Fuzzy cognitive maps approach for analysing the domino effect of factors affecting supply chain resilience: a fashion industry case study

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Abstract

The domino effect that occurs among the concepts that affect Supply Chain Resilience has only been marginally analysed, and no conceptual models have been proposed in the literature. In this work, a conceptual model for analysing this domino effect is developed. The method aims to identify which supply chain concepts can support the containment of disruptions and how these concepts affect one another. The proposed methodology is based on Fuzzy Cognitive Maps. The Cognitive Maps tool enables us to connect multidimensional and multidisciplinary concepts (e.g., sources of risk, disruption factors, supply chain management practices and other aspects). Moreover, this tool allows company managers to develop a detailed understanding of a system's behaviour and to explicitly consider the mind models of different players in the supply chain. A case study of the fashion industry supply chain is used to illustrate the application of the proposed method in an operating context. The proposed method enables a company to evaluate the hidden chain reaction of causes behind the most important factors that, from a single trigger event, are able to harm the entire Supply Chain. Through analysis of the causal relationships that this methodology highlights, decision makers can examine the domino effect among the concepts that influence Supply Chain Resilience in a step-by-step manner.

KEYWORDS: Supply Chain Resilience; Domino Effect; Supply Chain Management; Fuzzy Cognitive Maps; Fashion industry

1. Introduction

The increased density of global supply networks can lead local high-risk events to snowball in magnitude by damaging the critical infrastructure and, therefore, have regional or even global impacts (Ivanov et al., 2017). Many authors suggest that the disruption impact propagates further, even with amplification (Dolgui et al., 2017; De Sanctis et al. 2018; Vlahakis et al., 2018), among the nodes of a strongly connected supply network. The domino or ripple effect can occur when a disruption creates a chain effect downstream and upstream that impacts the performance of the supply chain (SC), rather than remaining connected to one part of the SC. The ripple effect analysis considers that disruption and recovery actions change the SC structural dynamics and impact the operations execution, while affecting the sales, service level and costs (Dolgui et al., 2018). Many authors agree upon the presence of this domino or ripple effect (Kinzig et al., 2006; Zhao et al., 2011; Scheffer et al., 2012) that is exacerbated by the increasing interconnection between companies.

In this uncertain environment, as Thomé et al. (2016) exemplify, the knowledge of connections between risk events becomes a driver for the development of a resilient SC. Resilience strategies lead to a constant state of readiness to respond to unforeseen events and an extended ability to respond and adapt to a changing environment, as well as to recover and adjust, returning to the state before the event or to a new and strengthened state. The literature broadly covers the study of relationships among the factors that influence Supply Chain Resilience (SCR). Zhao et al. (2011) focus more on a network perspective, stating that the supply network's resilience against disruptions lies in its ability to maintain operations and connectedness under the loss of some structures or functions. Many studies highlight those factors by conducting interviews with panels of experts and/or operators of the SC itself (Christopher and Peck., 2004; Pettit, 2008; Bueno-Solano and Cedillo-Campos, 2014). A research carried out by Ojha et al. (2018) provides a holistic measurement approach for predicting the complex behaviour of risk propagation for improved SC risk management.

What the literature lacks are the links between those factors. Sometimes, an event or factors that deviate beyond what is normally expected could be activated by a domino effect occurring among factors that seem to be very distant from the final event.

The key contribution of this research work lies indeed on developing a method for enhancing the analysis of the domino effect, by unveiling the causal and often hidden paths among factors influencing SCR, thus providing a novel representation of these patterns. A conceptual model is proposed for analysing the domino effect among multidimensional and multidisciplinary factors affecting the SCR. The proposed method is based on Fuzzy Cognitive Maps (FCMs) since they have a crucial role when connecting multidimensional and multidisciplinary concepts and when the concerned data are of an unsupervised type. In particular, the Cognitive Maps tool enables the connecting of concepts at many different levels (e.g., sources of risk, disruption factors, SC management practices and other aspects).

It is difficult, even for experts in organizational behaviour, to cognitively predict the causal effect of one factor on the others. FCMs are fuzzy-graph structures for representing causal reasoning. Their fuzziness allows hazy degrees of causality between hazy causal objects (concepts) and hereby lies the research approach novelty.

Indeed, this paper proposes the use of FCMs as a tool for creating metaknowledge and exploring the hidden implications of expert experience.

The conceptual model proposed in this work has been applied to a fashion industry SC. The domino effect analysis is interesting for this specific sector because the complexity of the current world economy has increased the degree of uncertainty of all fashion supply chain-related activities. The fashion industry SC is characterized by short product life cycles, volatile and seasonal demand, high product variety and long and inflexible processes (Resta et al, 2018). These factors can bring high uncertainty and complexity to the fashion industry, i.e., short product life cycles increase the challenge of new product development (Ciarapica et al., 2016).

To explain the research method, this paper is organized as follows: Section 2 reviews the extant literature and describes the factors affecting the SCR. Section 3 explains the FCM theory, while in Section 4, the research approach is described. In Section 5, a case study of a fashion SC is used to illustrate the application of the proposed method in an operating context. Section 6 summarizes the obtained results and the relevant discussion. Finally, Section 7 presents the study's conclusions.

