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Manufacturing and Supply Chain Flexibility: Building an Integrative Conceptual Model through Systematic Literature Review and Bibliometric Analysis

INTRODUCTION

Flexibility has long been a fundamental concept in operations management. The increasing demand for customized products; and the volatility in business environments due to social, political, economic and natural factors has kept flexibility on the agenda of both managers and academics, as it is an effective coping mechanism with such forces (Merschman and Thoneman 2011; Seebacher and Winkler 2013; Blomé et al. 2014; Xiao 2015; Ali and Murshid 2016; Teich and Claus 2017; Kaur et al. 2017). It has been discussed as part of operations strategy (Dey et al. 2019), as a cross-functionally and an inter-organizationally derived competence as well as a multi-dimensional, hierarchical system (Yu et al. 2015).

The earliest research on flexibility -commonly called manufacturing flexibility (MF) - considered it as part of operations strategy, examining its role among other competitive priorities, including cost, quality and delivery (Hayes and Wheelwright 1984). Particularly, manufacturing flexibility has been defined as the capability to react effectively (Mishra et al. 2014; Solke and Singh 2018) to competitive threats (Oberoi et al. 2007) adopting an internal and firm specific view. MF research has a history of at least three decades (Koste et al. 2004) and its maturity is evident from the large body of research on this topic encompassing multiple conceptualizations and frameworks (Beach et al. 2000; Jain et al. 2013, Mishra et al. 2014; Yu et al. 2015; Pérez-Pérez et al. 2016; Kumar and Mishra 2017 or Pérez-Pérez et al. 2018,). In time, the focus of research shifted from this internal and firm-specific view, to the more contemporary concept of an external, supply chain driven flexibility (Wadhwa et al. 2008; Bernardes and Hanna 2009; Stevenson and Spring 2009; Malhotra and Mackelprang 2012; Kumar et al. 2013; Thomé et al. 2014; Xiao 2015; Esmaeilikia et al. 2016; Shibin et al. 2016; Chatzikontidou et al. 2017; Kumar and Mishra 2017; Maestrini et al. 2017; Song et al. 2018). Supply chain flexibility (SCF) is defined as “the ability to rapidly reconfigure key supply chain (SC) resources in an attempt to maintain competitiveness” (Rojo et al. 2018, 637). It follows a logical extension of MF (Lummus et al. 2003; Singh and Acharya, 2013; 2014; Tiwari et al. 2015) complementing components of flexibility inherent at the firm level together with those at the inter-firm level (Stevenson and Spring 2007) derived from inter-organizational core processes in procurement/sourcing and distribution/logistics (Duclos et al. 2003; Singh and Sharma 2014; Esmaeilikia et al. 2016). Thus, SCF is a much broader concept, considering flexibility from the perspective of the entire value chain (Merchsmann and Thoneman 2011; Singh and Sharma 2014) that has emerged as a potential weapon to deal with current competitive uncertainties and associated risks (Chirra and Kumar 2018).

The concepts of MF and SCF are strongly interlinked -the conceptual development of SCF exploits the knowledge gained in manufacturing flexibility research- but still distinct (Merchsmann and Thoneman 2011; Kumar and Mishra 2017). As a consequence, “there is growing interest in the intersection of these two related, strategic concepts” (Li et al. 2018, 1), which collectively emerge “as the key objective for manufacturers and industrial supply chains” (Seebacher and Winkler 2013, 3415). The discussion of manufacturing and supply chain flexibility (MSCF) can prove useful for at least three reasons. One, there is value in taking an integrated perspective of the current state of these themes to understand its evolution and future direction. Two, it helps understand what kind of investments elevate flexibility by strengthening both MF and SCF simultaneously (Rao and Wadhwa 2002; Kumar and Deshmukh 2006; Kumar and Mishra 2017). Three, this review helps identify the antecedents and consequences of MSCF, the latter of which

shows its relation to the wider SC field and link to other complex SC concepts such as SC agility (Fayezi et al. 2017).

For these reasons, the main purpose of the paper is to provide a general overview of the status, trends and potential future research areas of MSCF field applying systematic literature review and bibliometric analysis that identifies thematic areas of MSCF through co-words. Co-words is a systematic and objective technique that focuses on the knowledge structure of the area studied. Thus, identifying the main topics of a research domain, assessing their level of development relative to each other, pinpointing the emerging ones and reflect on how these various themes can inform each other (Verbeek et al. 2002; Cobo et al. 2011). This study extends previous research MSCF, such as Seebacher and Winkler (2013) and Kumar and Mishra (2017) through a systematic literature review of the most up-to-date research. Consequently, this paper contributes to previous literature in four ways. First, the literature review covers until July 2018 and uses a large number of social sciences databases that helps to avoid potential bias towards a subset of journals and the likelihood of omitting significant work in this field. Second, we provide a systematic literature review, which starts when the scientific attention on flexibility began to grow in 1996 (Seebacher and Winkler 2013) and captures the fast-growing number of publications during the last two decades (Kumar and Mishra 2017). Third, it complements studies using co-citation analysis (Seebacher and Winkler 2013; Tiwari et al. 2015), where can one established the intellectual base of a research field rather than the content picture of the research topics (Cobo et al. 2011). In co-citation analysis, for many articles, it also takes time to start getting cited heavily and thus get picked up by the analysis (Feng et al. 2017). Four, based on a critical reflection on the different thematic clusters identified by co-words, this study advances on the development of an integrative conceptual model by identifying research opportunities to make future research investments more productive.

The co-words analysis resulted in the identification of five thematic clusters: the value-chain, capability and volatility clusters showed research topics that were taking a central role in the discussion on MSCF but were not mature yet. The SC purchasing practices and SC planning clusters involved work that were more focused and could be considered more mature. These clusters were then integrated in a framework that built on the competence-capability perspective and identified the major structural and infrastructural elements of MSCF as well as its antecedents and consequences.

The next section explains the methodology used in our literature review. Section 3 critically analyses the results and section 4 discusses opportunities for future research through an integrative framework.

METHODOLOGY

The analysis started with literature search. Literature reviews are used to evaluate past body of literature through a systematic design that provides a general overview of the status, trends and potential future research areas of a research field. It is an integral part of the research process and makes a valuable contribution to almost every step of the research design. That is because literature reviews contribute to establish the theoretical roots of a research study, clarify research ideas and develop their research methodology. Also, literature review “*serves to enhance and consolidate knowledge base and helps researchers to integrate their findings with the existing body of knowledge*” (Kumar 2019, p. 46), thus contributing to the contextualization of research findings. In summary, literature review gives an insight about what other researchers have done on a subject matter and what is yet to be done.

Systematic reviews include an iterative cycle of determining primary and secondary search keywords for retrieving a sample of relevant literature followed-up with a synthesis of the research to date as well as reflection on future opportunities. To this end, we use a three-step methodology (Durach et al. 2017; Maestrini et al. 2017) that is presented below:

Step 1: Collection of past literature and evaluation for appropriateness

A systematic keyword-based search covering six social sciences databases (Gligor and Holcomb 2012; Tiwari et al. 2015; Simangunsong et al. 2016; Moreira and Tjahjono 2016; Pérez-Pérez et al. 2018; Merigó et al. 2019) namely, Social Sciences Citation Index (SSCI), SCOPUS, JSTOR, ABI, Business Source Complete and Science Direct, was performed in July 2018.

To ensure that we capture the overlap between MF and SCF, we included “suppl* chain* flexib*”, and “manufact* flexib*” and the co-occurring terms “flexib* suppl* chain*”, “operat* flexib*” and “production flexib*” as primary terms of the search (Seebacher and Winkler 2013; Serrano-Bedia et al. 2013; Tiwari et al. 2015; Yu et al. 2015; Esmailikia et al. 2016; Singh et al. 2017). Additionally, the broader term “supply chain*” was included as a secondary keyword to guarantee the search being sufficiently inclusive to capture most relevant articles within the scope of our research objective. Thus, nine different Boolean two-by-two combinations of these primary and secondary keywords were used (see Figure 1), considering as search criteria title, abstract and keywords, in line with previous research (Fahimnia et al. 2015; Yu et al. 2015; Esmailikia et al. 2016; Grover and Kar 2017; Brozovic 2018; Abdelilah et al. 2018). Specifically, to capture the intersection of the MF and SCF domains, the connector AND was selected for these two-by-two combinations. Truncation symbol “*” was used to search all the ending variants of the selected keywords (Harkonen et al. 2015). This initial search attempts resulted in a total of 575 articles that was gradually cut down for appropriateness (see Figure 1).

