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AGILE SUPPLY CHAIN MANAGEMENT THEORIES, EMPIRICAL DATA, AND FUTURE DIRECTIONS

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ABSTRACT

Aim/Purpose	This is a literature review that defines agile supply chain management (ASCM), discusses several competing theories (particularly ones with some empirical evidence), their research limitations (e.g., cultural and industry homogeneity), and future directions for research that would add to the field's body of knowledge.
Background	Agile supply chain management (ASCM) is a relatively recent phenomenon, with most academic articles published between 2001 and the present. However, the ASCM literature is quite fragmented, with no dominant theory. Both the ASCM literature and private industry would benefit from a heterogenous (i.e., multi-site, multi-industry) empirical study in the U.S. In this context, several forward-looking topics are considered as business "problems of practice", including: 1) elaborating on existing agile supply chain rating instruments; and 2) generating empirical data from industry to support Zhu et al.'s (2022) EDGE supply chain framework. The challenges for supply chain managers are ones of assessing the agility of their firm's supply chain and deciding on a theoretically based action plan for making targeted improvements.
Methodology	The literature review was limited to refereed journals (i.e., does not include popular business journals, unpublished dissertations, etc.), yielding approximately 30 topic-relevant papers. The three-step review methodology (i.e., comprehensive material search, descriptive analysis and classification, theoretical and content analysis) attempts to replicate that of Shashi et al. (2020).
Contribution	This paper defines ASCM and examines some of its key theoretical paradigms, including Christopher's (2000) three-dimensional model for achieving agility, Lee's (2004) Triple-A framework, and Lin et al.'s (2006) "route to agility" drivers-capabilities-goals model. It then discusses empirical support for the respective theories as well as some of their research limitations (e.g., cultural and industry homogeneity). Finally, it reviews some of the germane tools developed to assess the appropriateness of an agile approach in industry. This effort

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	groups the literature into major theories with empirical support, identifies existing instruments to gauge an organization's level of agile supply chain, and proposes several potential lines of research that would help the practitioner assess and improve the agility of the supply chain.
Findings	In this context, several forward-looking topics are considered as business "problems of practice", including: 1) elaborating on existing agile supply chain rating instruments; and 2) generating empirical data from industry to support Zhu et al.'s (2022) EDGE supply chain framework.
Recommendations for Practitioners	The challenges for supply chain managers are ones of assessing the agility of the firm's supply chain and deciding on a theoretically based action plan for making targeted improvements.
Recommendations for Researchers	Here are some possibilities going forward: • Replicate the Balaji et al. (2015) TADS study with a more culturally and industrially diverse sample. In terms of theory, the TADS instrument has a link to Lin et al.'s (2006) notion of the SC agility index. The original pilot study used a small Indian steel industry sample. For example, a sample of 10 to 25 U.S.-based Institute of Supply Management (ISM) member companies might be used. Another variation from the original study might be varying the intervention intended to improve the firm's SC agility. • Operationalize the Hofman and Cecere (2005) proposed portfolio of agile SC metrics based on dimensions of speed, predictability, ease, and quality. In all likelihood, this would be a series of studies that would include development of scale items, questionnaire administration to an appropriate sample, and a factor analysis to evaluate item conceptual loadings. Here, the factor analysis ostensibly would be part of advancing the inherent theory. The next step would be an instrument reliability and validity study. • Conduct a correlational study to examine further the relationship between the agile SC and customer satisfaction. Such a study has its roots in the previous work of Jawahar et al. (2020), Kisperska-Moron and Swierczek (2009), and Power et al. (2001). • Advance Zhu et al.'s (2022) EDGE (i.e., enablers, suppliers, goals, and expertise) supply chain framework by doing a correlational study of firms whose agile SCs are blockchain and Internet of Things (IoT) capable. The authors themselves suggest this approach as no empirical data yet exists to support the EDGE model. • Similarly, conduct an empirical study to provide support to the Bamakan et al. (2021) six-layer evaluation system of service supply chain performance that is based on a blockchain-IoT-big data framework.
Impact on Society	Despite the diverse theoretical perspectives, there are tools available for supply chain managers to assess their firm's supply chain agility.
Future Research	This author recommends taking the direction suggested by Zhu et al. (2022), one of examining firms whose supply chains are blockchain and IoT capable. This approach would provide some empirical support to the EDGE supply chain framework.
Keywords	adaptability, agile supply chain management (ASCM), agility, alignment, leagile, lean, supply chain

INTRODUCTION

Over the past fifteen years, organizations have strived to improve their supply chains to get products and services to their customers more quickly, cheaply, and reliably; this is the notion of the ***agile supply chain*** (Lee, 2004). Companies such as Amazon, Procter & Gamble, Intel, Unilever, Dell, and Walmart have gained significant advantage by building more agility and heterogeneity into their supply chains (Berger, 2022; Brin, 2013; Lee, 2004). The 2011 Japanese tsunami and the more recent COVID-19 pandemic are examples of world-impacting events where businesses with more agile supply chains suffered fewer bottlenecks than did their competitors (Brin, 2013; Deconinck et al., 2020). Not surprisingly, a recent survey of 1,300 supply chain professionals indicated that 89% of them wanted to invest in supply chain agility within the next two years (Gartner, 2021). Given the heightened importance of agile supply chain management (ASCM) to firms, there has been renewed interest in both underlying ASCM theoretical frameworks and empirical support for them. Supply chain managers are motivated by questions such as "Which theory will help me increase my supply chain's agility?" and "Which tool will enable me to assess the agility of my supply chain?"

This literature review defines ASCM, considers some of its key theoretical frameworks, and discusses some of the germane tools used to assess the appropriateness of an agile approach as compared to lean or leagile (i.e., a hybrid combination based on a firm's needs). It addresses existing empirical support for the theories as well as some of the research limitations (e.g., cultural and industry homogeneity). Conclusions focus on future applications of ASCM for industry as well as potential research directions.

