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VIABLE SUPPLY CHAINS: THEORETICAL EVOLUTION AND EMPIRICAL EVIDENCE FROM THE ITALIAN FMCG SECTOR

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Abstract

Over the past forty years, supply chain management has evolved from a technical–logistical discipline focused on efficiency into a dynamic and complex system oriented toward resilience, adaptability, and sustainability. This paper critically retraces the conceptual evolution of supply chains—from Lean to Agile, Resilient, Adaptive, and finally Viable Supply Chains—framing these paradigms in light of today's volatile, uncertain, and digitalized environments. Through a narrative literature review and an empirical survey involving 112 Italian fast-moving consumer goods (FMCG) companies (245 respondents), the study investigates the adoption level of Viable Supply Chain principles across four key dimensions: end-to-end visibility, predictive capabilities through Artificial Intelligence, rapid reconfigurability, and integration of ESG criteria. Findings reveal that most firms have limited first-tier visibility, an

embryonic adoption of AI (only 10.9% have pilot initiatives), and insufficient digital competences within procurement teams (44.2%). Nevertheless, 70% of firms collaborate with suppliers to reduce environmental impact, showing increasing awareness of sustainability. The study concludes that Italian FMCG firms are in a transitional phase: while recognizing the strategic importance of digitalization and sustainability, they have yet to fully embed viability into decision-making and operations. The paper contributes to the ongoing debate on the future of Supply Chain Management, advocating for a Complex-Aware Supply Chain—a system able to learn, adapt, and regenerate in highly complex contexts.

Keywords:
Supply Chain Management, FMCG, Viable Chain

1. Introduction

Over the past forty years, the supply chain has evolved from a technical–logistics domain focused on efficiency into a vital, strategic system for firms' survival and competitive advantage. The complexity of today's supply chains stems from the need to manage high volumes, wide product assortments, tight timelines, and variable demand patterns while ensuring product quality, compliance, and cost-effectiveness across the entire chain. In addition to these market-driven requirements, uncertainty and variability create growing managerial complexity in relationships with an expanding set of suppliers and customers. Some have labeled this period as VUCA (an acronym coined in the 1980s at the U.S. Army War College), characterized by Volatility, Uncertainty, Complexity, and Ambiguity. What is particularly noteworthy is how global events over the years have continually introduced new features in organizational design.

During this time, the definition of the supply chain has been enriched with new adjectives that highlight its key characteristics while reflecting market shifts and the responses companies must adopt to remain competitive. Thus, the supply chain has been described as lean, agile, resilient, adaptive, and viable. A study conducted on a sample of roughly 250 companies in the fast-moving consumer goods (FMCG) supply chain sought to assess whether they have adopted viability strategies. The results show that Artificial Intelligence (AI) is still at an embryonic stage; a substantial share of the sample reports lacking, within the purchasing team, the skills needed to use digital technologies and forecasting tools. Suppliers are also selected based on environmental sustainability criteria, and a large percentage of firms collaborate with them to reduce environmental impact. In terms of visibility, most companies have visibility only at the first tier of supply; only a small share reaches the second tier or beyond. Firms tend to invest first in immediately impactful tools—such as technologies that optimize routes and reduce empty miles while lagging in the integration of advanced AI platforms.

Table 1.1: *Use of Et Al. in APA Style*

Number of Authors	First Text Citation	Subsequent text
One or two	Palmer & Roy, 2008	Palmer & Roy, 2008

Three, four, or five	Sharp, Aarons, Wittenberg, & Gittens, 2007	Sharp et al., 2007
Six or more	Mendelsohn et al., 2010	Mendelsohn et al., 2010