From 575 papers, those appearing in more than one database (192) were deleted, leaving 383 unique documents. Subsequently, two complementary searches were performed. Firstly, all references of the sampled papers (backward snowball search) and all works that cited papers contained in the sample (forward snowball search) were checked as well through the use of Google Scholar as a secondary platform for completeness (Moussaoui et al. 2016). Secondly, those journals in our sample containing “Flexible” or “Flexibility” in the title and currently indexed in JCR (Journal Citation Reports) or SJR (Scimago Journal & Country Rank) were re-examined by extending the search of selected keyword combinations from title, abstract and keywords to “all fields”. 19 and 50 additional papers were identified, respectively, thus increasing the sample to 452.

Then, to guarantee reliability, the sample was screened for content refinement. Although in most cases the lack of fit with article’s scope could be identified from the title, abstract and keywords, sometimes it was necessary to read the article to ascertain its suitability. For this reason, and to gain sample robustness, all the authors of this paper examined those articles for which their research domain was unclear, until reach an agreement. Furthermore, papers containing keyword combinations only in the references list were removed from the sample (Fahimnia et al. 2015; Tiwari et al. 2015; Musa and Dabbo 2016), leading to a final sample of 222 papers.

FIGURE 1 ABOUT HERE

Step 2: Thematic identification through bibliometric analysis: co-words technique

The co-words technique uses the keywords of a sample of studies to identify the major themes in the domain of interest, which are then analysed and interpreted (López-Fernández et al. 2016). The technique is based

on a simple principle: the co-occurrence of particular keywords in individual papers collectively can help us identify the major research themes on a specific topic, in our case manufacturing and supply chain flexibility (Callon et al. 1995). Co-word analysis involves two steps: One, identification of thematic clusters and the networks of keywords that define each of them. Two, a graphical representation of the thematic clusters' maturity relative to each other, called the strategic matrix. Both steps, obtained through the specific bibliometric computer program REDES2005, are explained below.

The thematic clusters and the networks of keywords that define each of them are identified by the strength of the union of these keywords. In order to measure this strength, the frequency at which two keywords co-occur within a paper is measured by a normalised index, getting a symmetrical co-occurrence matrix. The value of this index depends on both the frequency at which keywords occur independently as well as their joint appearances. The normalized index is calculated as $e_{ij} = c_{ij}^2 / c_i c_j$ where c_{ij} is the number of documents in which two keywords i and j co-occur and c_i and c_j represent the number of documents in which each one appears. In REDES2005, the keywords are clustered into themes by using the simple centers algorithm (Coulter et al. 1998; Cobo et al. 2011). The keywords that represent the clusters and the papers in the clusters are then reviewed by the researcher to identify the themes.

The graphical representation of the thematic clusters' standing relative to each other is constructed in REDES2005 using two dimensions: centrality and density (please refer to Callon et al. (1995) or Benavides-Velasco et al. (2013) for technical details). Centrality measures how often the theme under question appears with the other themes in the field, being understood as a measure of the importance of a theme in entire research field analyzed. Density measures the strength of relations between the keywords that define a theme. It captures how well developed a theme is. Centrality (c_r) and density (d_r), are calculated as:

$$c_r = \text{rank}^{c_i} / N$$

and

$$d_r = \text{rank}^{d_i} / N$$

where rank^{c_i} is the position of theme i among all the themes that have been sorted in ascending order with respect to centrality. Rank^{d_i} is the same with respect to density. N is the total number of themes and is used to standardize c_r and d_r values to the range [0 1] (Muñoz-Leiva et al. 2012).

The combination of both parameters allows to map the research clusters within four possible quadrants of the strategic matrix. Core/central clusters, located in the upper right quadrant, are both well developed and take a quite central role in that field. Specialization clusters, located in the upper left quadrant, are well developed but are more niche themes. Peripheral clusters, located in the lower left quadrant, are both weakly developed and marginal. Emergent clusters, located in the lower right quadrant, are fundamental for the overall research domain but not yet well developed. The field's overall level of maturity is determined by the collective configuration of all of the clusters (please see Callon et al. (1995) page 79 for specific details of meaning of strategic matrix positions).

Step 3: Labelling the Thematic Clusters and Critical Reflection

In order to complement and enrich the results of the previous step, a more fine-grained process is carried out (Maestrini et al. 2017) in order to identify potential future research areas of the research domain analysed and synthetizing them in an integrative framework. It consists, firstly, of a close examination of each of the articles in each thematic cluster to collect information about the main theoretical and methodological aspects, results and gaps identified. Secondly, all authors worked, both independently and together, to

characterize the focus of the articles in each cluster and how they contribute to MSCF domain (Di Stefano et al. 2010).

FINDINGS

This study concurs with the vast literature that considers SCF an extension of the flexibility beyond the manufacturing enterprise (MF) to a broader concept from the viewpoint of the entire value chain (Vickery et al. 1999; Blomé 2013; Tiwari et al. 2015; Yu et al. 2015; Kumar and Mishra 2017). Unlike MF, defined as an ability to react effectively (Mishra et al. 2014; Solke and Singh 2018; Pérez-Pérez et al. 2018) to competitive threats (Oberoi et al. 2007) adopting a firm specific view that considers merely the physical resources employed in manufacturing processes, “*SCF entails the implicit requirement of flexibility within and between all partners in the chain*” (Tiwari et al. 2015, p. 768). Thus, SCF complements flexibility inherent at the firm level together with flexibility at the inter-firm level (Stevenson and Spring 2007) derived from inter-organizational core processes in procurement/sourcing and distribution/logistics (Duclos et al. 2003; Singh and Sharma 2014; Esmailikia et al. 2016).

Different from recent bibliometric reviews adopting either citation analysis (e.g. Seebacher and Winkler 2013; Tiwari et al. 2015) or meta-analysis (e.g. Yu et al. 2015), co-words analysis, is employed in this paper to address a general overview of the status, trends and potential future research areas of MSCF. As a complement of co-words analysis this study identifies temporal distribution of scientific contributions and journal productivity in the MSCF field. Specific results are described below.

Figure 2 shows the number papers per year to illustrate the evolution of this area. The figure captures the fast-growing number of publications during the last two decades. Particularly, since the early 2000s papers on MSCF have been published regularly. The number of articles peaked during 2009-2014 and continued steadily since then, suggesting an enduring interest in the topic.

FIGURE 2 ABOUT HERE

Table 1 shows journal productivity in the field. The research in the area is spread across a number of high quality publications including International Journal of Production Economics, International Journal of Operations & Production Management, International Journal of Production Research, Journal of Operations Management and Global Journal of Flexible Systems management as the top five leading the list with over 10 papers each. The high number of papers on MSCF in these journals, which are papers from a wide array of operations and supply chain topics, could indicate the level of interest in this topic.

TABLE 1 ABOUT HERE

By using co-word analysis for mapping science, clusters of keywords are obtained. In this case, the co-words analysis resulted in five thematic clusters. The keywords that delineate them are provided in Table 2. Clusters of keywords are particularly useful to future researchers, and help them choose the most appropriate search keywords depending on their topic of interest (López-Fernández et al. 2016).

TABLE 2 ABOUT HERE

Then, each research cluster obtained in co-words analysis is mapped into a two-dimensional space which is shown in Figure 3 by two parameters (“density” and “centrality”). According to the quadrant in which they

are placed we can find four kinds of clusters (see step 2 methodology section). Results of figure 3 show that MSCF field is still not fully developed. Two clusters are specialized –Purchasing and Planning-, and the remaining three clusters –Value Chain, Capability and Volatility- are emergent -encompass transversal and important themes for MSCF field that they are not still well developed (Callon et al. 1995). Furthermore, a critical analysis revealed that the two biggest clusters identified have a high dynamism because they are composed of different sub-themes showing a rich and complex structure.

FIGURE 3 ABOUT HERE

Figure 4 shows the articles published per year in each thematic cluster and, if available, its sub-themes between 1996 and 2018. Of the emergent clusters, the value chain and the volatility clusters seem to have been established more recently, in the early 2000s. Furthermore, both encompass sub-themes. All of the sub-themes have seen regular coverage, except for the distribution sub-theme, for which the published papers are almost all between 2010 and 2013. The capability cluster suggests regular research over the years. As for the two specialization clusters, the Planning cluster shows a more recent and relatively constant stream of published papers while the number of articles on Purchasing shows a slowdown.