METHODOLOGY

Selection and classification of the respective articles is based on graduate-level literature review standards (Locke et al., 2010; Machi & McEvoy, 2016). The review was limited to refereed journals (i.e., does not include popular business journals, unpublished dissertations, etc.), yielding approximately 36 topic-relevant papers. The three-step review methodology (i.e., comprehensive material search, descriptive analysis and classification, theoretical and content analysis) attempts to replicate that of Shashi et al. (2020), albeit on a smaller scale. Several additional non-refereed articles were used to supply facts or interpret some of the primary sources. Appendix A summarizes the list of articles by study type (i.e., empirical study, mixed-methods, theoretical, etc.). For research studies, Appendix B provides a breakdown by culture or target population.

BIASES AND LIMITATIONS

Most theoretical and research articles on ASCM have been published between 1999 and 2021. There is an emerging subgenre in the ASCM literature related to the COVID-19 pandemic, with germane articles starting to be published in early 2021. These articles were intentionally excluded from the review because we do not yet have enough perspective to incorporate them into the mainstream ASCM literature.

Similarly, there has been a convergence of lean, agile and hybrid leagile theoretical work in the ASCM literature. Here, a few critical articles were included, primarily as a foundation for discussing ASCM. Unlike the Shashi et al. (2020) article, which was intended to be a comprehensive ASCM literature review, this is a more cursory effort, with the intent of identifying avenues of future research.

CRITICAL SUMMARY OF THE ASCM FIELD

Much of the ASCM empirical research can be traced to a few theoretical hubs, most prominently the work of Christopher (Christopher, 2000; Christopher et al., 2006), of Lee (2004), and of Lin (Lin et al., 2006; Zhu et al., 2022). Many of these academic endeavors have pragmatic applications, with a focus on improving agile supply chains in industry. For example, there is a group of empirical studies

focused on identifying the characteristics of agile supply chains with the goal of improving agility. However, the field is by no means unified, having both vestigial branches and standalone efforts devoted to agile SC assessment tools (Rahiminezhad Galankashi & Helmi, 2016). Empirical studies vary both in quality and generalizability to industry. This review is organized along lines of ASCM theory, measurement tools, and empirical work, although there is overlap between the three.

Definition of Agile Supply Chain Management

Agility is a firm's ability to respond swiftly to changes in the supply chain environment with appropriate business strategies, partnerships, systems, and operational skills (Balaji et al., 2015; Kant et al., 2016). The agile organization typically is characterized by the flexibility in its supply chain, as manifested in flexible manufacturing systems (Christopher, 2000; Christopher et al., 2006). Moreover, agility permeates the firm through its capabilities, information systems, logistical processes, partnerships, and mindsets (Christopher, 2000; Christopher et al., 2006; Kant et al., 2016). In his Triple-A supply chain framework, Lee (2004) asserted that successful supply chains are not only agile, but also adaptable and with partner interests aligned throughout the chain. Hofman and Cecere (2005) opined that firms should assess their supply chain agility using metrics tuned to components of speed, reliability, ease, and quality.

ASCM Theories

The ASCM literature is by no means unified. Table 1 summarizes some of the key theoretical articles. General ASCM foundational theories include Christopher's (2000) multidimensional model, Lee's (2004) Triple-A framework, and Lin et al.'s (2006) drivers-capabilities-goals model, which are discussed in more detail below. In a subgenre, Gunasekaran and colleagues (Gunasekaran, 1999; Gunasekaran et al., 2019) have advanced an agile manufacturing model, which will not be discussed further here. Bamakan et al. (2021) utilized a blockchain-Internet of Things (IoT)-big data framework to develop their six-layer evaluation system of service supply chain performance. However, intriguing this model is, there is little yet in the way of subsequent empirical data to support it.

Table 1: Brief Summary of Key ASCM Theoretical Articles

THEORETICAL ARTICLE	MAIN CONTRIBUTION
Bamakan et al. (2021)	Proposed an adaptive six-layer, network-based fuzzy inference systems (ANFIS) framework that highlights the importance of blockchain and artificial intelligence (AI) in assessing service supply chain (SSC) performance.
Christopher (2000); Christopher et al. (2006)	A multidimensional model which portrays supply chain strategies along lean, agile, and "leagile" (i.e., hybrid) dimensions.
Rahiminezhad Galankashi and Helmi (2016)	Expanded on the notion of leagile supply chains, culminating in an operational leagile framework and a proposed assessment tool.
Gunasekaran (1999); Gunasekaran et al. (2019)	Identified five core competencies of agile manufacturing: transparent customization, agile supply chains, intelligent automation, total employee empowerment, and technology integration.
Hofman and Cecere (2005)	A supply chain agility model with component metrics of speed, reliability, ease, and quality.
Kant et al. (2016)	Performed a comparative analysis of lean, agile, and leagile constructs, building on the work of Christopher (2000) and colleagues.

THEORETICAL ARTICLE	MAIN CONTRIBUTION
Kumar et al. (2019)	Comparative analysis of 17 agile manufacturing articles, culminating in an agile manufacturing framework with seven factors (or issues): HR-related, organizational culture, supplier-related, customer-related, innovation, concurrent engineering, and information technology.
Lee (2004)	Chronicled the Triple-A framework, whereby the supply chain performance stems from success at agility, adaptability, and alignment components.
Lin et al. (2006)	A drivers-capabilities-goals model that described a supply chain's route to agility and used fuzzy logic to evaluate the model.
Shashi et al. (2020)	This is a comprehensive ASCM literature review that put the theories in context and suggested future directions for researchers.
Zhu et al. (2022)	Described agile dimensions (i.e., flexibility, speed, learn, innovation, and people and proposed an EDGE (i.e., enablers, suppliers, goals, and expertise) supply chain framework that they applied to blockchain and Internet of Things (IoT).