2. Literature Review

Different empirical studies have been conducted to analyse the perspective of SCR, along with those of SC Robustness and business continuity theories. Ivanov et al. (2017) summarized the most relevant research on supply network resilience and disruption, outlining the existing definitions, measures and subject level of the analysis. Christopher and Peck (2004) offered a conceptual model to classify some sources of SC risks and suggested methods for overcoming those risks. Gunasekaran et al. (2015) introduced the relationship between complexities and proactive management practices in SCR, particularly due to global sourcing strategies. Munoz and Dunbar (2015) extended the understanding of operational resilience via a quantitative evaluation of multiple transient response measures across multiple tiers. Their objective was to construct a multidimensional, multi-echelon operational SCR metric. The study utilizes disruptions as the experimental inputs for a serial SC simulation model. Another example can be found in the work of Jain et al. (2017), who developed a hierarchy-based model for SCR, explaining the dynamics between various enablers and validating the model empirically. Recently, Ivanov et al. (2019) analysed the impact of digitalisation and Industry 4.0 on the ripple effect in the SC. This study investigated about existing relations between big data analytics, Industry 4.0, additive manufacturing, advanced tracking systems and SC disruption risks and how digitalisation can contribute to enhancing ripple effect control.

Concerning the fashion industry, there are abundant studies about risk management (Hon Kam et al., 2011; Freise and Seuring, 2015; Martino et al., 2015; Mehrjoo and Pasek, 2016; Choi and Ren, 2016). However, to the best of our knowledge, there is little research concerning the domino effect analysis among resilience concepts in the fashion industry. Torstensson and Pal (2013) discuss critical success factors in developing resilience in the textile sector, e.g., financial resources, relational networks, material assets, strategic flexibility, operational flexibility, continuous improvements, learning and cultural aspects. Recently, Costuleanu et al. (2015) focused on the relationship between SCR and a crucial social dimension of fashion sector employees, i.e., creative involvement and degree of wellbeing. Robles and Severson (2016) developed a 4-step conceptual framework (convergence of evidence, disruption simulation, scenarios evaluation, and options thinking) to perform a case study assessment of the resilience of a luxury fashion retailer.

Regarding the methodology proposed in this work, it is possible to highlight that FCMs have been used by other researchers to study systems resilience. Aleksic et al. (2013) assessed organizational resilience using fuzzy linguistic variables to express the relative importance of factors. Azadeh et al. (2014) made use of FCM to describe the causal relationships among the following nine factors of engineering resilience: teamwork, awareness, preparedness, learning culture, reporting, flexibility, redundancy, management commitment, and fault tolerance. Muller et al. (2012) used fuzzy architecture to assess critical infrastructure resilience, considering redundancy and adaptability primary components of infrastructure resilience. FCMs have never been used for developing a conceptual model to analyse SCR.

2.1 Factors Affecting Supply Chain Resilience

To identify the main factors affecting SCR, a literature review was conducted. The literature search was carried out in relevant literature databases, including Emerald, Metapress, Science Direct, Scopus, and Web of Science, using two sets of keywords. To find cross-sectorial research studies, the first set included the following keywords regarding only the topic: “Supply Chain”, “Resilience”, “Risk”, “Disruptions”, “Domino

Effect" and "Supply Uncertainties". The second set also included the fashion sector and its sub-sectors, as follows: "Fashion", "Textile", "Apparel", "Footwear", "Leather", "Jewellery", "Perfumes" and "Cosmetics", in accordance with the definition by Brun et al. (2008).

Subsequently, to both results, different filters were applied to select relevant studies constituting the core set of articles for selecting the main concepts to include in the cognitive map. The filters were defined as follows:

- Substantive relevance, defined as the adequacy of the articles to address and capture the investigated phenomenon, was ensured by requiring that the articles contain a keyword in their title, abstract or keywords;
- Only English-language articles were considered;
- The remaining abstracts were read to ensure substantive relevance;
- The remaining full articles were read to ensure substantive relevance.

No time limit or limit on publication type was adopted in these searches. Through the application of the first two filters, 95 papers were identified, of which 58 were defined as relevant (33 and 25 papers resulting, respectively, from the first and second sets of keywords).

In this study, the term "Factors" refers to different SCR aspects (Bevilacqua et al., 2018a). We aim at analysing the domino effect among multidimensional and multidisciplinary factors. Therefore, we summarized as "Factors" the sources of risk (e.g., terrorism, war, crises, blackouts, etc.), the conceptualizations of resilience (e.g., visibility, velocity, collaboration, etc.), other SC concepts (e.g., lean production, outsourcing, agility, etc.) and other aspects (e.g., organizational relationships, sustainable development, etc.). We list all the factors mentioned in the 58 selected articles (table 1).

INSERT TABLE 1 ABOUT HERE

Several authors have sought to identify factors positively or negatively affecting SCR. A noteworthy list was developed by Pettit et al. (2008). These authors connected SCR to capabilities and vulnerabilities, highlighting that SCR is achieved through not only the SC's capabilities but also, and primarily, by identifying a balance between capabilities and vulnerabilities. The vulnerability is the incapacity of the SC, at a given moment, to react to the disturbances and, consequently, to attain its objectives. Among the vulnerability factors there is the connectivity. This factor is related directly to the SC design and allows strong capabilities in the areas of collaboration, visibility, and flexibility to be created, thus contributing to balanced resilience through the management of interrelated operations between multiple tiers of suppliers and customers.