FIGURE 4 ABOUT HERE

Using the clusters and sub-streams identified by the co-words analysis, table 3 provides a general and comprehensive portrayal of each cluster and its subsequent sub-streams and the supporting literature base for each for guaranteeing literature review's traceability.

Considering the rich tradition and complexity of each cluster, far more than its label suggests; we next proceed to provide a critical analysis of them:

TABLE 3 ABOUT HERE

Value chain cluster (44.14%): It concentrates the greatest number of papers and includes those papers that address some fundamental concerns of the field. While it doesn't rate highest on centrality and density, the body of literature in this thematic cluster and its closeness in position to the upper left quadrant suggest it to be the most fully developed among all the themes.

Specifically, the *MSCF conceptualization and operationalization* stream addresses several issues for the development and consolidation of the field, such as the conceptualization (Stevenson and Spring 2007; Reichart and Holweg 2007; Bernardes and Hanna 2009; Esmailikia et al. 2016), operationalization (Saghiri, 2011; Moon et al. 2012; Maestrini et al. 2017) and research evolution (Seebacher and Winkler 2013; Tiwari et al. 2015; Yu et al. 2015) of manufacturing and supply chain flexibilities, individually, and in relation to each other. Other research lines raise more general questions about MSCF. Moving from the strategic to the operational:

The *strategic MSCF management* stream predominantly comprises qualitative studies on SC design (i.e. Goldsby and Garcia-Dastugue 2003; Chandra et al. 2010). One line of research offers conceptual models on MSCF-related decision-making (Kumar et al. 2006; Manuj and Sahin 2011), while another investigates the effect of different MSCF design options (Salvador et al. 2007; Engelhardt-Nowitzki 2012; Tanrisever et al. 2012; Singh and Sharma 2014) and MSCF policies' design (Lee and Kincade 2003; Soon and Udin 2011) on SC performance. The quantitative articles in this research line explore the relationships between SC

strategy, manufacturing flexibility, visibility and performance. In general, the studies find evidence of positive direct effects of SC strategy on MSCF (Fantazy et al. 2009) and of MSCF on performance (Lo 2016; Dansereau et al. 2014). The effects of MSCF options and policies on SC sustainability are also of interest (Chandra et al. 2010; Dansereau et al. 2014; Fantazy and Salem 2016).

The *collaboration and MSCF* stream advocates strategic and integrated view of upstream production to obtain a competitive advantage (Omar et al. 2012). Most papers are empirical, with a limited presence of theoretical research discussing how MF is affected by the bullwhip effect¹ (Richardson 1996; Stank et al. 2001; Kayis and Kara 2005) and outsourcing (Dabhilkar and Bengston 2008; Fredriksson 2014). The most recent qualitative (Scherrer-Rathje et al. 2014; Manders et al. 2016) and quantitative empirical studies (Omar et al. 2012; He et al. 2014; Willis et al. 2016) build on strategic management theories and extend the collaboration- flexibility-performance relationship with the incorporation of inter-organizational information systems. These systems are considered a prerequisite for building effective cooperative relationships by allowing the sharing of real time information between business partners (Pierre and Luc 2007; Kume and Fujiwara 2016). Among the most frequently analysed inter-organizational systems are virtual integration, collaborative product commerce or vendor managed inventory (Banker, and Bardhan 2006; Wang et al. 2006).

Finally, the *distribution and MSCF* stream predominantly comprises case studies centred on transportation planning decisions, both in forward logistics (Yu et al. 2012; 2013; Ishfaq 2013;) and reverse logistics (Sasikumar and Haq 2010; Bai and Sarkis 2013). Forward logistics has a more extensive empirical tradition in evaluating key logistics capabilities to ensure SC stability. The role of different transportation flexibility options in various contexts have been explored (Naim et al. 2010; Lagoudis et al. 2010). Those vary from international distribution centre operations (Yu et al. 2012; 2013) to the container liner-shipping sector (Mason and Nair, 2013a; 2013b). By contrast, there is little research on reverse logistics flexibility. It focuses on operational decision-making, such as choice of logistics operating modes (Sasikumar and Haq 2010) or programmatic evaluation (Bai and Sarkis 2013). The results suggest that, in general, reverse logistics networks are more complex than that of forward logistics, thus increasing the information management requirements.

The **volatility cluster (22.98%)** focuses on the link between MSCF and uncertainty (Fayezi et al. 2014). It is composed of three sub-themes.

The *MSCF and business uncertainty* stream, sheds light on the use of MF -by type and level- to cope with uncertainty (Calvo et al. 2006; Wang et al. 2016). Much of the work within this line examines, either theoretically (Garavelli 2003; Sawhney 2006) or through case studies (Scavarda et al. 2015; Simangunsong et al. 2016), how match the different flexibility strategies adopted by SC partners in response to various types of business uncertainties (Candace et al. 2011). The limited quantitative studies explore either the direct (Wang et al. 2006; Nagarajan et al. 2013; Kim and Chai 2016) or the moderating (Wong et al. 2011; Qu et al. 2014) effects of business uncertainty on the MSCF-performance relationship, as well as the development of MSCF capability to respond to dynamic and turbulent environments (Zhang et al. 2005; Lim et al. 2010; 2012). Theoretically, these quantitative studies tend to build on *contingency theory* (Wong et al. 2011; Kim and Chai 2016) or *Resource Based View* (Zhang et al. 2005; Sawhney 2006; Nagarajan et al. 2013). This stream highlights the importance of matching flexibility strategies to the business uncertainty experienced (Candace et al. 2011; Fayezi et al. 2014).

¹ Bullwhip effect: “the progressive increasing of upstream production variability caused by demand variability at the retail level in the chain” (Pereira 2010, p. 6358).

The *MSCF and risk management* stream is dominated by conceptual and modelling based papers. The general relationship between SC risk management and flexibility is well established; different forms of flexibility are some of the most effective options for risk mitigation (Bandaly et al. 2012) and even in reducing the link between business uncertainty and SC risks. MSCF has particularly received attention with respect to stakeholder-driven risks (Bandaly et al. 2013). Supply contracts are an effective means to reduce such stakeholder-driven risks and can be used to complement operational flexibility types (Reimann and Schiltknecht 2009a). Overall, the benefits of supply contracts are evident at even relatively low levels (Tang and Tomlin 2008). The quantity-flexibility contract provides value to both the buyer and supplier by reducing the trade-off between customer service level and inventory risk and is indeed useful even when a multiple-echelon SC is considered instead of dyads (Kim et al. 2013). However, other studies (Benaroch et al. 2010) have showed that it is not only the usage -i.e. quantity-, but also the different sourcing options and pricing models by which the buyer could be offered flexibility. There are also studies that consider the impact of risk and risk attitudes on flexibility investments finding both positive (Tomlin 2006; Reimann and Schiltknecht 2009b) and negative relationships (Zhao et al. 2013). Finally, MSCF can also be considered in conjunction with financial hedging. Product flexibilities act as a complement to financial hedging in risk mitigation, whereas postponement flexibility acts as a substitute (Chod et al. 2010).

The *MSCF and agility* stream suggests SC agility and MSCF are tightly interlinked. At times these terms are also used interchangeably therefore creating an ambiguity about their differences (Bernardes and Hanna 2009; Um 2017). Thus, a main concern has been understanding if and how these terms differ from each other (Giachetti et al. 2003; Yang 2014; Fayezi and Zomorri 2015) as well as from other related concepts such as leagility (Narasimhan et al. 2006; Purvis et al. 2014). Braunscheidel and Suresh (2009) have provided clarity for agility by conceptualizing and operationalizing it as a multi-dimensional measure that is distinctly different from MF. Studies that aimed to delineate these two concepts consider MF to be an antecedent of agility (Swafford et al. 2006a; 2006b; Chan et al. 2017; Um et al. 2017). While not always articulated, a competence-capability perspective is prevalent in this relationship² (Chiang et al. 2012). This research line also includes studies that focus on the organizational factors that significantly affect the flexibility–agility link, usually through survey-based research, with a few exceptions based on case studies (Fayezi et al. 2015), and analytical approaches (Wadhwa et al. 2007). The most notable factor is integration, which unlike the supplier integration discussed in value chain cluster, also accounts for customer integration as a priority for developing agility (Braunscheidel and Suresh 2009; Chiang et al. 2012; Fayezi et al. 2015). The link between integration, MSCF and agility has been extended by considering other factors including learning (Tse et al. 2016) and technology (Swafford et al. 2008).