Note. Sources: Bamakan et al. (2021); Christopher (2000); Rahiminezhad Galankashi and Helmi (2016); Gunasekaran (1999); Gunasekaran et al. (2019); Hofman and Cecere (2005); Kant et al. (2016); Kumar et al. (2019); Lee (2004); Lin et al. (2006); Shashi et al. (2020); and Zhu et al. (2022).

Christopher's (2000) Multidimensional Model

As shown in Figure 1, in Christopher's (2000) multidimensional model there are several characteristics of the agile supply chain. It must: 1) Be *market sensitive*, or capable of responding to real demand; 2) Be *virtual*, or capable of utilizing information technology to share data between supply chain partners; 3) Have *process integration*, or a collaborative working relationship between SC partners that includes a data sharing, common IT systems, and joint product development; and 4) Be *network based*, or an integrated group of partners with shared goals and processes, rather than standalone entities (Christopher, 2000).

The model did not view agility in isolation as a supply chain strategy. Rather, it presented a taxonomy scheme using replenishment lead times and demand variability to triage the appropriate pipeline strategy for the supply chain. Figure 2 summarizes the model.

According to Christopher et al. (2006), the preferred SC pipeline strategy may be agile, lean, or leagile. Based on the supply and demand combinations shown in Figure 2, the model identified ideal pipeline selection strategies for a firm as:

- Short lead time + Predictable demand = Lean continuous replenishment
- Short lead time + Unpredictable demand = Agile quick response
- Long lead time + Predictable demand = Lean, planning and execution
- Long lead time + Unpredictable demand = Leagile production, logistics postponement

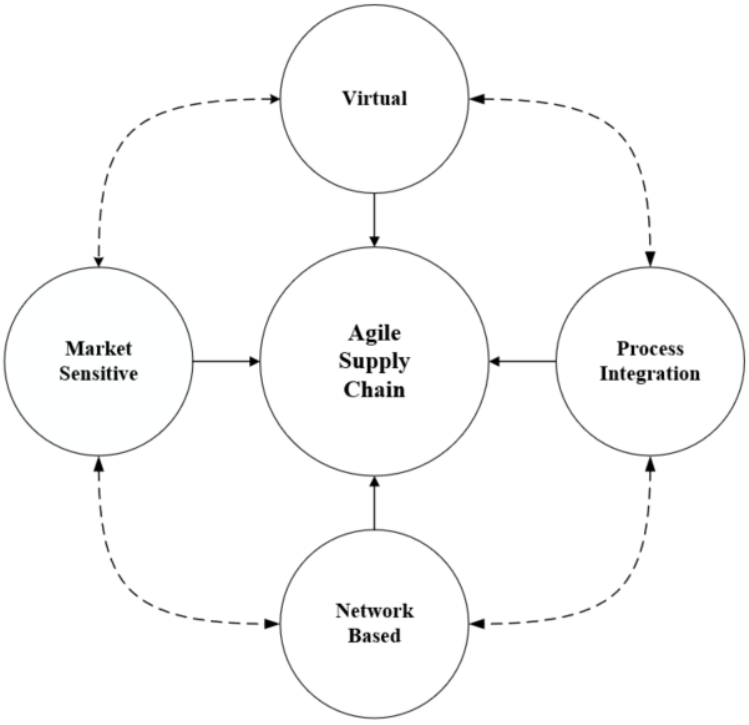

Figure 1: Characteristics of the Multidimensional Agile Supply Chain
Note. Figure adapted from Christopher (2000).

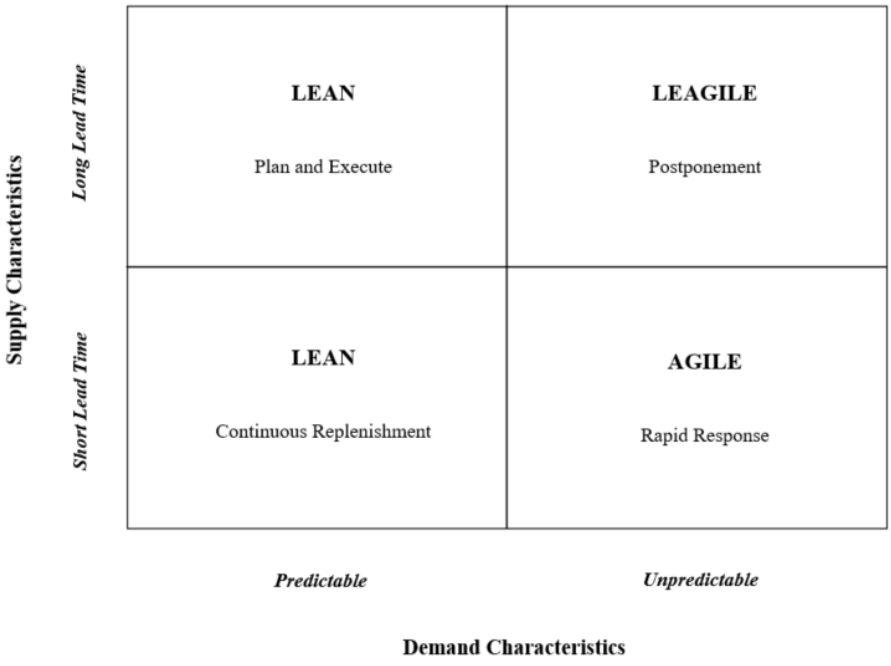

Figure 2: Supply Chain Pipeline as a Function of Supply and Demand
Note. Figure adapted from Christopher et al. (2006).

The authors suggested that firms use this model of lead time and demand variability measures to build their supply chain strategies. They acknowledged that additional empirical support was needed to substantiate the model's validity as well as its utility for triaging supply chain strategies in the workplace.

Lee's (2004) Triple-A Framework and Derivatives

In Lee's (2004) Triple-A framework, for a firm to reach a sustainable competitive advantage through its supply chain, it must achieve progress along multiple dimensions: 1) *Agility*, or the ability to deliver products at the same cost, quality, and service level despite supply and demand volatility; 2) *Adaptability* over time to markets and evolving company strategies; and 3) *Alignment* of the interests of all partners in the chain so that the respective firms optimize performance as their interests are aligned (de Boer, 2018; Lee, 2004). Supply chain competitive advantage emerges when the firm is competent in all three components – agility, adaptability, and alignment – and master of at least two (Lee, 2004).

