Towards a conceptual model of manufacturing supply chain configuration for EU textile and apparel industry

Sara Harper (sara.harper@hb.se)
The Swedish School of Textiles, University of Borås, Sweden

Dr. Rudrajeet Pal
The Swedish School of Textiles, University of Borås, Sweden

Abstract

This article presents the development of a conceptual model for configuration of supply chains/networks for small series textile and apparel production, in contexts such as the EU. This configurational approach is needed due to the significant mismatch between current industry structures and the demand for small series production. The model, consisting of four elements with resulting themes and groupings, was developed through a systematic approach of the literature on the related types of production. The themes highlight the complexities and interdependencies that must be considered by managers. The linkages between the elements, in line with 3DCE, need to be further addressed.

Keywords: Supply Network Configuration, Textile and Apparel, Literature Review

Introduction

Competitive forces and Globalisation have led to extensive offshoring in labour intensive industries such as textile and apparel (T/A), in particular to exploit low labour costs (Appelbaum and Gereffi, 1994). However, with increasingly complex and global supply chains come challenges related to physical, and cultural distances (Stanczyk et al., 2017, Abbott, 2007). In reaction to these challenges, and for strategic benefits, reshoring has been observed in a number of industries, e.g. for flexibility and quality (Kinkel and Maloca, 2009). While reshoring has been observed in T/A (e.g. Gray et al., 2017, Robinson and Hsieh, 2016), it is considered unlikely that the majority of production will be reshored (Berg et al., 2017). However, premium products, in smaller numbers are possible to be produced competitively in higher cost locations (Martínez-Mora and Merino, 2014, Pal et al., 2017, Di Mauro et al., 2018).

However, in these labour intensive industries current configurations and capabilities are not sufficient to address this need. This is due to the focus on low cost mass production, economies of scale, and loss of capabilities/skills due to offshoring (Martínez-Mora and Merino, 2014, Gray et al., 2017). Thus, there is need for development of the capabilities and capacities in developed areas like the EU (Bontoux et al., 2017). This must be facilitated by understanding how the T/A manufacturing supply chain should be configured to competitively produce high value-added products in small series. Thus, a multitude of potentially relevant factors must be addressed to support managers

for this decision-making (Ketokivi et al., 2017, Pashaei and Olhager, 2015), necessitating a structured analysis.

The purpose of this paper is to develop a conceptual model that can guide supply chain/network configuration for T/A manufacturing in locations like the EU. This is addressed with the overarching research question:

- How should the supply network be configured for competitive textile and apparel production for EU based supply chains?

This is approached through a review of the diverse literature on small series production, with closely related demand-driven manufacturing and customisation. The motivation for addressing this literature together, is that focusing on one narrow topic would likely miss relevant trade-offs and considerations. The literature is unified and analysed using the definition and elements of supply network configuration (Srai and Gregory, 2008). This configuration approach provides a comprehensive structure, allowing for comparisons to be made. Additionally, the definition covers the notion of product-process-supply chain interdependencies (Fine, 2000, Fine, 1999), while enabling detailed analysis regarding supply chain structures and relationships. The analysis of the literature resulted in four models summarising the relevant themes which are instantiated through best practice industry cases. The identification of the themes and linkages between the elements of configuration provide guidance for EU decision-makers regarding reconfiguration and development of competitive localised supply chains. Moreover, gaps and opportunities for further research related are identified.

Supply Network Configuration

The concept and scope of supply network configuration (SNC), often referred to as supply chain configuration, overlaps in several ways with the considerations of supply chain management (SCM), and is closely related to supply chain design. Configuration, in the context of supply networks encompasses the structure of the constituent entities that make up the supply chain, linked in various ways (Srai and Gregory, 2008, Chandra and Grabis, 2016). According to Srai and Gregory (2008), SNC can be defined through four elements: (1) the network structure; (2) the main operations; (3) the roles and relationships; and (4) the value structure of the products/services. The four elements can be further defined by their main dimensions (Srai and Gregory, 2008). The structural element includes the overall network shape, including integration, complexity, coordination, and flexibility of the constituent operational processes together. The operational element includes the primary unit's activities, dynamics, levels of flexibility, and enabling IT systems. The relational element relates to the roles, and governance within and between the key partners. Finally, the value structure, relates to the composition, complexity of the products and services including demand characteristics and replenishment. Like Chandra and Grabis (2016) who position configuration as the calibration of the system elements to achieve product outcomes, Srai and Gregory (2008) discuss the need for SNC based on product segmentation. The process of defining these structures, dynamics and relationships in the supply network is a fundamental precursor for the coordination required by SCM (Chandra and Grabis, 2016, Fine, 2000).