Capability cluster (13.06%) emerges as a central research cluster the purpose of which is to understand MSCF from various theoretical perspectives (i.e. competence-capability, dynamic capability, resource-based view or knowledge-based view theories). It is dominated by empirical studies that try to shed light on the impact that different SC competences and capabilities (Shah and Sharma 2014) -specially technology (Chen et al. 2009; Devaraj et al. 2012; Jin et al. 2014) and knowledge (Kristal et al. 2010; Blomé et al. 2014; Rojo et al. 2016) - have on firm's responsiveness. The various theories applied in this stream and the resultant differences in conceptualization makes cross-comparison of studies difficult, yet there can be significant overlaps in the variables of interest. There is a high heterogeneity in the proposed models for exploring the impact of these SC competences and capabilities on performance. These models explore both SC

² This perspective conceptualized SCF as an internal competence, i.e. what the organization excels at the leads to the external capability of agility, which is the organization's ability to use its resources and processes to effectively respond to its environment dynamic needs.

competences-capabilities direct effect on flexibility (Kristal et al. 2010; Hall et al. 2010; Gligor 2014; Blomé et al. 2014; Rojo et al. 2016) and the mediator effect of MF on different SC competences-capabilities-performance³ relationships (Devaraj et al. 2012; Jin et al. 2014). A small number of studies have also explored the possible complementary/substitutive impact of different SC competences and capabilities (Malhotra and Mackelprang 2012).

Finally, the analysis suggests two specialization clusters: The **SC planning cluster (13.97%)** includes research that develops mathematical models to help the decision-making process of MSCF management. Papers in this cluster focus on capacity planning (Zhang and Tseng 2009; Chou et al. 2011; Negahban et al. 2014) or supplier selection and the optimal order allocation (Boulaksil et al. 2011), using multiple criteria models including the analytic hierarchy or network process, genetic algorithm or fuzzy set theory. The **SC purchasing practices cluster (5.85%)** comprises studies explaining the role of supply management practices on creating MSCF. Particularly they investigate what specific inter-firm practices, such as multiple sourcing, inventory buffers across the supply network, and/or supplier long-term relationships (Tachizawa and Thomson 2007; Tachizawa and Gimenez 2010; Gosling et al. 2010)- are used to achieve MSCF, individually or collectively.

DISCUSSION AND FUTURE DIRECTIONS

The themes of planning, purchasing, value chain, capability and volatility identified during the co-words analysis highlight the main areas of interest in the MSCF literature. Considering these themes through the competence-capability perspective, which was explained in the capability cluster in the previous section can help explain how these themes -and their sub-themes earlier- cumulatively define the MSCF domain. The resulting integrative framework is introduced in Figure 5.

The building blocks of the manufacturing and supply chain flexibility competence are the interconnected and reinforcing approaches to *planning* (the planning cluster), *partners* –in procurement (the purchasing cluster) and distribution (the distribution and MSCF sub-cluster) -, the *processes* that build manufacturing flexibility and finally *information sharing and communication* (the collaboration and MSCF sub-cluster) These can be considered as the key structural and infrastructural building blocks of manufacturing and supply chain flexibility (Slack 2005a; Merschmann and Thoneman 2011; Alves-Filho et al. 2015). It is worth noting that these building blocks are still predominantly considered in isolation (Li et al. 2018), providing opportunities for integrative studies (Kumar and Mishra 2017; Singh and Kumar 2017). Kumar et al. (2006) and Tiwari et al. (2015) conceptual models are good starting points in addressing this need. The strategy that supports and drives manufacturing and supply chain flexibility has received significant attention and relevant papers were captured in our value chain cluster (the conceptualization and operationalization, and the strategic MSCF management sub-clusters) (e.g. Fantazy et al. 2009; Soon and Udin 2011; Lo 2016). The antecedents and contingencies are discussed in all clusters but particularly the MSCF and business uncertainty sub-cluster. Luo and Yu (2016) also offer an in-depth argument on contingencies approach, which could be extended further with different contingency factors in the future. Investigating several contingencies holistically is important (Simangunsong et al. 2012; Singh et al. 2017; Kumar and Mishra 2017), as most of the previous studies are fragmented and cannot help identify the more prominent, and even perhaps conflicting ones. Sanchez and Perez (2005) is an illustration of this point and should be complemented with studies outside the automotive sector. Finally, the impact of manufacturing and supply chain strategy on other supply chain factors such as sustainability (strategic MSCF management sub-cluster), risk (MSCF and risk management sub-cluster) and agility (MSCF and agility sub-cluster) has

³ Measures employed have a wide range of indicators from logistics, flexibility or delivery performance to overall firm performance.

been the focus of our volatility cluster and, given the interest in those topics, is likely to continue to be addressed in future studies. It also is in alignment with the conceptualization of flexibility as a competence and a means that feeds into each of these capabilities as an end (Zhang et al. 2003; Chiang et al. 2012).

FIGURE 5 ABOUT HERE

Future Research Opportunities in MSCF

Given that no single cluster appeared as a motor cluster shows that there is still significant potential in MSCF research. A closer look at figure 3, suggests that while the value chain, capability and volatility clusters all are quite central to this topic none of the clusters have reached the maturity to be considered exhaustive. The clusters are placed low on the density axis, in other words, there is a significant yet fragmented body of research. We provide some suggestions on how to move towards a more inter-connected field.

One approach is to go back to the roots of flexibility; at its heart flexibility is a coping mechanism against uncertainty. Yet, the conceptual work in the volatility cluster, on the relationship between uncertainty and MSCF suggests that there are distinct sources of uncertainty to be explored (Simangunsong et al. 2012). These can be grouped into three: uncertainties arising from the inside the company (i.e. intra-organizational uncertainty); uncertainties arising from the supply chain (i.e. inter-organizational uncertainty/risks); and finally, external uncertainties, which are outside a company's direct control. While the MSCF literature has investigated some of intra-organizational or external uncertainties such as those driven by business context including suppliers and customers (Nagarajan et al. 2013; Kim and Chai 2016), other types of uncertainties have received insufficient attention, including human resource management practices (Lim et al. 2010), management style (Lin 2003), business culture (Lim et al. 2012), parallel interaction, partnerships quality and dependence (Chang and Huang 2012), knowledge ambiguity (Rojo et al. 2016; Tse et al. 2016), company's financial position (Bandaly et al. 2012), customs dues (Braunscheidel and Suresh 2009) or country legislations (Fredriksson 2014). Furthermore, these uncertainties also need to be considered in relation to each other within the context of flexibility for two reasons. First, understanding the degree of different uncertainties could be relevant in prioritizing management actions (Govindan et al. 2017). Second, although some authors have claimed that a link may exist between different sources of uncertainty and risks, and thus is necessary to understand the effect that managing one source of uncertainty could have upon another (Yi et al. 2011), there is limited empirical work (Malhotra and Mackelprang 2012; Shah and Sharma 2014). This level of understanding of the context can help managers take a focused approach to the structural and infrastructural investments in MSCF (Slack 2005b).

An alternative to this approach would be to discuss MSCF as a means (Slack 2005b). The competence-capability perspective can be particularly effective. As we discussed earlier, flexibility has been considered as a competence that helps build capabilities in risk management, sustainability and agility (e.g. Shukla, Deshmukh and Kanda 2010; Chiang et al. 2012; Bag and Gupta 2017). Yet, we understand little in the underlying mechanism, in other words the 'how'. Understanding this link, through qualitative research, would also help understand how the various planning, collaboration, process and information-sharing elements reinforce each other to create the right MSCF competence. Furthermore, future research can explore the relationships between risk management and agility as well sustainability (Gunasekaran, Dubey and Singh 2016). The potential trade-off in risk management, agility and corporate social responsibility (CSR) is relatively unexplored. There even is little work on the direct link between CSR and MSCF (Chandra, Deshmukh, and Kanda 2010).

Even the individual structural and infrastructural elements of MSCF still have the potential for future research. For example, opportunities exist in studying MSCF in the context of multiple supplier or customers and even the whole SC network rather than individual dyads. In the past, internal, supplier and customer integration were investigated in separate, very context specific models, limiting a general perspective. In addition, the focus of research has been mainly on supplier integration (Chang et al. 2006; Wang, Tai, and Wei 2006; Omar et al. 2012; Willis et al. 2016). Future research should consider the potential interactions among internal, supplier and customer integration (Wong et al. 2011). Similarly, there are to date no empirical studies that investigate how to manage parallel interactions⁴, which is acquiring special relevance in the growing context of e-business. In SC relationships where the suppliers carry out a significant portion of the work originally handled by the buying organization, such as the lead suppliers for platforms in the automotive industry, agency theory could offer a potentially important interpretive frame in understanding their impact on MSCF (Simangunsong et al. 2012).