Firms may promote agility within their Triple-A supply chains in the following ways (de Boer, 2018; Lee, 2004; Whitten et al., 2012):

- Share information between partners in common IT and logistics systems;
- Improve planning through use of "what-if" scenario analyses;
- Build inventory buffers by stockpiling inexpensive and interchangeable components;
- Design the supply chain with postponement in mind; and
- Devise contingency and crisis management plans for supplier-induced disruptions.

Whitten et al. (2012) elaborated on the Triple-A model, extending it to describe how the Triple-A supply chain is related to overall supply chain performance as well as a firm's marketing and financial performance. As shown in Figure 3, they reported data indicating that: 1) When properly implemented, the Balaji

Triple-A supply chain strategy positively impacts overall supply chain performance; 2) Supply chain performance is positively related to both marketing and to financial performance,

Similarly, in support of the Triple-A framework, Yang (2014) reported data showing that IT capability, informational sharing, and operational collaboration between SC partners are all antecedent to a firm's supply chain agility, and that in turn agility is antecedent to both the chain's cost efficiency and its financial performance.

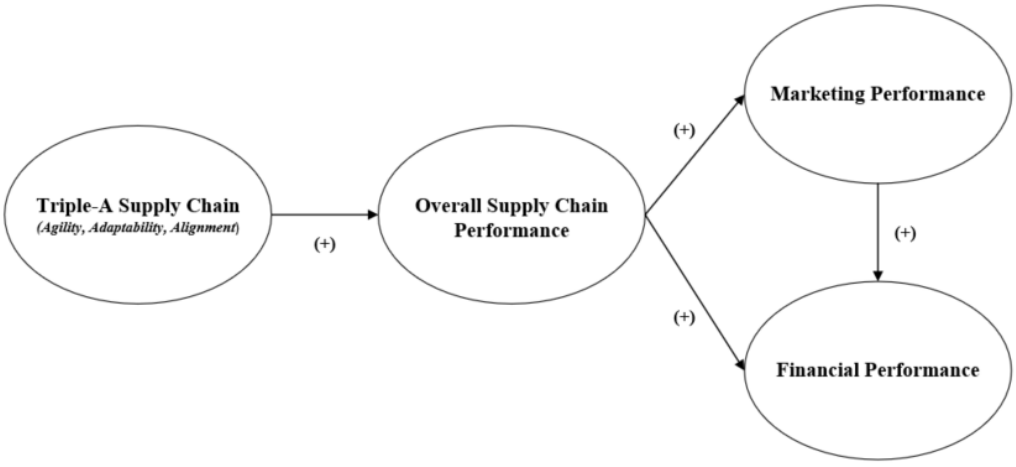

Figure 3: Triple-A Supply Chain Performance Model
Note. Figure adapted from Whitten et al. (2012).

Lin et al.'s (2006) Drivers-Capabilities-Goals Model and Derivatives

Another seminal work in ASCM theory was Lin et al.'s (2006) drivers-capabilities-goals model. As shown in Figure 4, in this framework a firm builds its agile supply chain with an ultimate goal of satisfying customers; this customer satisfaction paradigm is achieved through an agile SC that meets time, cost, functionality, and robustness objectives (Lin et al., 2006; Zhu et al., 2022). Such subgoals are met through emergence of agile drivers which serve as the building blocks of the agile chain, based on the firm's response to the business environment and which drive the chain's needed agility – its customer requirements, technology innovations, competitiveness in the market, and the ever-changing market itself (Lin et al., 2006; Zhu et al., 2022). If the supply chain responds successfully to the market, it develops capabilities (i.e., responsiveness, competency, flexibility, and speed) which give it a competitive advantage. These capabilities are maximized through specific enablers within the chain, such as the firm's partner relationships, its process and data integration abilities, and its marketing prowess (Lin et al., 2006; Zhu et al., 2022).

Zhu et al. (2022) elaborated on the Lin et al. (2006) framework with their own EDGE (i.e., enablers, drivers, goals, and expertise) model. In doing so, they expanded the definitions of the original model's goals, drivers, and enablers while relabeling capabilities as areas of expertise (Zhu et al., 2022). In doing so, they applied the refreshed language of their EDGE model to agile supply chains so that it could accommodate emerging technologies such as the Internet of Things (IoT) and blockchain.