The literature review on factors affecting SCR allows us to highlight some aspects; some factors were cited many times more than others. Risk management, for example, was cited 7 times throughout all of the papers. In fact, risk management is seen as a key factor to both prevent and mitigate SC disruptions. Fostering a risk management culture among the top managers of the SC is seen as a key factor in increasing resilience. Among the vulnerabilities, “Terrorism” was the most recurrent and cross-sectorial; this threat was mentioned 8 times throughout all of the sources. Solano and Cedillo-Campos (2014) aimed, for example, to understand how the disruptions produced by terrorist acts affect the performance of global SCs. Boin et al. (2010) addressed an interesting aspect, i.e., the reaction of the government to these severe events. In fact, the special measures applied after such events can create a political-administrative context that makes it very difficult to meet SC challenges. Moreover, economic crises were cited many times. This aspect, similar to terrorism, has been a common denominator in all recent research, due to the recent financial events that have struck the globe as a whole. Another important factor arising is environmental sustainability. The keywords "environment" and "sustainability" were cited more than 9 times combined. This frequency can be attributed to the importance of this aspect in the fashion industry. The consumer’s growing sensitivity to environmental issues (Ivanov, 2017), combined with the high environmental impact throughout all the production phases of a fashion SC (Caniato et al., 2012), are becoming influential drivers of SC performance.

3. Materials and Methods: Fuzzy Cognitive Maps

FCMs can facilitate the description of causal knowledge in a specific domain since they allow the modelling of highly interconnected systems (Bevilacqua et al., 2018b). Analysing classes and the causal relations among them can help identify hidden connections between everyday factors of the SC and major disruptions.

FCMs provide a graphical model of the behaviour of a dynamic system through a graph representation. In the graph, concepts (entities, states, variables, and characteristics of the system) are represented as nodes, and the associations between the concepts are represented as weighted edges. Specifically, each weight indicates the degree of influence from the cause concept C_i to the effect concept C_j, ranging in [−1, 1]. The interconnections between concepts are defined according to experts' opinions through semi-structured interviews (Eden, 1988; Laukkanen, 1998) or input from documents and historical data (Axelrod, 1976). More detail on the method used to collect and analyse linguistic values is provided in Section 4. In this work, the interconnections are evaluated through linguistic values, and, for each interconnection, the experts' opinion has been aggregated using the t-conorm fuzzy inference method for the union of fuzzy sets. For this purpose, in the proposed procedure, the ***max(a,b)*** operator has been adopted (Veronesi and Visioli, 2003). As reported in Figure 1, if $\boldsymbol{\mu}_a(x)$ and $\boldsymbol{\mu}_b(x)$ are two experts' judgements, the collective judgement ($\boldsymbol{\mu}_a(x) \cup \boldsymbol{\mu}_b(x)$) is defined, for each x* value, as the maximum value between $\boldsymbol{\mu}_a(x^*)$ and $\boldsymbol{\mu}_b(x^*)$, represented by the composite figure with marked edge.

INSERT FIGURES 1 ABOUT HERE

The overall linguistic weight in Figure 1 is transformed into a numerical weight with the use of the defuzzification method of the centre of gravity (COG) (Lin and Lee, 1996). As an example, it is possible to analyse Figure 2. We can identify in (a) and (b) the fuzzified input 1 and 2 (i1 and i2), and the result is the grey trapezoid for each of them. The application of a specific fuzzy rule defines the output fuzzy set, represented in step (c), consisting of the union of the two fuzzified inputs (the grey composed shape). The black point represents the COG for the designed shape and its abscissa value (o1) is the numerical weight.

INSERT FIGURES 2 ABOUT HERE

Once defined the collective FCM, it is possible to evaluate the indirect and total causal effect (Axelrod, 1976), whose knowledge allows for a thorough map analysis. Starting from each FCM concept, all possible causal paths ending in the specified top-event have been identified to understand the relevance of the causal effect of a concept on another one: "$Ci \rightarrow C_{k1} \rightarrow \ldots \rightarrow C_{kn} \rightarrow Cj$" (see function "PathsIdentification" in Appendix 2).

Kosko (1986) refers to the Indirect Effect (IE) from Ci to Cj to calculate how the causality Ci impacts to Cj, and to the Total Effect (TE) of Ci on Cj to identify the most relevant causal path starting from Ci and ending in Cj. According to Kosko approach, in this work the indirect effect IE_k of concept C_i on concept C_j has been calculated as shown in Equation (2):

$$IE_k(C_i, C_j) = min\{r(C_p, C_{p+1})\} \qquad (2)$$

I_k is evaluated as the minimum number of the e_{ij} weight along with a single path from the i-th to j-th concepts, and p and p+1 are contiguous left-to-right path indices.

The total causal effect $TE(C_i,C_j)$ (Equation 3) is otherwise evaluated as the maximum of the indirect effect of concept C_i on concept C_j, i.e., as the most difficult of the weakest connections between the i-th and j-th concepts.

$$TE(C_i, C_j) = max\{I_k(C_p, C_{p+1})\} \qquad (3)$$

Hence, the indirect effect amounts specify the weakest causal link in a path and the total effect operation amounts to specifying the strongest of the weakest links (Kosko, 1992). The IE and TE calculus has been carried out through the function "IndirectTotalEffectCalculation" realised in Matlab (see Appendix 3).

4. Research Approach

The structured research approach proposed in this work consists of 2 phases divided into steps as shown in Figure 3.

The first phase, the "Development of a Cognitive Modelling Group", aims at defining a general framework that can be applied to every SC. This framework identifies the most important SC concepts and how these concepts affect each other and the SCR.

The second phase, "Development of an FCM", is developed for analysing a specific SC, and it allows SC managers to identify several paths that are a concatenation between concepts towards the top event (i.e., Supply Chain Resilience) and that formulate SC design strategies to increase the SCR.

INSERT ABOUT HERE FIGURE 3

The first step of the proposed method, i.e., "Problem identification", is necessary to define the scope and the focus of the analysis and to set all the relevant parameters of the model.

The second step, “Literature Research”, is based on the research in the extant literature, and it aims at identifying all the factors that influence the SCR and analysing how these factors affect it.