Similarly, inter-organizational information sharing and communication systems are critical, although less studied, in the context of uncertainties, risks and MSCF (Stevenson and Spring 2009). Not to mention, there has been relatively little work on technology and knowledge transfer as additional sources of risk and uncertainty; sometimes technology solutions can increase supply-chain vulnerability due to complexity and reliance thus reducing MSCF (Simangunsong et al. 2012). At the same time, these systems enhance the process and quality of decision-making and consequently improve SC alignment and reduce SC planning complexity (Blomé et al. 2014). There is also still room to explore how firms use their current information sharing and communication technologies and exploit the advantages generated by existing partner relationships with both suppliers and customers (Jin et al. 2014). Additional gaps in this context are the challenges for SMEs to adopt some of the existing technologies thus disadvantaging them as well as preventing the buying firm to integrate technologies across suppliers. There are still unanswered questions around the fairness in distributing the gains from using such technologies, the role of the cultural contexts in knowledge sharing in global supply chains and the effectiveness of informal vs. formal knowledge sharing mechanisms in developing MSCF. Likewise, some social media technologies have been relatively ignored in MSCF literature, yet they can potentially have disruptive effects.

Apart from these gaps in content, there is additional opportunities from a methodological perspective. Quantitative studies are scarce, relatively recent and very context specific (Tipu and Fantazy 2014; Fayezi et al. 2015; Saghiri and Barnes 2016; Lo 2016). Most of them come from emerging economies (i.e. India, Taiwan), where supply chains are still developing and decision-making structures show differences. Multi-country studies are absent except for He et al. (2014). This is surprising given that several prominent supply chains cover vast geographic areas, and, therefore, synchronizing a series of interrelated activities in these distributed, global networks is a major challenge. Finally, the MSCF purchasing practices cluster was dominated by studies from Spain. However, considering that sourcing practices can differ significantly across countries, future studies could extend their samples to other geographical contexts. Furthermore, in the international context, the adoption of these practices can result in the development of different ownership and control structures in the supply chain, e.g. control shared with other members or under responsibility of the focal firm, the selection of which may be affected by other variables such as power, level of dependency or country factors that are still absent from the literature, yet are likely to have significant impact on MSCF.

⁴ It considers the complexity arising due to the way in which customer interacts with multiple identical suppliers (Simangunsong et al. 2012)-.

In summary, the results of this review suggest that MSCF requires a carefully planned, tailored and integrated network of organizations for whom the goal is (Kumar et al. 2006, Swafford et al. 2006, Tiwari et al. 2015): 1) Adaptability, which is the ability to effectively adjust the SC network design and strategy to meet structural changes in markets; 2) Alignment, which focuses on creating the incentives for the individual network partners to motivate all to work together in developing MSCF; and, 3) Awareness, that is, the ability to identify dynamic market requirements, customer needs and business risks. The fulfilment of these three objectives help companies establish MSCF that can support customized products and better preparedness against disruptions.

CONCLUSION

This study reflects on the current state of MSCF research by identifying the major themes in this field and their respective level of maturity, integrating them through a framework and suggesting future research opportunities. Our sample is composed of 222 peer-reviewed papers published during the last two decades. It was analysed using co-words analysis, which resulted in five thematic clusters revealing a still evolving field. The analysis was extended with a critical reflection of these themes, discussing the current state and knowledge gaps for each individually. Finally, the five clusters were discussed through an integrative framework, the relationship between the thematic clusters were explained and the main research opportunities for MSCF were identified.

Despite of the academic relevance of the paper, it also aims to have practical relevance to managers focused on improving their understanding of MSCF. Managers must plan, organise and manage MSCF that is in alignment with and supportive of the organization's strategic goals. The integrative MSCF framework can help managers to see how the various themes in this larger, fragmented research domain fit together, the synergistic effects of some decisions and in some cases the trade-offs one faces. The integrative framework allows managers to keep track of the main structural and infrastructural decisions they need to make to support MSCF. In addition, it highlights some of the enablers such as procurement to MSCF. Finally, the framework links MSCF to some very contemporary challenges in supply chain management such as agility, risk management and sustainability. The framework can be considered a high-level roadmap to building MSCF helping managers keep track the various decisions they need to make in relation to their planning, processes, relationships and supporting activities.

Despite these contributions, this paper is not without limitations, which provide opportunities for further research. First, this article may have ignored some relevant knowledge as it focused only on peer-review, English-published articles available at the time of search. Including additional knowledge from other sources might somewhat influence the results and the conclusions drawn. Further research may include a large set of academic publications, professional magazines and/or reports.

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Key questions

Q1: How MF contributes to the development of SCF?

Q2: How MSCF domain has evolved in the last two decades?

Q3: What are the main research opportunities for further development of MSCF research domain?

Q4: What are the major structural and infrastructural elements supporting MSCF, and how can they be integrated in a conceptual model?

Table 1. Publications per Journal in the Area of Manufacturing and Supply Chain Flexibility

International Journal of Production Economics	24
International Journal of Operations & Production Management	15
International Journal of Production Research	14
Journal of Operations Management	11
Global Journal of Flexible Systems Management	11
The International Journal of Logistics Management	8
European Journal of Operational Research	7
Production Planning & Control	7
Operations Research	6
Supply Chain Management: An International Journal	6
Journal of Management Information Systems	5
Management Science	5
Journal of Enterprise Information Management	5
Asia Pacific Journal of Marketing and Logistics	3
Computers & chemical engineering	3
International Journal of Systems Science	3
Journal of Business Logistics	3
Journal of Manufacturing Technology Management	3
Business Process Management Journal	3
Journal of Purchasing and Supply Management	3
Industrial Management & Data Systems	2
Industrial Marketing Management	2
International Journal of Flexible Manufacturing Systems	2
International Journal of Operational Research	2
International Journal of Physical Distribution & Logistics Management	2
Journal of Construction Engineering and Management	2
Omega	2
Risk Management	2
TQM	2
Transportation Journal	2
Decision Sciences	2

Note: We only represent journals that have published more than one paper.

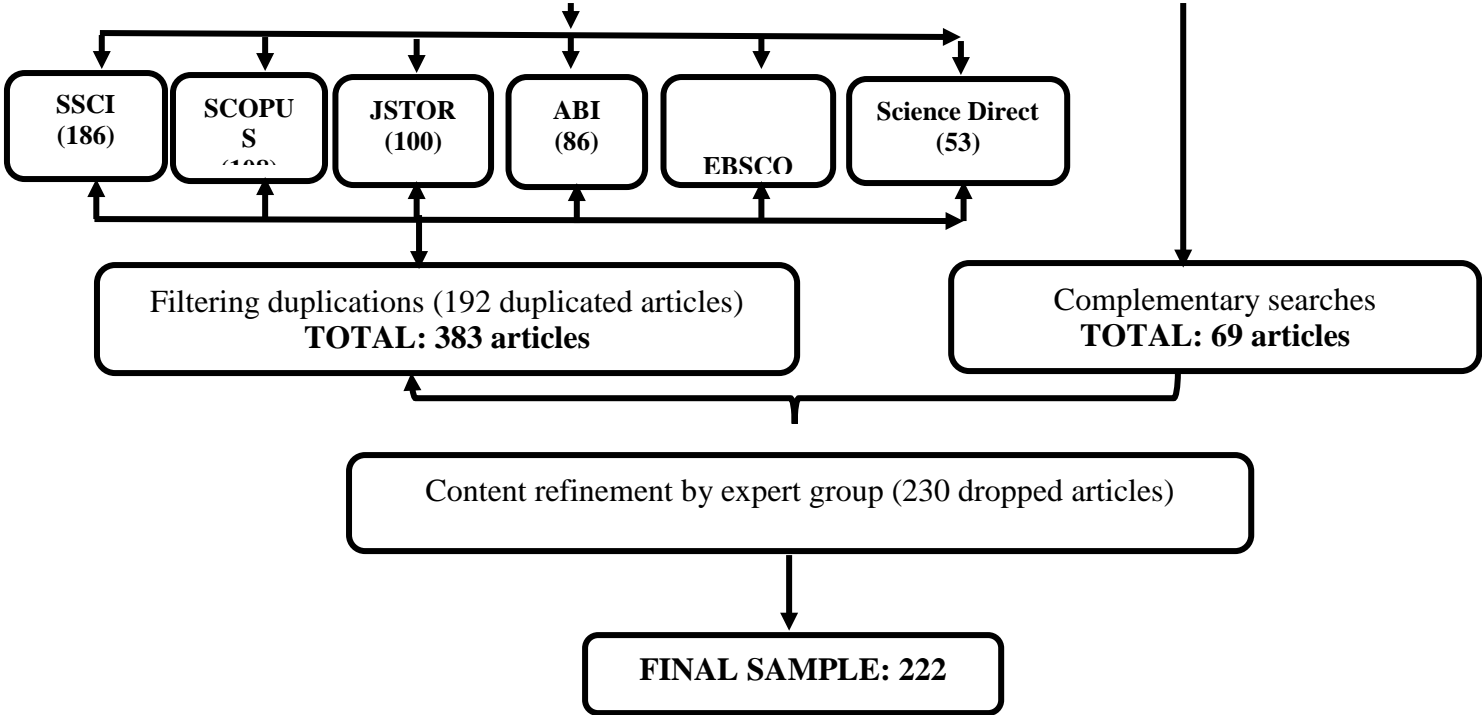
Table 2 Main Groups of Co-Words Identified Using Hierarchical Clustering Analysis