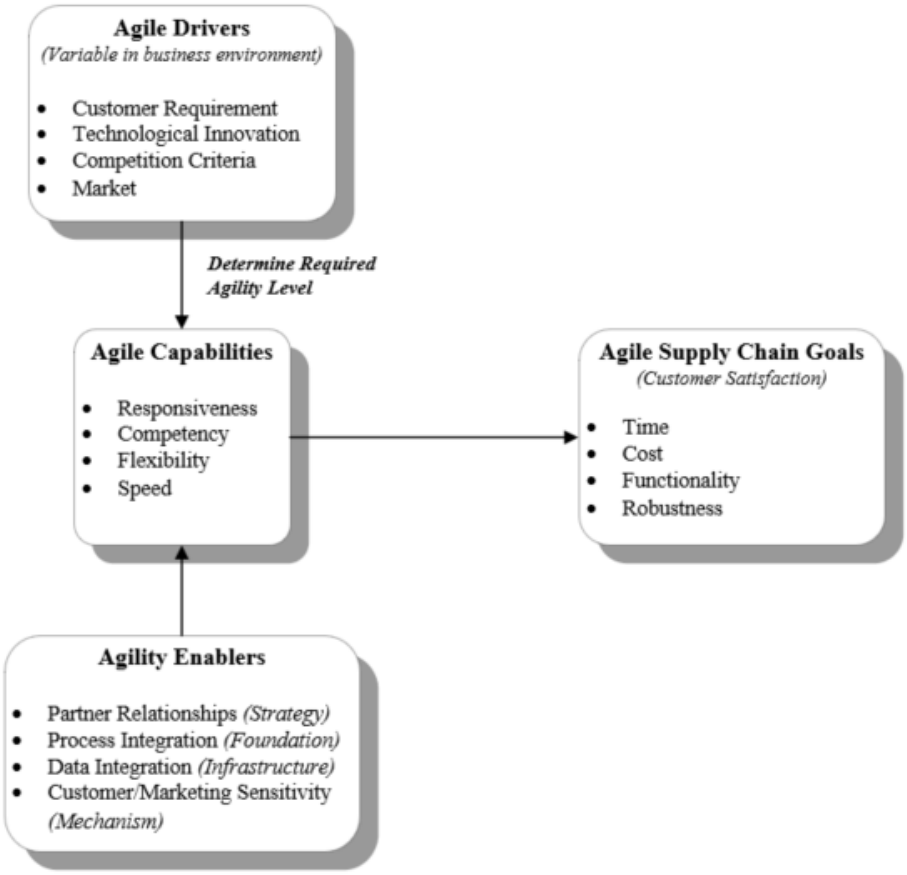

Figure 4: Lin et al.'s (2006) Drivers-Capabilities-Goals Model
Note. Adapted from Lin et al. (2006).

ASCM Theory: Summary

The prominent theoretical branches in the ASCM literature include:

- Lean/agile/leagile theory (e.g., Christopher, 2000), which views agility in the context of supply and demand, on lean's focus on cost efficiency, and on the pragmatism of hybrid SC designs;
- Triple-A theory (e.g., Lee, 2004), which views agility as one of several dimensions (along with adaptability and alignment) that impact overall supply chain performance;
- Drivers-capabilities-goals theory (e.g., Lin et al., 2006), where firms employ agility and its component competencies to meet the goal of customer satisfaction; and
- Agile manufacturing theory (e.g., Gunasekaran, 1999), which was acknowledged but not discussed in depth here.

Since being introduced, the respective theories have appeared consistently in literature reviews and comparative analyses, and occasionally served as focal points for empirical research. There certainly is no unifying framework, and investigators seem content to employ theory pragmatically as they search for ways to hone supply chain agility in industry. Table 2 compares the strengths of these theories as applied to industry.

Table 2: Applied Utility of Main ASCM Theoretical Branches

THEORY	RELATED ARTICLES	STRENGTHS & COMMENTS
Lean/agile/leagile multidimensional	Christopher (2000); Christopher et al. (2006)	• Cost efficiency and SC agility increased in an unpredictable demand environment (Gligor et al., 2015); • Leagile SC designs were better for some companies due to ease of implementation (Jawahar et al., 2020; Kawa & Maryniak, 2019)
Triple-A	Lee (2004); Whitten et al. (2012)	• Substantiated that the agile supply chain mediates overall SC performance (Qrunfleh & Tarafdar, 2013; Tarafdar & Qrunfleh, 2017)
Drivers-capabilities-goals	Lin et al. (2006); Zhu et al. (2022)	• Zhu et al. (2022) elaborated on the original theory and applied it to new technologies such as blockchain and Internet of Things (IoT)
Agile manufacturing	Gunasekaran (1999); Gunasekaran et al. (2019)	• Established the core competency model of agile manufacturing

Note. Sources: Christopher (2000); Christopher et al. (2006); Gligor et al. (2015); Gunasekaran (1999); Gunasekaran et al. (2019); Jawahar et al. (2020); Kawa and Maryniak, (2019); Lee (2004); Lin et al. (2006); Qrunfleh and Tarafdar (2013); Tarafdar and Qrunfleh (2017); Whitten et al. (2012); and Zhu et al. (2022).

EMPIRICAL RESEARCH

During the past two decades, ASCM empirical research has followed four main pathways – industry surveys, the development of SC agility assessment tools, operational decision-making research, and case studies.

INDUSTRY SURVEY STUDIES

Table 3 presents selected industry survey studies. The basic methodology for most of these studies is to have supply chain managers complete questionnaires and/or semi-structured interviews on topics germane to their firm's agile supply chain capabilities. In some cases, the main research questions aim to provide empirical support to previously discussed theoretical frameworks. For example, the Gligor et al. (2015) study extended the Christopher lean-agile-leagile work (Christopher, 2000; Christopher et al., 2006), providing data which indicated that cost efficiency and agility both increase in an unpredictable demand environment. In another homage to the Christopher work, some studies cited the difficulty of implementing agile supply chain designs and that hybrid "leagile" designs were a better or more pragmatic solution for some firms (Jawahar et al., 2020; Kawa & Maryniak, 2019).

The Qrunfleh and Tarafdar studies (Qrunfleh & Tarafdar, 2013; Tarafdar & Qrunfleh, 2017) contributed data suggesting that the agile supply chain mediates overall SC performance, providing support to the Whitten et al. (2012) extension of the Triple-A theory.

Not all of the survey studies have strong theoretical groundings yet do contribute to the ASCM body of knowledge. For example, several studies found positive associations between a firm's agile SC capabilities and its level of either customer satisfaction or customer orientation (Jawahar et al., 2020; Kisperska-Moron & Swierczek, 2009; Power et al., 2001). Geyi et al. (2020) reported a positive correlation between agile SC capabilities and the chain's sustainable practices.