A “Taxonomy” step is necessary to group these factors. All factors must be clustered into a small number of concepts for two reasons:

1) many of the factors refer to similar topics (for instance, “Product Differentiation” and “Product Variety”); and

2) it is important to develop a shorter and more comprehensible questionnaire for experts. Experts must identify causal relations between concepts when completing the questionnaire. Since the length of the questionnaire could affect the likelihood of receiving incomplete questionnaires from experts, to reduce such likelihood, the research should focus on only a few concepts that influence the SCR.

A panel of experts, called the Cognitive Modelling Group, carries out the “Taxonomy” step according to the Delphi approach. A methodology based on a research group is chosen for its ability to produce more in-depth information through interactive discussion (Goldman, 1962).

In the step called “FCM Design and Refinement” (figure 3), the Cognitive Modelling Group identifies the links existing among the concepts outlined during the taxonomy step to build the cognitive maps and the adjacency and fuzzy weight matrix. As stated above, the FCM method is based on expert opinion, and these experts shape the world as a collection of classes and causal links between the classes. An FCM can describe the SCR using a model with signed causality that indicates the positive and negative relationships between SC concepts (Bevilacqua et al., 2018a). This step highlights both the direction and nature of the causality.

The final step, “Simulation with designed FCM”, is necessary to obtain an information system. An input vector is used in the FCM, and the result is opportunely processed so that it can be analysed by experts. The causal links are dynamic, where the effect of a change in one concept affects other nodes, which, in turn, may affect other nodes. The proposed method, based on FCMs, allows a company to evaluate the indirect and total causal effects among SC concepts. This is a key added value to the current state of the art regarding SCR.

5. Case Study

This paper focuses on a SC of the fast fashion apparel industry, which has changed greatly over the past decade. The business of the companies involved in this market is becoming increasingly complex and dynamic due to the increase of competitors; the market pressure in this sector is, in fact, constantly increasing, especially on the retail side (Mustafid et al., 2018), while demand volatility brings additional complexity to the entire SC in terms of bullwhip effect. In this context, a recent research (Dolgui et al., 2019) showed that the ripple effect influences the bullwhip effect through backlog accumulation over the disruption time as a consequence of non-coordinated ordering and production planning policies.

The case study of a fast fashion SC is used to illustrate the application of the proposed method in an operating context. In particular, the present case study is focused on the clothing industry. This industry, among the others cited, is characterized by a complex Supply Network since many businesses are involved in the production activities, and the SC actors are characterized by a high-grade fragmentation and critical geographical dispersion (Antomarioni et al., 2017).

In this work, to exemplify the most important aspects of the case study, while maintaining enough detail to represent the complexity, 4 tiers have been chosen to analyse the crucial steps along the SC, from the choice of the raw material to the delivery of the product to the final customer.

The key actor in the present case study is the manufacturer, as portrayed in the current industrial trend of the textile market, and the other actors were chosen accordingly to its business relations. The first actor, the tier one supplier, is a widely renowned producer in its field and is the manufacturer's main leather supplier. The remaining two actors are the manufacturer's main downstream business partners, both of which are involved in the shipping and retailing. Figure 4 shows the specific SC chosen, while table 2 provides a description of the SC players analysed in this case study. These players are selected because they are responsible for the greater mutual trade.

INSERT FIGURE 4 AND TABLE 2 ABOUT HERE

5.1 Development of a Cognitive Modelling Group

The literature review, as highlighted in Section 2, generates a massive amount of data, and more than 100 different factors (table 1) are identified. In the "Taxonomy" step, all these factors are clustered into a few concepts. According to the research approach proposed in section 4, the taxonomy of factors that affect the SCR is built on the extant literature and then refined and validated by a Cognitive Modelling Group following the Delphi method criteria. In particular, in this work, the group is made up of two academics whose research mainly focuses on SC Management and three managers for every player in the examined SC (14 people for the case study analysed in this paper). Taking into consideration the multidisciplinary competencies required for company managers to develop a cognitive map, the three managers are selected from different company functions, as follows: SC management, marketing and administrative functions. This ad hoc panel is created to encourage communication and meetings, during which the members can contribute their knowledge of the processes.

The first activity of this group is to identify concepts to be included in the cognitive map. The factors list (table 1) is given to the panel of experts. The instructions are to regroup the factors into a few concepts in an efficient way. The optimal breakdown point should be a number high enough to maintain the level of detail but low enough to make the analysis simple. A consensus is reached after three iterations of the Delphi analysis with the identification of 29 concepts (table 3). A "top event" is described as a single event that is influenced by all other events. In this case, the top event is the concept "Supply Chain Resilience" (C30).

INSERT TABLE 3 ABOUT HERE

5.2 Development of a FCM

In the "FCM Design and Refinement" step, the Cognitive Modelling Group identifies the links existing among the concepts outlined during the taxonomy step to develop the cognitive maps (see figure 5), the adjacency and fuzzy weight matrix.

INSERT FIGURE 5 ABOUT HERE

The Cognitive Modelling Group defines the relationship weight between every pair of linked concepts. This step is carried out through interviews and questionnaires submitted to the Cognitive Modelling Group. The Cognitive Modelling Group is asked to define the relationships among concepts using linguistic variables and according to a Likert scale of ten values, in which 0 means no correlation and therefore is associated with no answer. For instance, the first question was: “what is the relationship weight between "Operation management strategies" and all other concepts? This question has been reformulated for every concepts (29 times) in order to evaluate how each concept affect one another. Table 10 in appendix 4 is an excerpt from the questionnaire provided for the managers. Specifically, table 10 refers to the first question.