Cluster	Co-Words
Value chain	Supply chain management, flexible, flexible organization, flexible supply chain, value chain, distribution management, integration management, manufacturing industry, collaboration, strategic design, manufacturing flexibility
Volatility	Flexibility, supply chain, agility, responsiveness, uncertainty, risk, risk management, dynamism
Capability	Performance, strategy, capability, competence, dynamic capability, resource-based view
Purchasing	Sourcing, survey, long-term relationships
Planning	Design, flexible manufacturing, capacity investment, production.

Table 3. Themes, sub-themes, descriptions and papers

General cluster description and sub-streams identified		Sub-stream Description	References
Value chain: general MSCF management and conceptualization	<i>MSCF conceptualization and operationalization</i>	The evolution of MSCF research; definition of MSCF; operationalization of MSCF; key antecedents of MSCF	Rao and Wadhwa (2002); Duclos et al. (2003); Minner (2003); Wadhwa and Rao (2004); Holweg (2005); Reichart and Holweg (2007); Stevenson and Spring (2007); Bernardes and Hana (2009); Saghiri (2011); Moon et al.(2012); Simangunsong et al. (2012); Seebacher and Winkler (2013); Singh and Acharya (2013); Sing and Acharya (2014); Tiwari et al. (2015); Yu et al.(2015); Esmailikia et al. (2016); Gligor and Holcomb (2012); Kumar and Mishra (2017); Maestrini et al. (2017); Singh et al. (2017)
	<i>Strategic MSCF management</i>	Supply chain decision-making within the context of flexibility; performance effects of alternative MSCF designs and MSCF policies'	Cvsa and Gilbert (2002); Goldsby and García-Dastugue (2003); Lummus et al. (2003); Lee and Kincade (2003); Bish et al. (2005); Lummus et al. (2005); Krajewski et al. (2005); Ndubisi et al. (2005); Sanchez and Perez (2005); Kumar et al. (2006); Kumar and Deshmukh (2006); Calvo et al. (2007); Salvador et al. (2007); Coronado and Lyons (2007); Fantazy et al. (2009); Siddiqui et al. (2009); Chandra et al. (2010); Manuj and Sahin (2011); Richardson and Snaddon (2011); Soon and Udin (2011); Siddiqui et al (2012); Tanrisever et al. (2012); Dansereau et al. (2012); Engelhardt-Nowitzki (2012); Wang (2012); Foo et al. (2013); Stevenson (2013); Babazadeh et al. 2013); Gosling et al. (2013); Singh et al. (2013); Klueber and O'keefe (2013); Correl et al. (2014); Singh and Sharma (2014); Dansereau et al. (2014); Thomé et al. (2014); Tipu and Fantazy (2014); Fantazy and Salem (2016); Lo (2016); Saghiri and Barnes (2016); Weeks et al. (2018).
	<i>Collaboration and MSCF</i>	Supplier integration, MSCF and performance; the bullwhip effect and MSCF; outsourcing and MSCF; MSCF and inter-organizational information systems	Richardson (1996); Stank et al. (2001); Gunasekaran and McGaughey (2003); Kayis and Kara (2005); Banker and Bardhan (2006); Chang et al. (2006); Avitattur and Swamidass (2007); Pierre and Luc (2007); Yang et al. (2007); Dabhiikar and Bengtsson (2008); Wang (2008); Dabhiikar et al. (2009); Pereira (2010); Savasanelil and Nesim (2010); Chu et al. (2011); Wong et al. (2011); Chu et al. (2012); Omar et al. (2012); Zainol et al. (2013); Fredriksson (2014); He et al. (2014); Scherrer-Rathje et al. (2014); Manders et al. (2016); Willis et al. (2016); Yu et al. (2018); Asmussen et al. (2018); Dwaikat et al. (2018)
	<i>Distribution and MSCF</i>	Transportation flexibility strategy and decisions related to forward and reverse logistics	Lagoudis et al. (2010); Naim et al. (2010); Sasikumar and Haq (2010); Yu et al. (2012); Karrenbauer (2012); Bai and Sarkis (2013); Ishfaq (2013); Mason and Nair (2013); Mason and Nair (2013a); Yu et al. (2013) Jain (2018);
Volatility: MSCF and uncertainty	<i>MSCF and business Uncertainty</i>	Proactive and reactive uses of MSCF strategies to face business uncertainty; the impact of uncertainty on the MSCF performance	Garavelli (2003); Zhang et al. (2005); Calvo et al. (2006); Sawhney (2006); Wang et al. (2006); Wadhwa et al. (2008); Lim et al. (2010); Candace et al. (2011); Lim et al. (2012); Nagarajan et al. (2013); Qu et al. (2014); Fayezi et al. (2014); Scavarda et al. (2015); Kim and Chai (2016); Simangunsong et al. (2016); Wang et al. (2016); De Giovanni and Massabò (2018);
	<i>MSCF and Risk Management</i>	MSCF as a risk mitigation strategy; the competing and complementary roles of MSCF, contractual flexibility and financial flexibility	Tomlin (2006); Chambost and Stuart (2007); Tang and Tomlin (2008); Reimann and Schiltnknecht (2009a); Reimann and Schiltnknecht (2009b); Benaroch et al. (2010); Chod et al. (2010); Cucchiella et al. (2010); Kim (2011); Bandaly et al. (2012); Chang and Huang (2012); Bandaly et al. (2013); Kim et al. (2013); Zhao et al. (2013); Treville et al. (2014); Arnold et al. (2015); Sreedevi and Saranga (2017); Chaudhuri et al. (2018)
	<i>MSCF and Agility</i>	Supply chain agility, supply chain integration and MSCF	Giachetti et al. (2003); Narasimhan et al. (2006); Swafford et al. (2006a); Swafford et al. (2006b); Wadhwa et al. (2007); Swafford et al. (2008); Braunscheidel and Suresh (2009); Chiang et al. (2012); Purvis et al. (2014); Yang (2014); Fayezi and Zomorodi (2015); Fayezi et al. (2015); Tse et al. (2016); Um (2017); Um et al. (2017); Fayezi et al. (2017); Chan et al. (2017)
Capability: factors for MSCF	<i>Network Competence-capabilities and MSCF</i>	Impact of SC competences and capabilities' based on technological and knowledge-based resources on firm's responsiveness and performance; complementary/substitutive effects of SC competences and capabilities on performance	Clyde (1999); Bloss and Pillai (2001); Lin (2003); McLaren et al. (2004); Narasimhan et al. (2004); Bardhan et al. (2006); Lummus et al. (2006); Ling Yee and Ogunmokon (2008); Chan et al. (2009); Chen et al. (2009); Song and Song (2009); Hall et al. (2010); Indranil et al. (2010); Kristal et al. (2010); Grawe et al. (2011); Rogers et al. (2011); Devaraj et al. (2012); Malhotra and Mackelprang (2012); Jitpaiboon and Sharma (2013); Gligor (2014); Jin et al. (2014); Blomé et al. (2014); Shah and Sharma (2014); Liao and Marsillac (2015); Nehzat (2015); Seebacher and Winkler (2015); Rojo et al. (2016); Han et al. (2017); Mishra et al. (2018); Niranjan et al. (2018)
Purchasing: supplier management practices and MSCF	<i>Purchasing practices to increase MSCF</i>	Supply management practices such as multiple sourcing; long-term relationships and inventory buffers across supply network and MSCF	Kara et al. (2002); Barad and Sapir (2003); Tachizawa and Thomson (2007); Govindarajulu and Daily (2009); Stevenson and Spring (2009); Tachizawa and Gimenez (2009); Tachizawa and Gimenez (2010); Cachon and Olivares (2010); Gosling et al. (2010); Boonlua and Photong (2012); Ojha et al. (2015); Saenz (2017); Pereira et al. (2018)
Planning: tools for MSCF decision-making process	<i>SC planning for MSCF</i>	Mathematical models for MSCF planning; MSCF capacity management in production planning; supplier selection techniques and optimal order allocation for MSCF	Huchzermeier and Cohen (1996); Nembhard et al. (2002); Aprile et al. (2005); Kazaz, Dada et al. (2005); Keong et al. (2005); Balakrisnan and Geunes (2003); Bish and Wang (2004); Ferdows and Carabetta (2006); Dauzere-Peres et al. (2007); Francas and Minner (2009); Hasuike and Ishii (2009); Dulluri and Srinivasa (2009); Schütz et al. (2009); Zhang and Tseng (2009); Chou et al. (2010); Mansoornejad et al. (2010); Chou et al. (2011); Das (2011); Boulaksil et al. (2011); Bassambo et al. (2012); Kavitha and Vijayalakshmi (2013a); Kavitha and Vijayalakshmi (2013b); Kemmoe et al. (2014); Kesen (2014); Negahban et al. (2014); Kavitha and Vijayalakshmi (2015); Kazemian and Aref (2016); Kume and Fujiwara (2016); Chirra and Kumar (2018); Kulkarni and Francas (2018); Kumar et al. (2018)