Evident in the discussion of the definition and positioning of SNC, are the problems related to complexity. While much has been addressed related to supply chain design, and the building blocks of design, the influencers relevant to strategic planning, e.g. the offerings, business models and the overall environment have not been adequately addressed (Melnyk et al., 2014). Thus, many solutions to these design or configuration problems presented lack the ability to address real world needs, including high product variety (Chandra and Grabis, 2016, Song et al., 2018). The inherent complexity also

significantly affects re-design (Krægpøth et al., 2017), which according to Fine (1999) is required in industries with fast clockspeeds. Thus, the nature of the design or configuration problem is inherently dynamic due to increasing volatility (Christopher and Holweg, 2011, Melnyk et al., 2014). In particular, demand for agility is a significant driver of re-design and is required to overcome difficulties related to weak forecasting and various kinds of complexity (Krægpøth et al., 2017). Customer needs and behaviour (Godsell et al., 2011), and adaptability are suggested to be more significant than product architecture for these changes, contrary to literature (Fisher, 1997, Pashaei and Olhager, 2015). However, product portfolio complexity is found to be a significant barrier (Krægpøth et al., 2017), especially with a product-focus. Thus, dependent on the strategic focus of the company different difficulties need to be taken into account for the SNC to achieve and maintain fit with the required supply chain strategy.

To better understand the complexities and interactive relationships among the relevant physical, economic, social and psychological structures within the four elements of SNC, the 3DCE framework can be beneficial (Ellram et al., 2007, Fine, 2000, Fine, 1999). The value structure of products or services, encompassing the composition of the products including complexity, modularity, variety, service, and demand characteristics (Srai and Gregory, 2008), highlights the importance of product architecture with demand (Godsell et al., 2011). This element relates to the unit operations through the Product-Process linkages relating to technology and equipment, and encompasses the concept of concurrent engineering (Ellram et al., 2007). The value structure relates to the elements relating to network structure and relationships through the Product-Supply chain linkages, including concurrent decisions related to product architecture and make or buy decisions and early involvement of suppliers or customers (Ellram et al., 2007). The unit operations relates to network structure and relationships through the Process-Supply chain linkage, and encompasses interrelationships between manufacturing systems, make or buy decisions, logistics, inventory, and IT usage and information exchange amongst all the key members in the supply chain including customers (Ellram et al., 2007, Fine, 1999). Thus for a better grasp of these complex interrelationships, the elements of SNC should be addressed individually, in line with their main dimensions, and understood through their linkages.

Methods

The methods for development of the model for supply network configuration were based on content analysis for a systematic approach to the literature. The resulting literature was analysed based on the elements and dimensions of configuration. The resulting themes were used to analyse several exemplary best practice cases in the industry to ground the model in the industry context.

Literature Review

The review method was guided by qualitative content analysis standards proposed for systematic reviews to increase the quality of the findings. The four main steps to undertake qualitative content analysis are (Seuring and Gold, 2012, Mayring, 2008): (1) Material collection; (2) Descriptive analysis; (3) Category selection; and (4) Material evaluation. Basing the methods on the systematic approach to review literature was intended to ensure quality of the research, by providing better transparency and potential for inter-coder reliability (Seuring and Gold, 2012). For this, established definitions were used for categorisation, providing foundation for emergent themes, in line with the authors' recommendations for theoretical grounding with openness to unexpected results. Based on the specific purpose of the review, to develop a conceptual model, the general

descriptive characteristics of the articles are not as relevant as their relationships to the elements of configuration and subsequent emergent themes. Thus, the focus of the presentation is on the themes, rather than on the diverse body of literature itself.