The term supply chain, coined in the 1980s, has undergone continual revision in response to social, organizational, and operational changes in the marketplace. Alongside this, technological evolution has provided firms with new tools that make information and its coordination more reliable and faster. As a result, the world of supply chain management (SCM) has shifted into a "new" paradigm characterized by digitalization, service orientation, sustainability orientation, and changing customer behaviors and expectations. The internet, the Internet of Things (IoT), data analytics, social media, and social data are transforming processes, systems, and mindsets (Nikitenko, 2019) as well as ways of working (Abdelli & Abid, 2025). Digitalization and additive manufacturing enable a transformation from physical flows to digital flows (Holmström et al., 2019). Service orientation and customization lead to greater customer centricity (Qi et al., 2020). Sustainability heightens perceived responsibility on the economic, environmental, and social dimensions (Purvis et al., 2019). Generation Z exhibits new purchasing behaviors and expectations (Dimock, 2019). All of this creates opportunities and challenges, further amplified by supply chain (SC) disruptions and volatile business environments.

Global, complex, and dynamic industrial supply chains were first addressed by Forrester (1968), while SCM was introduced in the early 1980s (Oliver & Webber, 1982). Houlihan's (1985) work, which predates modern SCM, integrates multiple organizational areas to improve the flow of goods from supplier to end customer across production and distribution chains. Among the early definitions, SCM is the management of the flow within a distribution channel from supplier to end customer (Cooper & Ellram, 1993); the management of processes to provide "horizontal" value to customers (Monczka & Morgan, 1997); and the coordination of business functions and tactics to improve the long-term performance of individual firms and the entire SC (Mentzer et al., 2001). The definition now widely accepted comes from APICS Foundations, which describes SCM as "the design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging worldwide logistics, synchronizing supply with demand, and measuring performance globally" (Cox & Blackstone, 2002).

At the outset, Houlihan (1988) argued that changes in the economic and competitive environment required a new approach to logistics. In light of the dramatic shifts of the past four decades, we must therefore ask whether current SCM concepts and practices are still adequate to address present and future challenges. To provide an evolutionary perspective, we first explored the main constructs of change and subsequently conducted an in-depth empirical analysis to understand how the business fabric is keeping pace with—and adapting to—what has been presented in the scientific literature.

This paper aims to answer how far companies are applying a strategy that meets the needs of today's markets. The research question is intentionally broad to allow wide exploration. In an initial scoping and in light of industrial practice, we found that current SCM practices primarily engage with four constructs—digitalization and automation, the human factor, sustainability, and end-to-end (E2E) visibility—that firms must master to compete in the future. The study focuses on these key elements, offering guidance for both researchers and managers. The structure that follows, after a review of past and future developments in SCM, presents the research methodology developed through a survey of the large-scale retail sector.

2. Evolution of Supply Chains

In the face of changing market conditions, the literature has progressively developed and proposed new terms to capture the key characteristics that a company—or a network of companies—should exhibit to remain competitive. With the application of Toyota's production model and Ohno's (1988) definition of waste, the 1990s saw the rise of supply chains designed to eliminate waste and reduce or remove all non–value-adding activities. Toyota assumed a leadership role in the global automotive industry by translating the traditional production organization into lean manufacturing. The goals of the Toyota Production System (TPS), beyond waste elimination, included building processes based on actual customer demand. This required training and developing all employees, adopting the perspective of a supply chain driven by real customer demand, creating a self-learning organization, and introducing and implementing standardized processes. Thanks to this approach, Toyota was able to manufacture products with fewer defects, shorter lead times, fewer suppliers, lower inventory levels, and reduced capital investment. The term "lean" dates back to 1988, when John Krafcik published "The Triumph of the Lean Production System" in Sloan Management Review. Womack and Jones (1996) define the lean approach as the systematic analysis and elimination of redundant activities in work processes, as well as sources of loss, with the aim of positively influencing quality, cost, and time. According to these authors, lean enables organizations to

do more with ever fewer resources—that is, with less labor, fewer machines, less space, and less time. NIST (2000) defines lean as "a systematic approach to identifying and eliminating waste through continuous improvement, flowing the product at the pull of the customer in pursuit of perfection."