The strengths of the causal relationships take fuzzy linguistic variables (figure 6). In addressing a decision-making process, the Cognitive Modelling Group is often faced with doubts, problems and uncertainties. Referring specifically to SCR, this uncertainty means that, for instance, the strength of a certain relationship concerning two concepts often cannot be precisely defined, the decision-maker is unable (or unwilling) to express his preferences precisely, and the evaluations or opinions are expressed in linguistic terms. To address this type of uncertainty correctly, we can resort to fuzzy logic (Zadeh, 1965). There are various types of fuzzy sets, each of which may be more suitable than others for analysing a given ambiguous structure; the present analysis uses triangular fuzzy sets. The triangular fuzzy sets play a specific role since it appears as the natural fuzzy counterpart to uniform probability distributions on bounded intervals. In particular, as asserted by Pedrycz (1994), the cuts of a triangular fuzzy set contain the “confidence intervals” of a symmetric probability distribution with the same mode and support. For these reasons, triangular fuzzy sets are often used to quantify linguistic data. The use of triangular fitness functions is fairly common in the literature (Karsak, 2004; Chan, 2005), as triangular fuzzy sets are among the few forms of fuzzy sets that are easy to manage from a computational point of view, yielding the optimal distribution-free confidence intervals for symmetric probability distributions with bounded support.

INSERT FIGURE 6 ABOUT HERE

The proposed linguistic values for the same interconnection are aggregated using the SUM method (Veronesi and Visioli, 2003) and they are transformed to a numerical weight using the defuzzification method of the

COG (Lin and Lee, 1996). The fuzzy weight matrix obtained in our fashion SC is shown in table 4. The results obtained from the "Simulation with designed FCM" step is presented in the next section.

INSERT TABLE 4 ABOUT HERE

6 Results

The first analysis conducted is aimed at sorting the nodes by the paths, starting from each node. We obtained 33822 paths. The most connected concept is "External Financial Risk"; 5428 paths start from this concept and end up with the top event "Supply Chain Resilience". The concepts called "Market volatility" and "Deliberate threats" follow "External Financial Risk" in the shortlist of concepts ordered by importance, which are associated with 3544 and 1776 paths, respectively.

The main aim of the simulation analysis is to unveil the concatenation of events towards the top event (i.e., "Supply Chain Resilience"). The most relevant paths of concepts within the route that leads to SCR can be highlighted by sorting the Indirect Effects (IEs). In particular, the most important paths (with an Indirect Effect higher than 0.6 or lower than -0.6) have been reported in table 5 with reference to the overall SC. This approach aims at analysing the domino effect among SC concepts. The selection of the levels ($|IE| \geq 0.6$) is only due to the necessity of reducing the paths set to have more readable tables, paying attention to the most critical paths (considering an evaluation range from -1 to 1). The experts have chosen |0.6| as threshold value since, according to the defined Likert scale, the majority of the identified paths have values lower than |0.4|, which represents the non-critical area for the analysed problem.

INSERT TABLE 5 ABOUT HERE

In appendix 1, the most important paths (with Indirect Effects higher than 0.6 or lower than -0.6) with reference to the SC players analysed in this work are shown. In particular, tables 6-9 highlight the domino effect of concepts affecting every player of the SC.

6.1. Results Analysis

The first path of table 5 (Path #1) is directly linked to the top event “SCR”. “Operation Management strategies”, with an IE of 0.74, is the most relevant concept for the SC analysed in the case study. Almost all the SC players highlight that adopting Operation Management strategies, such as lean production techniques, is fundamental to maintain a flexible supply chain and, therefore, a SCR; this can be observed by looking at the tables of the principal paths of the tier-one supplier and manufacturer actors (table 6 and table 7, respectively), in which the “Operation Management strategies” path stands out with an IE of 0.87. The relationship between Lean Production and SCR has been widely studied in the literature. Our results disagree with those obtained by Soni et al (2014). These authors stated that more lean and just-in-time SC networks have reduced the slack available to handle uncertain events and that doing so reduced SCR. On the other hand, Carvalho et al. (2011), highlighted that trade-offs between lean, agile, resilient and green (LARG) management paradigms are actual issues, and may help SCs to become more efficient, streamlined and sustainable. Managers of the tier one supplier and manufacturer analysed in this work believe that the efforts to achieve leanness or agility may help the efforts to achieve resilience. The direct interviews with managers highlighted that they consider lean practices as a way of deleting all waste, including time, and enabling a level schedule. A level schedule means that the manufacturing process must be kept away from volatility, uncertainty and variation.

The path “Fast fashion”-> “Flexible sourcing”-> “SCR” (table 5, Path #2), with an IE of -0.73, is also ranked at the top of the path list in Table 5. This result agrees with many authors’ research stating that “Fast Fashion” is a key characteristic of the modern fashion industry (Escalona Orcao and Ramos-Pérez, 2015; Mehrjoo and Pasek, 2016; Mehrjoo and Pasek, 2014). Moreover, this result highlights the following two aspects: 1) “Fast fashion” negatively affects the SCR and, moreover, 2) “Fast fashion” is the starting node of the path and is connected to flexibility concepts. For instance, the Manufacturer highlights the domino effect of “Fast fashion”, “Flexibility in order fulfilment” and “Manpower unavailability” (table 7, path #3). The classic assembly line, albeit adapted to the fashion industry, is no longer effective in a rapidly changing world. All the features that make fashion a "fast" sector require not only the least amount of time available to industrialize and produce a product but also the complexity and refinement of the finished product. The direct consequences are always new work cycles, new materials, the supply of complex accessories and semi-finished products.