The process of the literature search, with explicit inclusion and exclusion criteria can be seen in *Table 1*. The basic criteria of the literature search was that the documents were peer reviewed articles, published in journals, in English, published between the years 2000-2018. The limitation of 2000 was based on the emergence of articles addressing 3DCE after the first academic article on the subject (Fine, 2000).

Table 1 – Literature Search and Selection Process

Search criteria: Scopus Database		
Subject area: Business, Management and Accounting	Document and source type: Journal article Language: English	Year: 2000-2018
Search terms and strings: Title, Abstract, Keywords		
"supply chain" OR "supply network" OR "manufactur*" OR "producti*" OR "supply"; AND		
"small batch" OR "small lot" OR "small series" OR "lot size one"		93
"on-demand manufactur*" OR "purchase activated manufactur*" OR "demand driven manufactur*" OR "purchase driven manufactur*" OR "make-to-order"		278 *-1 dup.*
"customiz*" OR "customis*" OR "personaliz*" OR "personalis*" OR "individualiz*" OR "individualis*" →Further delimitation to inclusion of keywords dealing with manufacturing/production, supply chain (management), operations management, or customized products/production.		1722 752 *-26 dup.*
		1 096
Inclusion and exclusion process and criteria		
Documents from third string delimited to remove documents that used these terms incidentally when addressing other topics.	752 → 406	**777**
Exclusion criteria	**Inclusion criteria**	
Removed without potential contribution to at least three of the elements, as many exclusive focus on product development or operational issues.	Articles assessed for author's self-stated contributions and kept if significantly related to at least two of the four elements.	
→ Total 122	**→ Total 69**	
Several papers were added in based on their relevance to the context, supply network configuration for customization, and high cost competitive manufacturing.		**Total 75**

Though a complete list of articles cannot be included here, the journal that was most represented was *International Journal of Production Economics*, with 23 articles. The final list of articles were analysed based on the established definitions of the elements of network configuration, and related dimensions. The analysis was made individually within the elements, and regarding the relationships between the elements and dimensions, to comprehensively understand the emergent themes identified.

Industry Cases

As previously described, there is an inherent tension between the new requirements for small series production and traditional models focused on economies of scale and complex global sourcing. Despite the dominance of this traditional model, localised apparel production has been suggested as potentially fruitful (de Treville et al., 2017). Within this context, industrial practice is in some ways ahead of academia, like with the development and operation of these new types of business models and related supply chains. Thus, examples from practice were crucial additions, to better orient the configuration model and provide actionable understanding of the resulting literature. To identify notable examples in practice, a review of secondary literature was conducted. The identification of practical examples was done through exploration of:

- Relevant cases highlighted within academic literature, and others well documented in trade and business press.
- Industry related reports, like those presented by *McKinsey*, and through relevant EU projects like Education4FashionTech.
- News publications, industry specific and not, like *Business of Fashion*, *The Economist*, *The Guardian*.

The cases were sampled based on their relevance to the specific type of production, local, high-cost location, or small series, and being within the European context. The purposive sampling technique is not intended to be exhaustive but rather is used to instantiate the conceptual model in relation to best practice in the industry. Despite the possibility of neglecting some radical cases which have not been documented, there are significant benefits gained through analysing the characteristics of highly visible cases. In particular the analysis enables further gaps and opportunities to be identified.

Amongst the various sources, *Business of Fashion* with *McKinsey* were highly valuable in the process of highlighting the notable cases related to small series, European production. Prominent is the example of Zara, highly discussed in both business and academic literature due to the pioneering business model and related supply chain (e.g. Christopher, 2000). More recently, the innovative factory and production system piloted by Adidas in Germany has been extensively discussed in relation to the company's offerings and the individual technologies being utilised (Economist, 2017). Additionally, relevant within the discussion of unique or small series products is the technology developed by Unmade, used for their own brand and through numerous collaborations (O'Connor, 2018, Unmade, n.d.). The company's technological offering has been positioned as a solution to the difficulties in meeting demand for increasingly customised products at mass production costs, while maintaining high quality. Finally, Burberry's supply chain redesign through reshoring production is notable and was detailed in an academic article by Robinson and Hsieh (2016). Thus, the final cases are: (1) Zara: Small series production for quick response; (2) Adidas: Speedfactory, products and technology; (3) Unmade: Digital platform and knitted garments; and (4) Burberry: Local production and new business model. Additional documentation about these cases was compiled from various sources to get an overview of the relevant aspects for analysis.

