supply chain).

A common consensus towards reconfiguration as the highest level of development in the supply chain paradigm with all-inclusive paradigms has been ascertained. The developments in the reconfiguration field have led to the identification of several overlapping paradigms, covering almost all the well-established paradigms and critical factors to access reconfiguration allied performance measures but are limited at the system level. Although digital tools can automate and integrating the supply chain as a system of systems and enable better transparency, the sophistication level required for incorporating everything from a spreadsheet to the dynamic integrated system of several players, capabilities as well as robotics and Industry 4.0 enabled technologies to inspect, report, sense and adaptive response initiation makes the whole picture rather complex.

Skilled expertise is required to excel in maximum aspects, i.e., multi-tasking and multi-field experts of the integrated process as a system to interpret data and allied response triggering mechanisms to maintain a competitive edge under several complex considerations. Innovation and dynamic network capabilities practices to maintain a competitive edge are getting tougher daily. Such complex analysis requires the integration and collaboration of critical thinking and Industry 4.0 smart practices, an essence of Industry 5.0, to improve responsiveness at a more sustainable dimension, thereby prospering the requirements at the individual, societal, and global economic levels. The research paradigms under Industry 5.0, evolving sustainable dimensions and real-time dynamic agility are nascent. This study explores the present research paradigms, i.e., flexibility, reconfigurability, and digital SC outputs as a facilitator of prime importance towards future technologies.

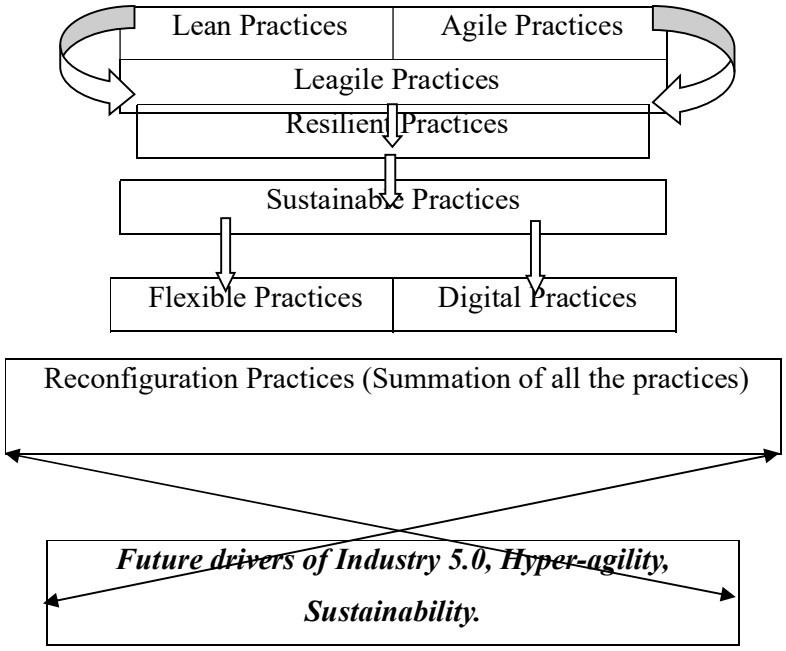

Fig 2. A research roadmap to Reconfiguration as the platform towards future drivers

THEORETICAL ADVANCEMENTS ON FUTURE DRIVERS AND SUITABILITY OF RECONFIGURATION AT THE FOREFRONT

Hyper-agility Aspect of Supply Chains

Supply chain agility has been considered an enabler of quick response to changes and providing a competitive edge under uncertain situations. However, during the disruption of Covid-19, several organizations with supply chain agility could not respond quickly (Do et al., 2021), and the agility capabilities evaluation was a necessary step for future events. Supply chain hyper-agility is an extension of supply chain agility. Certain distinct concepts can be identified as hyper-agility focusing on the quick response to grab the opportunities under disruptive events against long-term planning, and at the operational level, can introduce new products or services within a few days.

Opportunities under such disruptive events are only short-term and may not have long-term benefit opportunities. The short-term perspective of goals and response at ultra-speed is at the core of hyper-agility and is suitable for colossal demand but for a shorter period. Disruption can even lead to extraordinary demand, and under Covid-19 disruption, several organization ramped up their supply chains extraordinarily, and some even changed the product category

earlier in operating. Although the practices adopted could not fulfil the extreme demand for essential medical kits and tools, further government intervention was required (Sharma, 2020 & Iyengar, 2020).

Critical paradigms utilized under a hyper agile environment emerged as dealing with the network alignment to capture the aroused opportunities from disruption is reconfiguration, expansion of working employees, i.e., flexibility aspect, Industry 4.0 automation, data analytics tools and several online social platforms, i.e.., digital tools for economic performance improvement. Although the research development in hyper-agile paradigms is nascent, specific requirements needed to achieve hyper-agility, have been highlighted from the broader perspective of the dynamic capability view (Raj et al., 2023).

Customer Involvement

The level of customer engagement is a critical factor and affects supply chain operations. Mass production strategy was considered suitable for Industry 2.0 aspects, and globalization rendered personalized goods and services to customers at low cost. Industry 3.0 was based on developments in computing and IT tools utilization for various customized products, i.e., mass personalized products demand. The shift in nature from cheap, mass-produced products, exploiting economies of scale to more expensive customized products and Industry 4.0 aspects demanding design and manufacturing as per individual customization at a low cost and in large quantities poses a challenge for the supply chain.