Table 3: Summary of Key ASCM Survey Research Studies

STUDY	DESCRIPTION
Christopher et al. (2006)	In addition to a case study, they analyzed previously collected survey data on vendor responsiveness to product volume change and order mix data; used to refine the Christopher (2000) lean-agile-leagile model.
Geyi et al. (2020)	Survey study of 311 United Kingdom "higher carbon and energy intensive supply chains" indicated a positive correlation between sustainable practices and agile SC capabilities.
Gligor et al. (2015)	Survey data came from 283 U.S.-based SC managers. While Christopher et al. (2006) suggested that SC pipeline strategy should be based on demand level (i.e., predictable: lean; unpredictable: agile), this empirical work indicated that the strength between cost efficiency and agility increases in an unpredictable demand environment – that is, that the two are not mutually exclusive.
Jawahar et al. (2020)	In a survey of 100 Indian auto parts manufacturers, found that ASCM is positively associated with customer satisfaction. Respondents viewed a hybrid (i.e., leagile) approach as better, primarily for pragmatic reasons of implementation.
Kawa and Maryniak (2019)	In a survey of 71 large and medium Polish ecommerce firms, they found that cost efficiency supersedes the construction of agile logistics. Lean and agile tended to have blurred edges, and hybrid ecommerce SC designs dominate for pragmatic reasons.

STUDY	DESCRIPTION
Kisperska-Moron and Swierczek (2009)	Questionnaire data were collected from a heterogeneous (but self-selected) cross-section of 96 Polish firms. A factor analysis revealed that four factors were positively associated with a firm's agile SC capabilities – its customer relationships; its partner relationships; its competitor relationships; and its IT mastery.
Malakouti et al. (2017)	Survey research of 197 Malaysian SC managers revealed that entrepreneurial orientation (EO), supplier relations, resource management, just-in-time (JIT) methodology, and technology utilization (TU) were drivers of ASCM while participatory management style was not.
Power et al. (2001)	Surveyed a cross-section of 962 Australian manufacturing firms to identify factors crucial for agile supply chains. "More agile" firms were higher in customer focus, supplier involvement, and technology proficiency while "less agile" firms were more internally focused.
Qrunfleh and Tarafdar (2013); Tarafdar and Qrunfleh (2017)	Survey data from U.S.-based supply chain executives indicated a mediating effect of ASCM on SC performance. Supports Whitten et al. (2012) model of Triple-A strategy modulating overall SC performance.
Yang (2014)	Survey respondents came from 137 Shanghai manufacturing firms. Cost efficiency was found to mediate between SC agility and overall SC performance.

Note. Sources: Christopher et al. (2006); Geyi et al. (2020); Gligor et al. (2015); Malakouti et al. (2017); Power et al. (2001); Qrunfleh & Tarafdar (2013); Tarafdar & Qrunfleh (2017); and Yang (2014).

Measurement Tools: Assessing Supply Chain Agility in Industry

Another method within the ASCM empirical literature is that of measurement tools used to assess a firm's supply chain agility level. A common objective in such research is not only to gauge a firm's current level of SC agility, but also to measure improvement based on targeted interventions (Balaji et al., 2015; Ben Ruben et al., 2013). Table 4 encapsulates this small group of studies.

Balaji et al. (2015) reported that their Total Agile Design Systems (TADS) questionnaire was employed to assess the case study firm's supply chain baseline agility and also detected a post-intervention increase in agility of 20 to 25 percent. Ben Ruben et al. (2013) also used a case study to pilot an agility instrument, while Rahiminezhad Galankashi and Helmi (2016) employed the Delphi method to operationalize Christopher's (2000) leagile construct with their proposed leagile SC assessment tool. Finally, Hofman and Cecere (2005) proposed the use of a portfolio of agile SC metrics based on dimensions of speed, predictability, ease, and quality, which is included as it may have potential for future empirical work. This may be a vestigial effort, with no follow-up empirical work that could be discovered. One of the authors (Hofman) retired from Gartner in late 2020 while the other did not respond to inquiries.

Table 4: Summary of ASCM Assessment Tools

STUDY	DESCRIPTION
Balaji et al. (2015)	Introduced Total Agile Design Systems (TADS), an 11-factor questionnaire used to calculate the SC's agility index. Reported that TADS before/after scores in a small Indian steel industry sample showed specific interventions increased SC agility by 20 to 25 percent.
Ben Ruben et al. (2013)	Developed an 8-factor SC agility questionnaire based on a synthesis of previous researchers' efforts. Used a case study of an Indian auto parts manufacturer to opine that the instrument would be sensitive to interventions aimed at increasing SC agility.
Rahiminezhad Galankashi and Helmi (2016)	Operationalized an aspect of Christopher's (2000) framework with a leagile SC assessment tool.
Hofman and Cecere (2005)	Proposed the use of a portfolio of agile SC metrics based on dimensions of speed, predictability, ease, and quality.

Note. Sources: Balaji et al. (2015); Ben Ruben et al. (2013); Rahiminezhad Galankashi and Helmi (2016); Hofman and Cecere (2005).

Operational Decision-Making Studies

There is another group of germane studies that are focused on helping supply chain managers make decisions about their SC networks. These works are concerned with operational decision-making, although several investigators (Matawale et al., 2016; Pearson et al., 2010; Wu & Barnes, 2009) cite Christopher's (2000) article in defining the agile supply chain. Table 5 summarizes the research.

Several of these efforts studied the key factors that enable supply chains to be more agile (Navid & Ismaeli, 2012; Pandey & Garg, 2009; Pearson et al., 2010; Sangari & Razmi, 2015; Sangari et al., 2015). Two studies (Matawale et al., 2016; Wu & Barnes, 2009) were aimed at developing decision-making models for selecting agile supply chain suppliers. Sangari and Razmi (2015) found that supply chain business intelligence (BI) competence is a multidimensional construct stemming from technical, managerial, and cultural competence and that supply chain BI is an enabling factor of supply chain agility.

One characteristic of these studies is that they often used fuzzy logic (and other statistical methods) for analysis (Matawale et al., 2016; Navid & Ismaeli, 2012; Pandey & Garg, 2009; Pearson et al., 2010; Sangari et al., 2015). For example, researchers utilized the DEMATEL (i.e., decision making trial and evaluation laboratory) technique to study supply chain production planning (Navid & Ismaeli, 2012) and factors related to SC network agility (Sangari et al., 2015).