Findings

The following findings are structured in line with the elements and dimensions of SNC (Srai and Gregory, 2008). The conceptual figures present the main groupings and resulting thematic items associated. In the figures, the different associations are visually distinguished by the type of lines linking the group to the emergent themes. Further, the text provides description of the themes and the different interrelationships with few representative references.

Value Structure of the Product/Service

As previously stated, the value structure element encompasses the product composition including complexity, modularity, and service, levels of variety, demand characteristics, and product replenishment modes (Srai and Gregory, 2008). Here the main dimensions addressed are the demand characteristics, variety and structure of the products, and the supply chain drivers of the products. The dimensions guided the development of the emergent themes presented below. The resulting themes are presented in *Figure 1*.

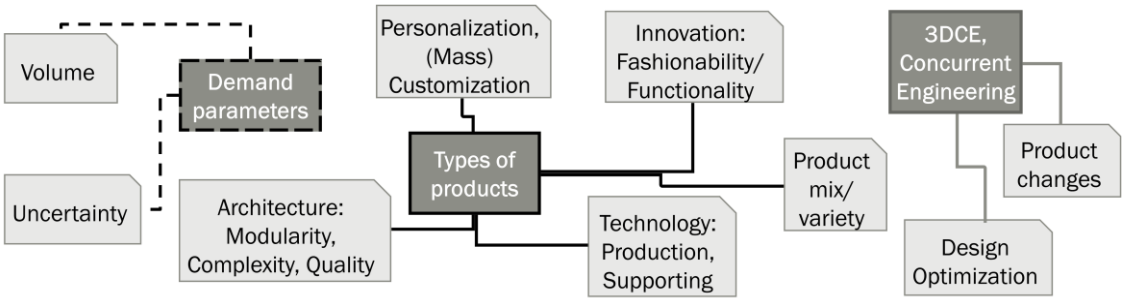

Figure 1 – Resulting Themes: Value Structure of the Product/Service

The literature contributions relating to this element have required groupings similar to the dimensions. The demand characteristics dimension has resulted in two *Demand parameters*, *Uncertainty* and *Volume*. Critical within the discussion of small series production is demand uncertainty, associated with different levels and types of personalisation offered, and moderating the mass customisation, customer satisfaction relationship. While, smaller demand volumes are key, a certain level of demand is required for certain strategies, e.g. custom and standard products in a flexible factory (Cattani et al., 2010). Specific to the products, the structure dimension resulted in a group of interrelated aspects associated with the *Types of products*. Including the type of innovation or combination of product innovation being offered, e.g. custom styling and/or functionality. This is closely related to the level and type of *Personalisation, (Mass) Customisation* being offered, which is also extensively defined in terms of product architecture and the questions related to quality, as well as being enabled by production and supporting technologies. The importance of enabling technologies is key with respect to the Zara, Adidas, and Unmade cases, whereas quality and authenticity is key for Burberry. Additional product level considerations related to the *Product mix/variety*, as high variety products that require responsiveness are appropriate, and as previously mentioned mixed customisation is suggested as a beneficial product strategy. Many of these considerations related to the types of products also act as supply chain drivers, and several of the articles have emphasised this interdependence. Thus, the other main group is related to *3DCE, Concurrent Engineering*, with particular focus on the interdependencies for optimisation and in relation to the level of product changes (e.g. Marsillac and Roh, 2014).

Principal Unit Operations

As discussed the operational element relates to the internal manufacturing processes, including all activities, value adding and non-value adding, the flow of material and information within and between the key unit operations, flexibility, replenishment dynamics, and supporting systems like digital infrastructure (Srai and Gregory, 2008). Here the dimensions addressed are related to the type of principal unit operations or main manufacturing system, and the dynamic of the processes and flows. The resulting themes are presented in *Figure 2*.