KEYWORD COMBINATIONS: 1) “suppl* chain flexib*” AND “manufact* flexib*”, 2) “suppl* chain flexib*” AND “operation* flexib*”, 3) “suppl* chain flexib*” AND “production flexib*”, 4) “flexib* suppl* chain*” AND “manufact* flexib*”, 5) “flexib* suppl* chain*” AND “operation* flexib*”, 6) “flexib* suppl* chain*” AND “production flexib*” 7) “suppl* chain*” AND “manufact* flexib*”, 8) “suppl* chain*” AND “operation* flexib*”, 9) “suppl* chain*” AND “production flexib*”



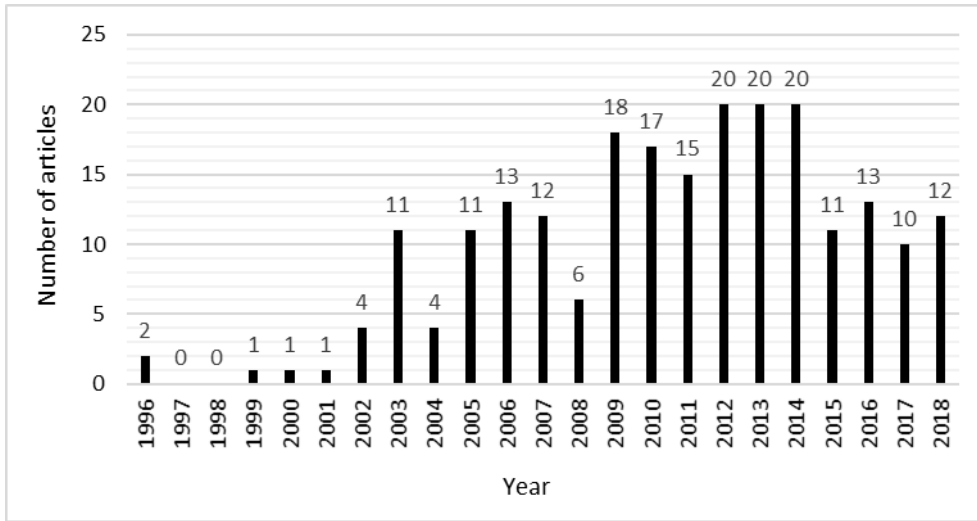


Figure 2. Number of Articles per Year in the Area of Manufacturing and Supply Chain Flexibility

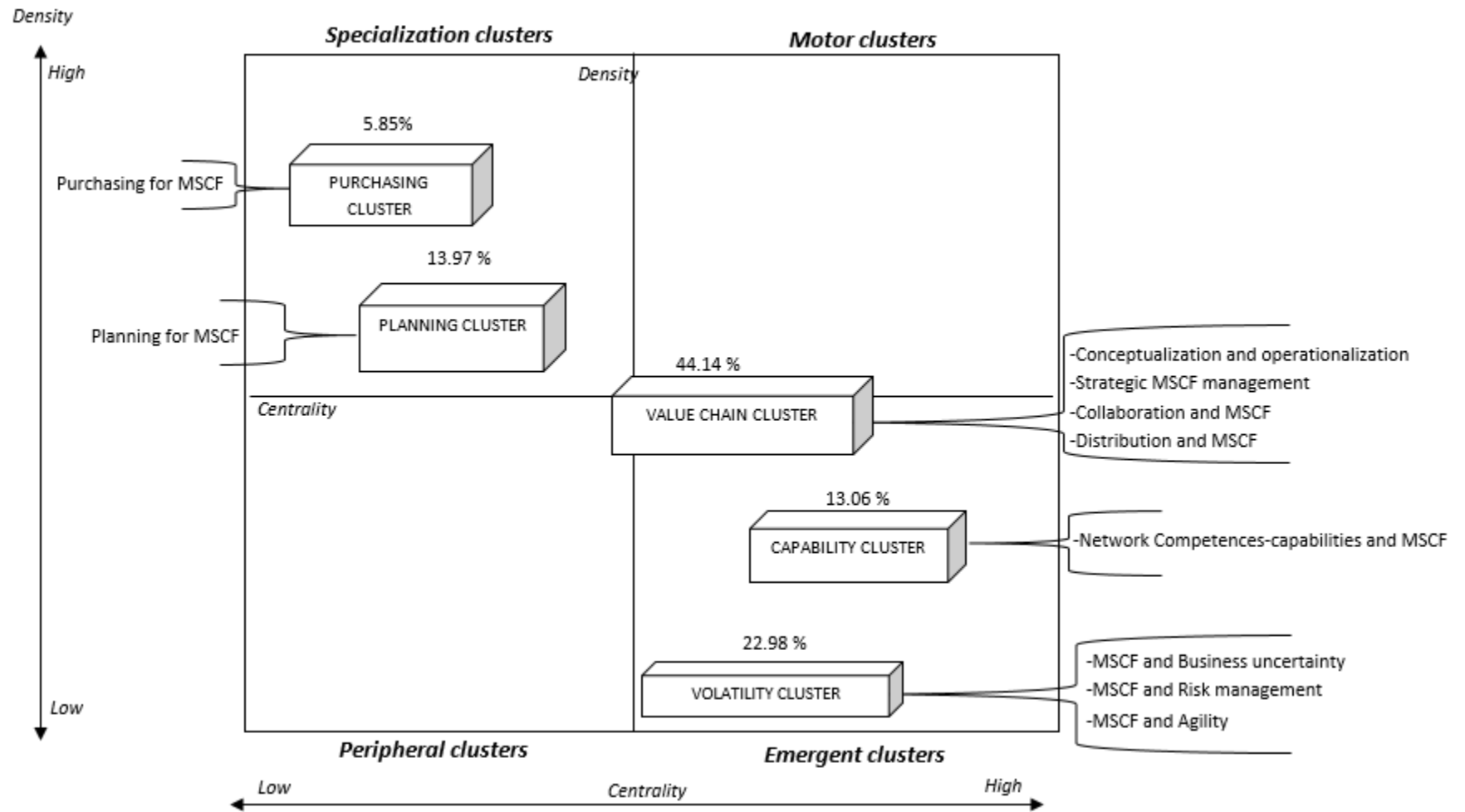
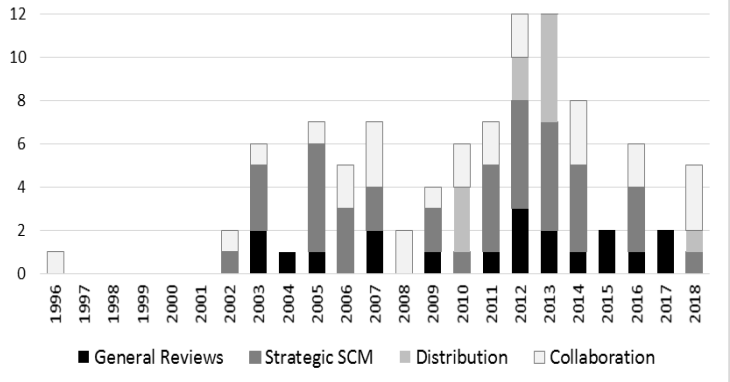
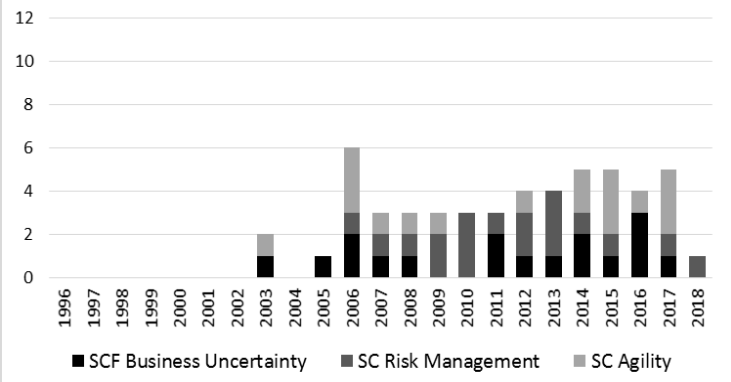