Therefore, a flexible production structure is crucial to efficiently address sudden turnarounds of the market in a timely manner. This is also true for the final ring of the SC, i.e., the retailer. In fact, the paths "Fast Fashion – Flexible sourcing – SCR" (table 9, path #2) and "SC Vertical Integration Degree - Flexible sourcing- Fast Fashion -SCR" (table 9, path #6), both have IE values lower than -0.78.

The paths "Natural Phenomena – Materials Flow Interruption – SCR" and "SC Length – Materials Flow Interruption – SCR" follow with IE values of -0.71 (Paths #3 and #4, Table 5). This result shows that these two concepts contribute negatively to the SCR. A natural catastrophe can seriously damage the everyday activity of the SC. Moreover, a significant SC length can increase the probability of such disruptions occurring. Trivially, the more actors that compose the SC, the greater probability there is of one or some of them being hit by a disruption. This result shows that the Natural Phenomena concept is a concern to the shipper SC actor, which evidently must keep the Material Flow running to be resilient in the SC context (table 8 path#2). Examining Table 5, it can be observed that "Material flow interruption" is the last concept linked to SCR in 10 paths (3, 4, 12, 14, 16, 17, 18, 19, 20 and 22). This confirms that in this industry sector, it is critical for all actors to contribute to a timely delivery of products to keep pace with the current fashion trends.

The market position of a company is also fundamental (table 5, path #5). Brand attractiveness and internationalization are at the core of the fashion industry, and the brand of a company can increase and maintain high SCR. This result agrees with many studies affirming the importance of this factor for the fashion industry (Martino et al., 2015).

Moving forward in Table 5, "Sustainable development" is the starting node of path #6 "Sustainable development-Media and public opinion-Market Position-SCR" (IEs equal to 0.68). Therefore, the concept "Sustainable development" activates a path that positively contributes to the SCR. Sustainable development, in fact, represents an increasing issue that must be addressed by the fashion industry actors due to the current market trends and consumer behaviour (Macchion et al., 2015; Şen, 2008; Mehrjoo and Pasek, 2016).

This result is also aligned with paths #7-10, where "Media and public opinion", "Technology development", "Counterfeit" and "Deliberate threats" along with "Market Volatility" are all linked to "Market Position", before connecting to "SCR". Observing the results shown in Tables 7 and 9, it can be noted that the concept of "Market Position" is crucial, even from the point of view of the manufacturer and retailer; in fact, it is directly linked to SCR, with IE values of 0.87 and 0.90, respectively.

Another interesting aspect can be observed when analysing paths 21, 22, 23, and 24 in table 5: in each path, "Market Competition" is the starting node of many concepts that form the paths connecting to SCR. This result confirms that the factor of competition is preponderant in the fashion industry (Vaagen and Wallace, 2008; Wang et al., 2012; Dewi et al., 2015) and highlights that market competition can strongly influence the SCR of a fashion company. In particular, path #23 shows that increasing the market competition will positively affect the technology development and this enables companies to use more sophisticated tools and models in operations management and improve the overall SCR.

The last paths in table 5 (paths #25-#27) show the link between uncertainty and risk. The uncertainty of demand ("Market Volatility"), increased use of complex global supply networks ("SC length"), and "Institutional Policies" are drivers of risk exposure.

7 Discussion

When a researcher wants to study the SCR, he must deal with some main problems, as follows:

- First, the SCR is connected to concepts and factors at many different levels that belong to disciplines often distant from each other, as follows: the sources of risk (e.g., terrorism, war, crises, blackouts, etc.), the conceptualizations of resilience (e.g., visibility, velocity, collaboration, etc.), other SC concepts (e.g., lean production, outsourcing, agility, etc.) and other aspects (e.g., organizational relationships, sustainable development, etc.). There is a lack of scientific literature or useful objective data to correlate these factors using traditional statistical tools or through other techniques, such as system dynamics. Despite this lack of objective and numerical data, it is undeniable that there are links between some factors that must be considered and that refer to different sectors (for instance, between "governing restriction" and "material flow interruption" or between "operation management strategies" and "market competition", etc.).
- In addition, in some cases, the activation of some factors could trigger other factors, and this could generate a ripple or domino effect. Even this aspect, although it is not easy to analyse for the same reasons expressed above, can be vital to be understood for company managers to guarantee the survival of the entire SC. The goal is to prevent the triggering of factors that have a domino effect on the SCR.

- Moreover, we are dealing with the analysis of resilience not only of a single company but of an entire SC. This creates a further research challenge because every single company that is part of the SC could have different factors and disruptions that impact its own resilience, and they could present specific paths of factors that lead to a different domino effect. We have to find a methodology for evaluating both the factors that impact a single company and those that impact the entire SC, analysing the specific paths and then integrating the specific problems of individual companies to have a comprehensive view of the whole SC.

This work has tried to answer these problems by developing a methodology that aims at defining a general framework that can be applied to any SC. The proposed approach can allow company managers to identify the most important SC disruptions and to define SC design strategies to increase system resilience through a different approach from those cited in the literature review. First, this approach ensures results consistency with a two-step validation method consisting of a literature review and panel of expert's review when listing the factors and then the concept subjects of the research.