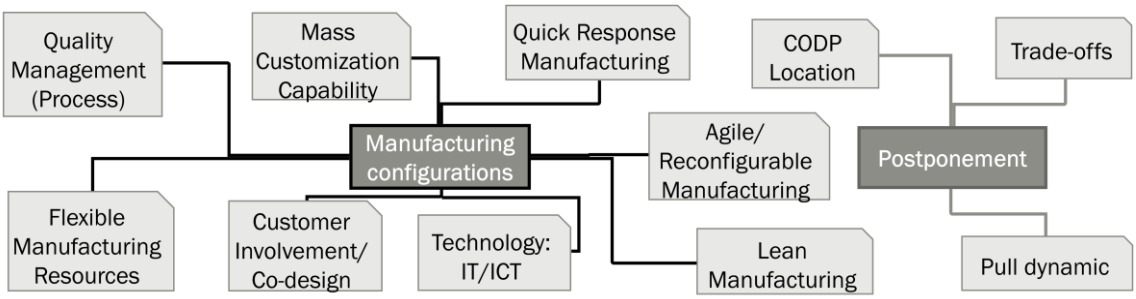

Figure 2 – Resulting Themes: Principal Unit Operations

Within the literature addressing the operational and manufacturing aspects, the types of unit operations discussed required groupings into different associated *Manufacturing configurations*, and *Postponement* with the accompanying benefits and decisions. Prominent in the discussion of the manufacturing system configurations are the different types of *Flexible Manufacturing Resources*, including machines, structures, workers and product aspects, requiring a balance with technology use and customer involvement for mass customisation (Salvador et al., 2015). Further emphasis is placed on the necessity for *Agile/ Reconfigurable Manufacturing*, which is described as requiring a *Lean Manufacturing* foundation but with more advanced enabling technologies, related to ICT. For Adidas flexible production and supporting technologies are highly important, and for Unmade the combination of knitting technology and their innovative platform enables automatic custom production. Additionally discussed is *Quick Response Manufacturing* with a focus on time based competition, which is highlighted in both the Zara and Burberry cases. Additionally discussed are general enablers and aspects associated with *Mass Customisation Capability*, like being strengthened by *Quality Management* practices (Kristal et al., 2010). The literature on manufacturing system dynamics focused on the *Pull dynamic* in general, and defining the location of the Customer Order Decoupling Point – *CODP*, and the resulting *Trade-offs* to be addressed with these decisions like lean vs. agile, and costs vs. benefits of customer involvement (e.g. Piller et al., 2004).

Supply Network Structure

The structural element relates to the shape and tiers of the network, including location, complexity, ownership, integration, coordination, flexibility, material and information flows (Srai and Gregory, 2008). Here the focus is on the structure and coordination both upstream and downstream, and the geographical location or spread of the activities. The resulting themes are presented in *Figure 3*.

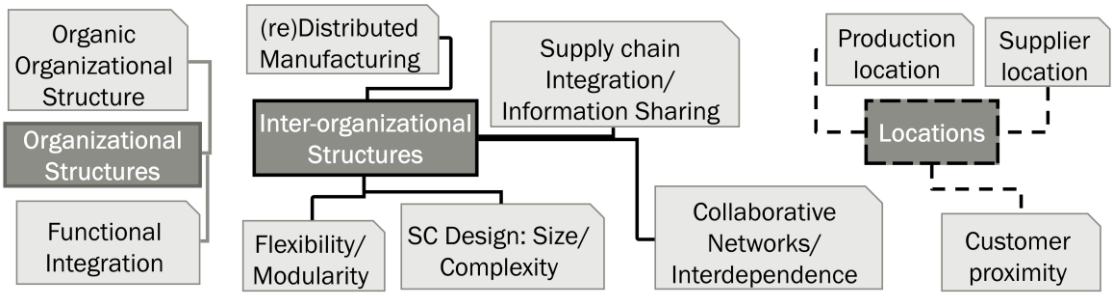

Figure 3 – Resulting Themes: Supply Network Structure

The structural aspects addressed within the dimension regarding structures and related coordination necessitated grouping into *Organisational Structures* and *Inter-*