While this group of studies offers potential contributions to solving problems of practice for supply chain managers (e.g., identifying enablers of agile supply chains), a limitation is that they tend not to delve deeply into ASC theory.

Table 5: Summary of Studies Focused on Agile SC Network Decision-Making

STUDY	DESCRIPTION
Matawale et al. (2016)	Used vague sets to develop a decision-making tool for agile supply chain vendor selection. Employed a case study as an example.
Navid and Ismaeli (2012)	Surveyed agile supply chain decision makers and then used DEMATEL technique to identify the most important items in SC production planning.
Pandey and Garg (2009)	Utilized an interpretive structural modeling (ISM) to identify those variables associated with making a supply chain more agile.
Pearson et al. (2010)	Employed phase plane analysis to identify the characteristics of an ideal supply chain network; asserted that this methodology may be applied to target out of control processes (e.g., supplier unreliability) in the network. Employed three case studies to source data for analysis.
Sangari and Razmi (2015)	Reported that supply chain business intelligence (BI) competence is a multidimensional construct arising from technical, managerial, and cultural competence; also found that supply chain BI is an enabling factor of supply chain agility.
Sangari et al. (2015)	In a case study of an automotive company in Iran, used a hybrid evaluation method (i.e., fuzzy logic, DEMATEL, and analytic network process) to pinpoint factors critical to SC agility; goal was to identify enabling factors to improve network agility.
Wu and Barnes (2009)	In two simulations, had SC experts (i.e., Delphi groups) complete surveys; then used multiple statistical techniques to develop a decision-making model for selecting agile SC suppliers.

Note. Sources: Matawale et al. (2016); Navid and Ismaeli (2012); Pandey and Garg (2009); Pearson et al. (2010); Sangari et al. (2015); and Wu and Barnes (2009).

Case Studies

The Balaji et al. (2015) and the Ben Ruben et al. (2013) articles were case studies that the respective authors utilized to pilot their agile SC assessment tools. In their mixed-methods effort, Christopher et al. (2006) used case-based research as a prelude to using survey data to refine their taxonomy of supply chain strategy selection. Costantino et al. (2012) described a case study where they presented their model for optimizing an Italian manufacturer's agile supply chain, where they included issues such as site selection for distributors and retailers to enhance the firm's agility. Finally, several of the SC decision-making studies employed the case study approach to develop their models (Matawale et al., 2016; Pearson et al., 2010; Sangari et al., 2015).

While this group of studies is small, it demonstrates that the case study approach has utility in advancing the development of both agile supply chain theory and decision-making models.

Research Limitations

The body of ASCM empirical research contains several large survey studies that provide support for existing theories about agile supply chain design and occasionally advance the field with their individual insights (Christopher et al., 2006; Geyi et al., 2020; Gligor et al., 2015; Jawahar et al., 2020; Kawa & Maryniak, 2019; Kisperska-Moron & Swierczek, 2009; Malakouti et al., 2017; Power et al., 2001; Qrunfleh & Tarafdar, 2013; Tarafdar & Qrunfleh, 2017; Yang, 2014). Some of the studies suffer from either cultural or industry homogeneity (or both), which may limit the validity and generalizability of the reported results (e.g., Jawahar et al., 2020; Kawa & Maryniak, 2019; Kisperska-Moron & Swierczek, 2009).

The state of agile SC assessment tools is less evolved, with the described instruments either remaining in the formative stages (Hofman & Cecere, 2005; Rahiminezhad Galankashi & Helmi, 2016) or stemming from small pilot studies (Balaji et al., 2015; Ben Ruben et al., 2013). For the Balaji et al. (2015) and Ben Ruben et al. (2013) questionnaires to take hold in academia or industry, results need to be replicated with more culturally and industrially heterogeneous samples. Indeed, this may be a fertile avenue for subsequent research. Similarly, the Hofman and Cecere (2005) proposed portfolio of agile SC metrics would require further development to obtain an operationalized tool, followed by an instrument validity and reliability study.

As with the disparate ASCM theories, the empirical work is fractured in the sense that individual studies sometimes: 1) do not link well to theory; and 2) have research questions based on examining narrow problems in single industries. This does seem to be the case among the SC decision-making studies reviewed. Finally, the reader may note that some of the articles originate from somewhat obscure refereed journals. Appendices A and B provide some high-level demographics on the articles reviewed.

Future Directions

When conducting a literature review for future research, considerations include assessing the state of the field and identifying potentially fruitful avenues for original research (Machi & McEvoy, 2016). Another issue is how the topic in question lends itself to research. At this juncture, an ASCM-related topic would be appropriate if evaluated as a business problem of practice (i.e., and not a cause-effect experiment).

Given that context, here are some possibilities going forward:

- Replicate the Balaji et al. (2015) TADS study with a more culturally and industrially diverse sample. In terms of theory, the TADS instrument has a link to Lin et al.'s (2006) notion of the SC agility index. The original pilot study used a small Indian steel industry sample. For example, a sample of 10 to 25 U.S.-based Institute of Supply Management (ISM) member companies might be used. Another variation from the original study might be varying the intervention intended to improve the firm's SC agility.
- Operationalize the Hofman and Cecere (2005) proposed portfolio of agile SC metrics based on dimensions of speed, predictability, ease, and quality. In all likelihood, this would be a series of studies that would include development of scale items, questionnaire administration to an appropriate sample, and a factor analysis to evaluate item conceptual loadings. Here, the factor analysis ostensibly would be part of advancing the inherent theory. The next step would be an instrument reliability and validity study.
- Conduct a correlational study to examine further the relationship between the agile SC and customer satisfaction. Such a study has its roots in the previous work of Jawahar et al. (2020), Kisperska-Moron and Swierczek (2009), and Power et al. (2001).
- Advance Zhu et al.'s (2022) EDGE (i.e., enablers, suppliers, goals, and expertise) supply chain framework by doing a correlational study of firms whose agile SCs are blockchain

and IoT capable. The authors themselves suggest this approach as no empirical data yet exists to support the EDGE model.