The concept of leanness then gave way to a new attribute: the supply chain needed to be ready to respond quickly to market changes. Christopher and other scholars discuss the agile supply chain as a system capable of reconfiguring itself to respond to demand variation and customer-driven customization. If "lean" is associated with efficiency, stability, and waste reduction, agility represents flexibility, speed, and adaptation to variability. The origins of agility as a business concept lie in flexible manufacturing systems. Initially, it was believed that the path to manufacturing flexibility ran through automation to enable rapid changes (i.e., reduced setup times) and thus greater responsiveness to shifts in product mix or volumes. This idea of manufacturing flexibility was later extended to the broader organizational context (Nagel & Dove, 1991), and agility emerged as an organizational orientation. Some authors began combining the two terms, thereby defining a new strategy that joined the hallmarks of leanness—minimal inventories and just-in-time (Womack et al., 1990)—with the hallmarks of agility: leagility. Leagility—the synergistic integration of lean and agile principles—was conceived and conceptualized for supply chains, with the goal of combining upstream efficiency and downstream responsiveness through the strategic use of the decoupling point and postponement. Theoretical evidence and classic models show that leagility is applicable and desirable in contexts characterized by high demand volatility, short product life cycles, and the need for variety/customization, while keeping costs and inventories under control. The original contribution by Naylor, Naim, and Berry (1999) demonstrates that lean and agile are not alternative paradigms but complementary ones, proposing integration along the entire supply chain. Subsequently, the work of Christopher & Towill (2001) formalized integrated models for hybrid supply chain design, providing a methodological basis for the lean–agile combination. Later literature (e.g., Mason-Jones, Naylor & Towill, 2000) consolidated the link between leagility and structural network choices.

The new millennium began with a series of disruptive events that underscored the limits of overly lean supply chains. The attacks of September 11, 2001, natural disasters (Fukushima) in 2011, and the 2008 financial crisis brought resilience to the forefront as the ability to absorb a shock. Christopher & Peck (2004) define resilience as "the ability of a system to return to its original state or move to a new, more desirable state after being disturbed"—in

other words, a system's capacity to absorb, adapt, and recover from disruptions while maintaining supply chain performance. A supply chain disruption can be defined as an internal or external event that alters the normal or planned flow of goods and services within a supply chain. Literature reviews on supply chain disruptions and supply chain risk management can be found in Tang (2006), Snyder et al. (2006), Vakharia and Yeniparzarli (2008), Natarajarathinam et al. (2009), Schmitt and Tomlin (2012), and Snyder et al. (2016). Supply chain disruptions can take many different forms, including production difficulties or operational risks (Xia et al., 2004), wholesale price changes due to cost fluctuations (Xiao & Qi, 2008), supply shortages (Xiao & Yu, 2006), and sudden demand drops tied to market conditions (Xiao et al., 2005). Much of the academic literature on supply chain disruptions focuses on understanding and modeling strategies firms can adopt to mitigate a disruption, such as holding safety stock (Song & Zipkin, 1996; Tomlin, 2006), sourcing from alternative suppliers (Tomlin, 2006; Song & Zipkin, 2009; Babich et al., 2007; Hopp et al., 2009), rescheduling production (Bean et al., 1991; Adhyitya et al., 2007), redesigning transportation routes (MacKenzie et al., 2012), or producing in an alternative facility (MacKenzie et al., 2014).

A firm may attempt to build a supply chain that is resilient to disruptions (Sheffi, 2005) by reconfiguring its resources or improving its infrastructure (Ambulkar et al., 2014). Resilience becomes central to confronting an increasingly unpredictable world, but it may be insufficient when faced with changes that are not temporary but structural. Hence a new term—coined by Nassim Nicholas Taleb (2012)—is adopted: antifragility. Something is defined as antifragile if it not only resists shocks but improves because of them. While resilience aims to return a system "to the way it was," antifragility describes systems that grow and strengthen through uncertainty, disorder, and stress. In other words, survival is not enough; the shock should be viewed as an opportunity to improve. Business applications include supply chains that experiment, learn from mistakes, and adopt emerging technologies during crises. Antifragility introduces the idea of continuous learning from disruptions (Nikookar et al., 2021).