Flexibility aspects of the volume-variety mix, make-to-order processing technologies, quality, costs, and times under supply chain practices are continuously evolving, credited to cloud-computing, blockchain, IoT, data mining, ERP and other data integration tools, vision technologies like AR, VR and CAD, automation and robotics, digital manufacturing, and other technological tools (Novais et al., 2019).

The Transition towards Industry 5.0 and Evolving Sustainable Dimensions

A new paradigm of the digital supply chain is under discussion, i.e., Industry 5.0, which focuses on incorporating societal and environmental perspectives. The dehumanization aspect of Industry 4.0 concerns society, individuals as well as government and the urge to include significant human contributions in future industrial revolutions, their return to workplaces,

explore the hybrid potential of cognitive skills, critical thinking abilities of humans and speed, accuracy by automation and intelligent production system (Longo et al., 2020).

The concept of Industry 4.0, wherein automation and robotics have been utilized as competitors to humans, now under the aegis of Industry 5.0 practices will rely on collaboration and integration of human-machine interactions, AI algorithms, and automation to enhance productivity and response. AI in people's daily life and Society 5.0 are some of the implications that will not only be restricted to organizations but also more open towards solving societal problems. The sustainability aspects will be extended for the benefit of society and for the sustainability of the economy by creating expertise skills in human-machine connectivity and allied employment opportunities. Resilience, sustainability, and digital SC are concurrent strategies to adopt in Industry 5.0.

Robust Practices and Concurrent Strategies

Supply chain evolving triggers have led to several developments in concepts and practices. However, the quest for robustness and innovation to maintain a competitive edge under any circumstances needs continuous refinement and performance measures evaluation. Dynamic supply chain/network structure capabilities are continuously subjected to performance improvements from individual or aggregated research concepts. The series of shocks and disruptive events caused by the onset of the Covid-19 outbreak and several geographically dispersed regulatory constraints hampered the performance of the global supply chain and resulted in several sufferings.

Research practices developed to date were subjected to critical, practical, and unfamiliar exposure, wherein most failed in achieving performance improvement and target achievement under extremely high pressure of demand for essential commodities. As a result, several organizations went bankrupt, and laying off employees hampering sustainable practices became common. Human-centric focus and extension of sustainable dimensions/targets to societal and individual prosperity were realized. Specific organizations could sustain and improve their performances in economic, societal and reputation aspects by utilizing innovations, robustness, flexibility, and reconfigurability quickly.

As evident from previous discussions, SC's reconfiguration principles and digital aspects with dynamic capabilities and innovative practices hold an absolute position under such scenarios to deliver a competitive advantage. The concurrent aspect of the dynamic supply chain

requires simultaneous sensing, responding, controlling, evaluating and decision-making, wherein an optimal engagement and management of different robust practices under one single plan will be no easy task.

CONCLUSION AND DISCUSSION

The theoretical aspects and practicality of Flexible SC, Digital SC and ultimately, Reconfigurable SC act as the facilitator towards goals for human-centric, resilient, and new sustainability dimensions for Industry 5.0 and the hyper-agile environment. The research developments and practices in the supply chain indicate exploration of the overlapping concepts and interactive relationship study as a prime methodology. The literature study establishes the reconfigurable practices as of fundamental position under whatever scenario subjected to and can be applied to other significant research angles under different orientations. In this sense, leagile, flexible, resilient, digital, and sustainable practices can be incorporated into a single reconfiguration framework with practices from different paradigms. Moreover, current research practices' drivers are continuously evolving; therefore, reconfiguration prospects must be explored under such situations. As a system of several systems, the supply chain will be under dynamic uncertainties, and disruptions may become a new norm. The task under such a situation would be increasingly complex to generate a competitive edge.

The present study on evolving paradigms in supply chain research indicates several indications of triggers that may be evolving. It may emerge as a sudden event in the not-too-distant future, and the capabilities and innovativeness will be again under examination for target achievement and performance improvement. In this context, Industrial 5.0 and allied extension in sustainability dimensions and the need for supply chain agility under extreme pressure from a reconfiguration perspective have been carried out since the Reconfigurable SC has been advocated as the most recent and robust among all the paradigms. The consensus that can be agreed upon is the positioning of Reconfiguration at the forefront for future evolving challenges.

Although evolving drivers may be divergent from existing research practices, the scope and applicability of the reconfiguration principle cannot be denied. Rather than focusing on individual research paradigms requirements, the reconfigurations provide a more holistic and robust practice that can be utilized with dynamic capabilities and integration towards several

challenges of future business context. In future, along with the engineering perspective of the supply chain, the ecological perspective may be combined, and consideration of innovative practices will treat the supply chain as an ecosystem. Reconfiguration practices under such ecological systems and subjected to divergent drivers will require identifying and interacting several factors from the qualitative and quantitative aspects.

ACKNOWLEDGEMENT

This is an improvised version of the paper presented at 12th International Conference on Management Practices & Research, ICMPR 2023 organized by Apeejay School of Management, New Delhi on 29 April 2023

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