Second, this approach, through the FCM model, offers a tool to overcome some specific problems (previously highlighted) in the development of the SCR. The FCMs have never been used before in this research area and with these objectives. In particular, the use of FCMs allowed us to overcome various obstacles, as follows:

- FCMs allowed us to connect a large number of different multidimensional and multidisciplinary factors and to give a weight to this link.
- In addition, FCMs highlighted the chain reaction of causes behind the most important concepts able to harm the entire SC through the use of an Indirect Effect (IE). These chains of concepts define the paths that we have identified in the article as a "domino effect". The FCM is used for analysing a specific SC, and it allows SC managers to identify several paths that are concatenated among concepts towards the top event (i.e., "Supply Chain Resilience") and formulate SC design strategies to increase the SCR.
- The FCM methodology allowed us to carry out both the evaluation of the pathways of a single company (tables 6-9) and to integrate the information obtained from the companies to perform an assessment of the domino effect for the SC as a whole (table 5). This approach provides a detailed understanding of the behaviour of the system and allows us to explicitly take into account the mind models of different players in the SC.
- Moreover, the contribution of all the players' points of view can add a new approach to SC problems, disruptions or solutions. The cognitive map allowed us to obtain a graphical and mathematical representation

of a manager's belief system. Different situations activate a part of the belief system (i.e., the set of concepts and relationships) of a manager, which appears to be relevant to the issue. The map describes the conscious perception of reality, i.e., the way in which a SC player considers a particular situation or a particular problem. Specifically, the FCM approach helps analysts effectively model complex systems that show causal relations between relevant concepts and allows for the management of inherent uncertainties.

8 Conclusions

The core contribution of the proposed paper is the development of a practical tool to unveil hidden domino or ripple effect paths among factors affecting SCR. Through a guided process, a panel of experts is established to analyse in depth a specific issue, concerning different expertise areas such as manufacturing, production and operations management in order to model an overall and collective mental model to be examined. The proposed framework identifies the most important SC concepts that support or affect SCR and how these concepts affect each other. This paper offers an application of this methodology through the analysis of a fashion industry case study. This case study highlighted the potential of cognitive maps in their explanatory and reflective functions and their support of decision making in SC design. The analysis conducted in this study can unveil the concatenation between events towards the top event (i.e., SCR) unknown to the experts in a specific field.

The information collected through this analysis can be used as both a basis for defining SC design strategies and as a guide for the negotiation process aimed at reducing the existing levels of disruption and improving the mitigation measures to be taken.

The further research is focused on two directions, as follows:

- Identification of cycles among the principal paths, and how these cycles are connected to each other. A cycle is a course or series of concepts that recur regularly in the FCM. The presence of a cycle indicates a recursive domino effect that can bring a positive or negative effect on the SCR. Moreover, these cycles can be connected to each other and the activation of a cycle can trigger another one. The definition of links among those cycles can break the negative ones or enforce the positive ones.
- The discussion of the results of this paper highlights how the expertise area of each member of the panel affects the concepts identification and the strength of the relationships. Thus, it will be crucial

to provide a mechanism to properly evaluate the experts' knowledge effect on the FCM realization, taking into consideration a different credibility value for each expert judgement according to their experience in the topic.

Appendix 1 - Tier-one supplier, Manufacturer, Shipper and Retailer principal paths

INSERT ABOUT HERE TABLES 6-9

Appendix 2 - The hidden paths identification function

All possible causal paths ending in the specified top-event have been identified through an algorithm implemented in Matlab. In this work, the top-event concept (SCR) represents the target concept for the analysed issue. The final result is the variable hidden_paths containing all the identified FCM hidden paths.

```
function hidden_paths=PathsIdentification(adjacent_matrix,top_event)

% Begin: all the one-to-one connections are identified
[r c v]=find(a~=0);
arches=[r c];
[val ind]=sort(arches(:,1));
arches=arches(ind,:);
% end
% System output initialisation
hidden_paths=[];

% all paths starting from each node are analysed
for node=1:size(adjacent_matrix,1)-1
    AMapp=adjacent_matrix;
    [r c v]=find(AMapp~=0);
    OneStepNode=[r c];

    % Condition 1: All the paths starting from the top event node are omitted
    % Begin Condition 1
    [r c v]=find(OneStepNode(:,1)==top_event);
    OneStepNode(r,:)=[];
   % end Condition 1

    paths=OneStepNode(OneStepNode(:,1)==node,:);
    n=size(paths,1);
    [r c v]=find(paths(:,end)~=0);
```

```
% Condition 2: all of the one-step nodes not ending in the top_event one are valued
% Begin Condition 2
[r c v]=find(paths(r,end)~=top_event);
% end Condition 3

% Condition 3: it is prevented the possibility to identify more times the same path
% (relevant in case of cycles identification)
% Begin Condition 3
AMapp(node,:)=0;
AMapp(:,node)=0;
% end Condition 3

paths1=[];
while not(isempty(r)) % the procedure is applied until one-step node are identified
    for j=1:size(paths,1)
        [r1 c1 v1]=find(AMapp~=0);
        OneStepNode=[r1 c1];

   % Begin Condition 1
        [r2 c2 v2]=find(OneStepNode(:,1)==top_event);
        OneStepNode(r2,:)=[];
        % end Condition 1

        EndNode=paths(j,end);
        if EndNode~=0 && EndNode~=top_event
            [r3 c3 v3]=find(OneStepNode(:,1)==EndNode);
            replications=length(r3);
            app=[repmat(paths(j,:),replications,1) OneStepNode(r3,2)];
            [r4 c4 v4]=find(arches(:,1)==EndNode);
            if not(isempty(r4))
                AMapp(EndNode,arches(r4,2))=0;
            end
        else
            app=[paths(j,:) 0];
        end
        paths1=[paths1;app];

    end
    paths=paths1;
    paths1=[];
    [r c v]=find(paths(:,end)~=0);

    % begin Condition 2
    [r c v]=find(paths(r,end)~=top_event);
    % end Condition 2

End
   % The previous iteration paths are concatenated to the new ones
   hidden_paths=concatenation([hidden_paths;paths]);
```

```
end
```