The surge of new technologies and the availability of real-time data have expanded the potential of modern supply chains, making them more collaborative and transparent. This gives rise to a new model found in both the literature and practice: the adaptive supply chain—a model that emphasizes not only the ability to react but to adapt in real time through the use of digital technologies (AI, advanced analytics, digital twins, blockchain). According to Ivanov

(2025), the adaptive supply chain is a network that blends resilience, agility, and sustainability, embedding them within a digital, dynamic system capable of continuous reconfiguration. It is not about returning to "normal" after a crisis; rather, it is about operating in a state of permanent adaptation, able to harness the potential of data and emerging technologies.

The fundamental features of an adaptive supply chain include:

- End-to-end visibility, enabled by sensors, IoT, and blockchain;
- Predictiveness, via machine learning algorithms and digital twins that simulate future scenarios;
- Rapid reconfigurability, with the ability to redesign suppliers, logistics routes, and production capacity in short order;
- Digital collaboration among partners and ecosystem actors;
- Integration with ESG and sustainability criteria, steering decisions not only on cost and speed but also on environmental impact.

Reaching the most recent period—marked by conflicts and the need to find new routes in intercontinental traffic, along with abrupt changes in tax regimes—Ivanov & Dolgui (2020) revive a term already used by Stafford Beer in 1972: viability. Thus are defined those supply chains that maintain their vitality and operational capability over the long term, even in turbulent environments. Viability is not merely survival but dynamic adaptation to preserve the vital functions of the network. Omega—The International Journal of Management Science describes the Viable Supply Chain (VSC) as a system that combines efficiency, resilience, and sustainability, ensuring long-term survival and vitality (Ivanov, 2020).

3. Research

The aim of the study—conducted on a sample of companies in the fast-moving consumer goods (FMCG) sector—was to measure whether the various actors are viable or whether adaptation to new market conditions is still lacking. The sector's turnover of approximately €135 billion clearly shows that it represents a significant share of Italian household consumption. The value generated along the business chain amounts to 4.2% of Italy's 2023 GDP. The FMCG market is about €98.2 billion in 2024 (+1.9% vs 2023), reaching an omnichannel value of €135.1 billion in 2024 (+1.8% vs 2023). The value chain supports roughly 1 million total jobs (of which ~739,000 are in related industries); the food & beverage segment includes ~60,000 firms; cosmetics about ~500 firms; and home care/detergents ~112–116 firms.

- Building on Ivanov's concepts of the adaptive viable supply chain and, subsequently, the viable supply chain, the questionnaire was designed to assess the state of development of:
- End-to-end visibility, extending beyond first-tier suppliers and customers to include second- and third-tier levels;
- Predictiveness, through software use or resorting to artificial intelligence to improve market forecasting;
- Rapid reconfigurability, i.e., the ability to redesign suppliers, logistics routes, and production capacity in short order;
- Adoption of ESG and sustainability criteria, guiding decisions not only by cost and speed but also by environmental impact.

The questionnaire—comprising 60 questions—was divided across the three core corporate functions essential to supply chain management: purchasing, warehouse management, and distribution channels. Each function was examined with a view to interpreting clear signals of change in value-chain collaboration, Artificial Intelligence (AI) adoption, and human resources. Particular attention was devoted to the role of artificial intelligence in terms of investments made, planned, and main results of adoption.

Emails were sent to roughly 300 companies in the FMCG supply chain; using CAWI (Computer-Assisted Web Interviewing), responses were obtained from 245 managers representing 112 companies. To improve information quality and consistency, questions were addressed to the relevant functional manager. The survey was administered from June 2025 to July 2025. Of the companies participating, 43% operate in manufacturing/processing, 45% in distribution, and 12% in services. The table below reports the number of respondents by organizational position (Table 1).