organisational Structures, with closely related *Locations*. The change in organisational structures both within and between the actors can be seen to more distributed, collaborative, and organic structures (e.g. Srai et al., 2016). Further, the inter-organisational structures can be characterised by overall design, complexity, and level of flexibility in the structures and dynamics. Additionally, there is an emphasis on *Functional Integration* internally, which was also found to enhance integration and information sharing externally (Gu et al., 2017). Integration has also been emphasised for coordination and strengthening relationships. The locational aspects involved focus on the importance of *Customer Proximity*, however digital connectivity considered crucial (Da Silveira, 2011), and the location of suppliers and production (Martínez-Mora and Merino, 2014). Supplier proximity, to customers, is key for Zara's Quick Response, also for Burberry, and is the eventual goal of the Adidas Speedfactory, and Unmade business models.

Network Relationships

As stated previously, the relational element includes the nature of the interactions or transactions between the key network partners, including roles, inter-relationships, governance and trust, number and complexity, intra-firm relationships, and customer or supplier satisfaction measures (Srai and Gregory, 2008). Here the focus is on the types of relationships, roles, and governance within and between the partners in the supply network. The resulting themes are presented in *Figure 4*.

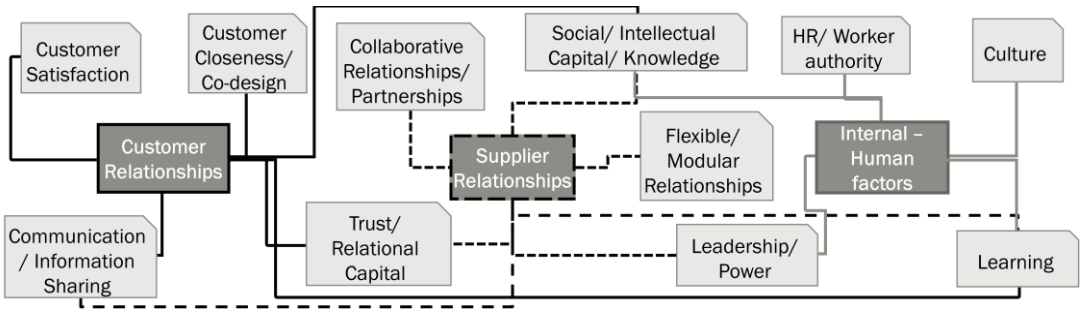

Figure 4 – Resulting Themes: Network Relationships

The variety of literature addressing the relational dimensions necessitated grouping into aspects related to upstream or *Supplier Relationships*, downstream or *Customer Relationships*, and the *Internal – Human Factors*. Notably very few articles specifically focused on the aspects of role or governance, instead focusing more on the types of relationships and relational characteristics, with particular focus on collaborative relationships. Collaboration is of significant importance for Unmade, and for Adidas to access technological competences like 3D Printing. Several of the relational aspects relate to more than one of the groups like trust, which is strongly related to other aspects with effects on all three relationship types, like *Communication/Information Sharing* as trust is required for and resulting from this level of openness (e.g. Shamsuzzoha et al., 2016). This openness is facilitated by leadership and power characteristics, and related to learning. Learning, related to close/collaborative relationships upstream and down, is enabled by worker authority which is of high importance (e.g. Yin et al., 2017), and associated with knowledge/intellectual capital. Cultural aspects can be significantly challenging when transitioning to collaborative inter-organisational practices. Further there is a strong emphasis on *Customer Satisfaction*, related to customer orientation, closeness and supplier involvement.

Concluding Remarks

In line with the literature, the findings further highlight the complexities, considerations, and interdependencies that must be taken into account for configuration of the textile and apparel supply chain/network for small series production. This, work addresses the need for more research in this area taking a larger picture view and providing support for managers. Specifically, the resulting emergent themes from the literature can provide guidance for managers for their supply network configuration and design decisions. While, the individual elements have been initially detailed here, the linkages between the elements of configuration must be addressed further.

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