Figure 3. Strategic matrix, thematic clusters and research lines

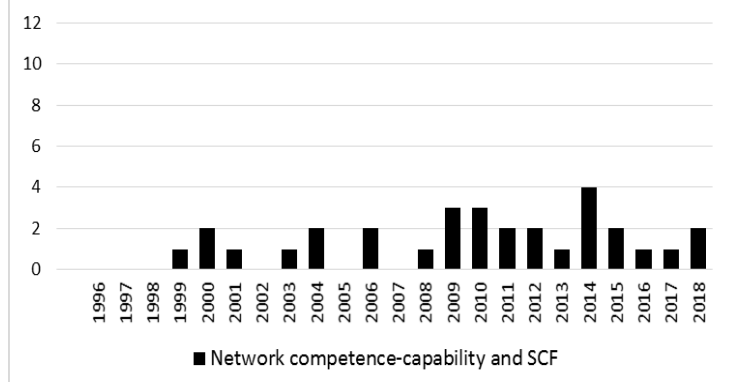
Value chain cluster



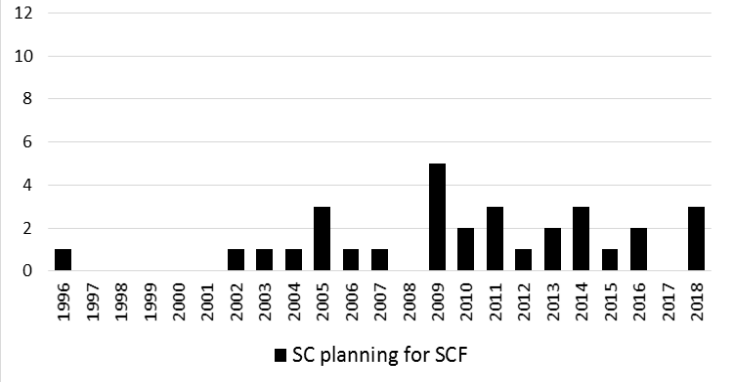
Volatility cluster



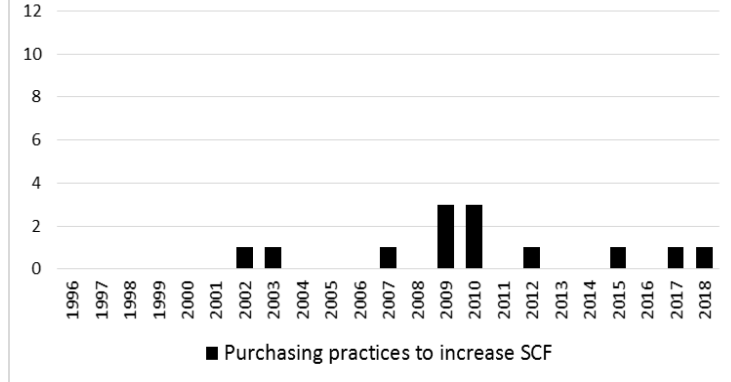
Capability Cluster

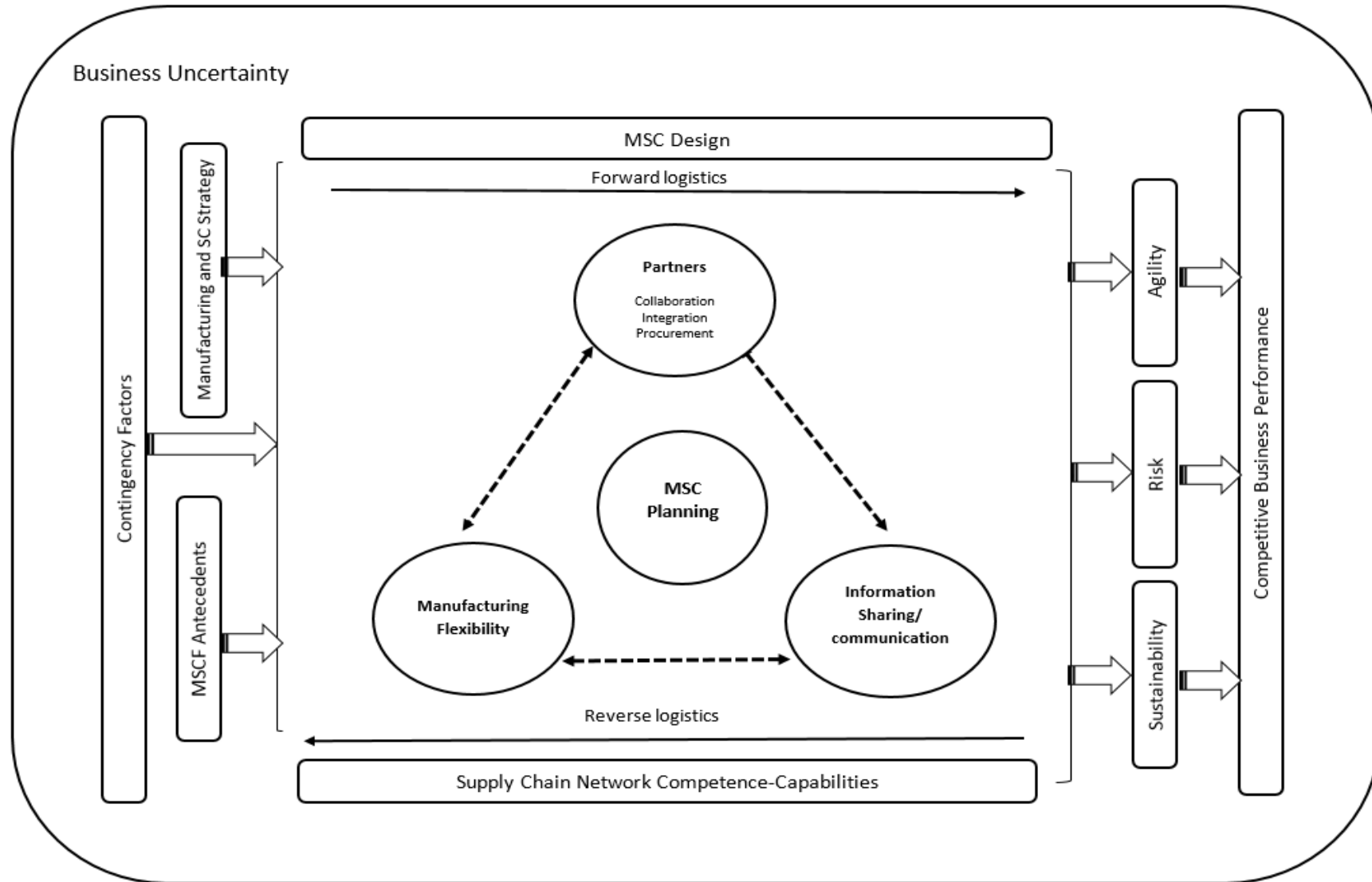


Planning cluster



Purchasing Cluster





Note: Manufacturing and Supply Chain (MSC); Manufacturing and Supply Chain Flexibility (MSCF)

Figure 5. Integrative framework