Table 1: *Roles of the respondents*

Roles	NR	PERC
Supply Chain manager	62	26%
Logistics manager	60	25%
Operations manager	28	12%
Purchase Manager	14	6%
IT manager	14	6%
CEO	12	5%

Consultant	8	3%
Transport manager	5	2%
Technology manager	4	2%
Trade Marketing Manager	4	2%
R&D	3	1%
Owner	3	1%
Other	22	10%

4. Procurement

The impact of artificial intelligence on purchasing is believed to help reduce lead times and costs, even though the majority of companies (85.45%) stated that they do not use AI in this area. Only a marginal share (7.27%) reported benefits in line with expectations, while just 5.45% (made up exclusively of distribution and manufacturing companies) declared improvements above expectations. Among the companies that use AI, 10.91% are piloting AI applications to manage procurement, 18.18% are in the selection phase, 34.55% say they are evaluating the investment, and 36.36% state there are no plans at present. The low adoption rate is largely attributed to the fact that this strategy is not among corporate priorities (75.68%), while one third of the sample reports lacking internal skills to manage it (37.84%). A further 8.11% say implementation is too expensive, and only one respondent states it is not useful.

In 69.23% of cases, companies' objective is to develop and invest in technological solutions that support operators' work, making it simpler and error-proof; 13.46% declare a neutral stance, while about 17% do not consider this opportunity at all. With regard to sustainability—both environmental and social—a constantly evolving picture emerges. About 58% select suppliers also based on their commitment to sustainable practices, while 25% remain neutral and 17.3% disagree. This suggests growing attention to the topic, though not yet fully consolidated.

Another highly topical and relevant issue is supply chain visibility. With specific reference to supplier visibility, the vast majority (77.08%) have control over first-tier suppliers, while only 8.33% extend visibility to second-tier suppliers and beyond. The adoption of digital tools to trace information along the supply chain is widely distributed: one third (33.33%) state that they use them, another third (35.42%) are evaluating them, while 31.25% have no solution in place. 56.25% of companies require transparency from suppliers regarding the origin of raw materials and components, while 35.42% limit such requests to only a few suppliers, and only

8.33% do not request this information. Multi-tier supplier traceability as a risk management process is already integrated in 39.58% of cases, but a further 37.5% are evaluating it, indicating ongoing evolution.

In summary:

- AI is not yet a tool used in procurement.
- Technologies are implemented to support operators' work.
- Suppliers are selected also in relation to their commitment to environmental and social sustainability.
- Supply chain visibility is largely limited to first-tier suppliers.

5. Warehouse

Overall, the responses depict a transition phase in corporate warehousing, marked by a wide gap between interest in new technologies and their actual implementation. Artificial Intelligence, although perceived as an opportunity, is still scarcely adopted: over 90% of companies state that they do not use it, and only marginal shares report concrete efficiency improvements. AI has not been adopted to optimize storage and picking activities: 38.18% state they have no plans, while 54.55% are evaluating the investment. Only a small percentage (7.28%) have already launched experimental initiatives and report being in an exploratory phase.

Regarding the adoption of AI systems to automate stock management and reduce inventory errors, companies confirm a cautious approach: 41.82% do not foresee implementation, 49.09% are evaluating it, and only 9.09% have launched concrete projects.

As for the overall level of warehouse automation, 37.74% have introduced no automation, while 30.19% report partial automation and 28.30% automation across entire functional areas; only 3.77% have reached full automation. These figures can be interpreted as still limited maturity. Investments in automated solutions are aimed at simplifying and making operators' work error-proof. In this respect, about 80% expressed full agreement with the statement (43.40% strongly agree and 37.74% somewhat agree). The main obstacles remain economic and strategic: investment costs (41.51%) and uncertainty about return on investment (22.64%) restrain further implementation.

In summary:

- Artificial Intelligence, although perceived as an opportunity, is not implemented.

- Regarding AI systems to automate stock management and reduce inventory errors, companies take a cautious approach.
- One third of the interviewed companies have not introduced any warehouse automation.
- Investments in technological solutions aim to make operators' work error-proof.
- The main obstacles remain investment costs and uncertainty about returns.