- Similarly, conduct an empirical study to provide support to the Bamakan et al. (2021) six-layer evaluation system of service supply chain performance that is based on a block-chain-IoT-big data framework.
- Employ the case study method to continue developing SC decision-making models, particularly if such work makes a more rigorous attempt to incorporate SC theory, a noted weakness in this line of research.

CONCLUSION

In this effort, key theoretical frameworks in agile supply chain management (ASCM) are examined and germane empirical studies are evaluated. The field is fractured in the sense that there is no unifying theory and research efforts tend to focus on narrow problems in single industries.

The key theoretical branches are: 1) Christopher's (2000) multidimensional theory (i.e., lean/agile/leagile), which views agility in the context of supply and demand, on lean's focus on cost efficiency, and on the pragmatism of hybrid SC designs; 2) Triple-A theory (Lee, 2004), which views agility as one of several dimensions (along with adaptability and alignment) that impact overall supply chain performance; and' 3) Drivers-capabilities-goals theory (Lin et al., 2006), where firms employ agility and its component competencies to meet the goal of customer satisfaction.

The empirical studies consist of survey research, assessment tools used to evaluate supply chain agility, and operational decision-making studies intended to help supply chain managers.

The Christopher lean-agile-leagile work (Christopher, 2000; Christopher et al., 2006) has been refined by some of the survey research. For example, Gligor et al. (2015) found that cost efficiency and agility both increase in an unpredictable demand environment. Similarly, other investigators noted the difficulty of implanting purely agile supply chain designs and that a leagile design was a more pragmatic solution (Jawahar et al., 2020; Kawa & Maryniak, 2019). Triple-A theory (Lee, 2004; Whitten et al., 2012) has been advanced by the Qrunfleh and Tarafdar studies (Qrunfleh & Tarafdar, 2013; Tarafdar & Qrunfleh, 2017), which suggested that the agile supply chain mediates supply chain performance.

The research on assessment instruments has focused on measuring the agile level in supply chain networks (Balaji et al., 2015; Ben Ruben et al., 2013; Rahiminezhad Galankashi & Helmi, 2016). Here, the thrust has been to triage current SC agility and to give supply chain managers ideas on areas for improving their networks.

The group of operational decision-making studies has been less theory-based, but nevertheless has contributed to the literature. Some looked at the key factors that enable supply chains to be more agile (Navid & Ismaeli, 2012; Pandey & Garg, 2009; Pearson et al., 2010; Sangari & Razmi, 2015; Sangari et al., 2015), while others (Matawale et al., 2016; Wu & Barnes, 2009) were aimed at developing decision-making models for selecting agile supply chain suppliers. Thus, these works help supply chain managers evaluate aspects of their SC networks.

Interestingly, the direction of ASCM research is expanding beyond agile supply chain design and agile manufacturing, to include the agile supply chain's application to new technologies (i.e., ecommerce, IoT, and blockchain) and its relationship to customer satisfaction. Specific recommendations have been made for future research, including the refinement of existing SC agility tools and correlational studies between the agile supply chain and pragmatic topics of interest (e.g., customer satisfaction and IT).

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APPENDIX A: SUMMARY OF ARTICLES BY STUDY TYPE

Study Type	Count	List
Case/pilot study	4	Balaji et al. (2015) Ben Ruben et al. (2013) Costantino et al. (2012) Sangari et al. (2015)
Empirical study	15	Geyi et al. (2020) Gligor et al. (2015) Jawahar et al. (2020) Kawa and Maryniak (2019) Kisperska-Moron and Swierczek (2009) Malakouti et al. (2017) Navid and Ismaeli (2012) Pandey and Garg (2009) Power et al. (2001) Qrunfleh and Tarafdar (2013) Sangari and Razmi (2015) Tarafdar and Qrunfleh (2017) Whitten et al. (2012) Wu and Barnes (2009) Yang (2014)
Mixed methods	3	Christopher et al. (2006) Matawale et al. (2016) Pearson et al. (2010)
Theoretical/literature review	11	Bamakan et al. (2021) Christopher (2000) Rahiminezhad Galankashi and Helmi (2016) Gunasekaran et al. (2019) Hofman and Cecere (2005) Kant et al. (2016) Kumar et al. (2019) Lee (2004) Lin et al. (2006) Shashi et al. (2020) Zhu et al. (2022)

APPENDIX B: SUMMARY OF RESEARCH ARTICLES BY CULTURE/SAMPLE POPULATION

Sample Population	Count	List
Australia	1	Power et al. (2001)
China	2	Wu and Barnes (2009) * Yang (2014)
India	5	Balaji et al. (2015) Ben Ruben et al. (2013) Jawahar et al. (2020) Matawale et al. (2016) Pandey and Garg (2009)
Iran	3	Navid and Ismaeli (2012) Sangari and Razmi (2015) Sangari et al. (2015)
Italy	1	Costantino et al. (2012)
Malaysia	1	Malakouti et al. (2017)
Multiple	1	Christopher et al. (2006) (North America, UK, Europe)
Poland	2	Kawa and Maryniak (2019) Kisperska-Moron and Swierczek (2009)
United Kingdom	3	Geyi et al. (2020) Pearson et al. (2010) Wu & Barnes (2009) *
United States	4	Gligor et al. (2015) Qrunfleh and Tarafdar (2013) Tarafdar and Qrunfleh (2017) Whitten et al. (2012)
N/A (Theoretical/literature review)	11	Bamakan et al. (2021) Christopher (2000) Rahiminezhad Galankashi and Helmi (2016) Gunasekaran et al. (2019) Hofman and Cecere (2005) Kant et al. (2016) Kumar et al. (2019) Lee (2004) Lin et al. (2006) Shashi et al. (2020) Zhu et al. (2022)

Note. * indicates that the study was conducted with multiple sample populations.

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