6. Distribution

AI is not used to improve the ability to maintain customer relationships: 67.80% do not use it; 15.25% recognize a tangible improvement (with results in line with or below expectations), and only 1.69% believe that AI delivered results above expectations. Overall, the data confirm that the sector is still in an experimental phase.

On the readiness to manage data—crucial to unlock AI's potential—a mid-level picture emerges: although with different degrees of development, about 58% report being ready on this topic or in preparation, while the remaining 42% have not yet pursued this path with conviction. This indicates that data centrality and the implementation of data lakes are perceived as relevant goals, but not yet consolidated.

Looking at areas of AI investment, 42.37% of companies report having no active projects, while among those investing, forecasting is predominant (33.90%). Initiatives in merchandising (1.69%), inventory (6.78%), sales dynamics analysis (6.78%), and procurement (8.47%) remain marginal. The focus on forecasting confirms the intention to strengthen predictive capabilities.

Internal skills are recognized as decisive for properly integrating customers into the digital supply chain processes. 70.69% strongly agree and 27.59% somewhat agree, indicating near-unanimous consensus on the importance of human capital in this transformation. Similarly, continuous training on AI tools, data management, and process improvement is seen as a key factor in developing effective omnichannel solutions: 46.55% strongly agree and another 46.55% somewhat agree. Only a marginal minority expresses neutral or opposing views.

As for the adequacy of existing skills, the assessment is less clear-cut: 48.28% consider them fairly adequate and 10.34% very adequate, but 20.69% remain neutral and over 20% highlight shortcomings, pointing to a significant gap to be addressed.

Regarding colleagues' overall perception of AI, half of respondents (50.00%) believe it helps daily work but has only a marginal impact on the business, while 37.93% see

it as a lever to increase efficiency and competitiveness, potentially with staff reductions. Only 8.62% fear job replacement and 3.45% do not recognize its usefulness.

In summary:

- Overall, the analysis shows an ecosystem in transition toward a more mature use of AI and digital technologies.
- Continuous training is recognized as an essential condition, although a perceived gap remains in the quality of existing skills.
- Data and the implementation of data lakes are perceived as relevant goals, but not yet consolidated.
- Internal skills are recognized as decisive for properly integrating customers into digital supply chain processes.

7. Conclusions

The research conducted on 112 companies in Italy operating in the FMCG sector—from manufacturing to retail, including logistics services—highlights that the conditions proposed by Ivanov for building viable supply chains are not met.

In particular, the companies that participated in the survey confirmed:

- Limited end-to-end visibility. Visibility beyond first-tier suppliers (i.e., to second-tier suppliers or further upstream) is confined to only a few cases. A similar situation emerges downstream toward the market: companies generally have visibility over first-tier customers, while only a limited number report broader visibility.
- Artificial intelligence is known, but rarely used. Very few companies are actually using AI, either for inventory control or for predictive analytics.
- Greater maturity on sustainability. The number of companies seeking to develop supply chains in which all actors comply with environmental and social sustainability practices is relatively high among respondents.

The research also highlighted that the development of strategies aimed at greater process automation and digitalization is intended to make operations safer and to reduce the likelihood of errors. High investment costs and uncertainty about the payback period are among the main barriers to further process automation.

The main contribution is twofold: (i) an evolutionary framework linking historical paradigms to viability as a system property; (ii) original evidence on the state of adoption in Italian FMCG, useful for calibrating transformation agendas. The study nonetheless has

limitations: sectoral scope (Italian FMCG), cross-sectional and self-report design (CAWI), absence of longitudinal objective KPIs, and lack of standardized multi-tier measures.

In short, the Italian FMCG sector appears aware but not yet mature relative to the requirements of a fully viable supply chain. Closing the gaps in visibility, predictiveness, reconfigurability, and ESG integration is the condition for moving from local efficiency to the systemic vitality demanded by complex, uncertain environments.

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