Appendix 3 - Indirect and Total Effects calculation function

In order to implement equations 2 and 3, the following Matlab code has been realised taking as input variables the weighted FCM matrix and the hidden paths matrix obtained by the “PathsIdentification” function. As function outputs, “IndirectEffects” and “Total Effects” contains the IE and TE for each FCM concept. The MainPaths variable identifies the most relevant hidden paths connected with the TE value.

```
function [IndirectEffects TotalEffects MainPaths]=
IndirectTotalEffectCalculation(weighted_matrix, hidden_paths)

% Output varibales inizialisation
IndirectEffects=[];
TotalEffects=[];
MainPaths=[];

% All the identified hidden paths are analysed
for i=min(hidden_paths (:,1)):max(hidden_paths (:,1))

    [r c v]=find(hidden_paths(:,1)==i); % all paths starting from node i are identified
    if not(isempty(r))
        PathsToAnalyse= hidden_paths(r,:);
        effetti=[];
        for j=1:size(PathsToAnalyse,1)
            app= PathsToAnalyse (j,:);
            app(app==0)=[];
            app1=[];
            for t=1:length(app)-1
                app1=[app1 weighted_matrix(app(t),app(t+1))];
            end
            app2=abs(app1);
            [valore index]=min(app2);
            effects =[effects; app1(index)];

        end
        IndirectEffects=[IndirectEffects;effetti];
        app1=abs(effects);
        [value index]=max(app1);
        TotalEffects=[TotalEffects; [i effects (index)]];
        [r c v]=find(effects == effects (index));
        if length(r)>1
```

```
            MainPaths=concatena( MainPaths, [PathsToAnalyse (r,:) effects (r)]);
        else
            MainPaths=concatena( MainPaths, [PathsToAnalyse (index,:) effects (index)]);
        end

    end

end
```

Appendix 4 – Excerpt from the questionnaire

According to the respondent experience, which of the factors listed below are related to "Operation management strategies"?

INSERT ABOUT HERE TABLE 10

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FIGURES

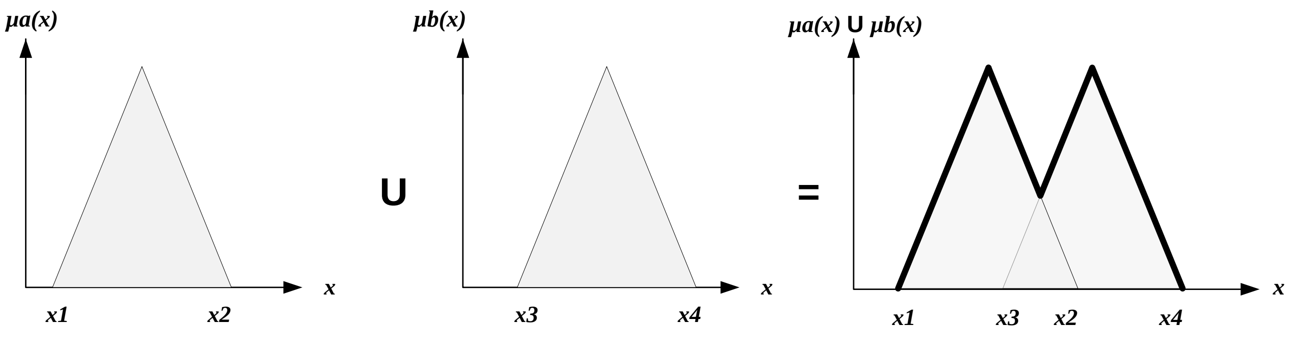


Figure 1

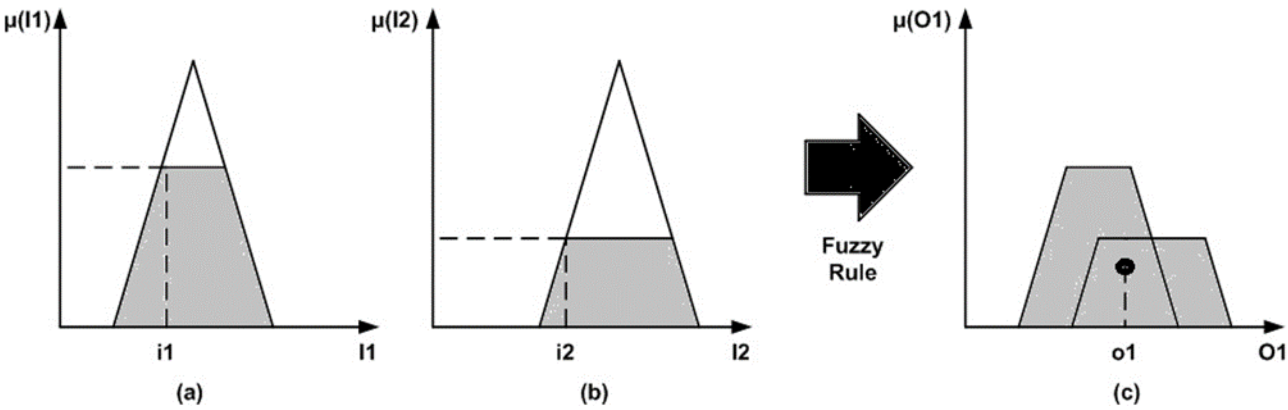


Figure 2.

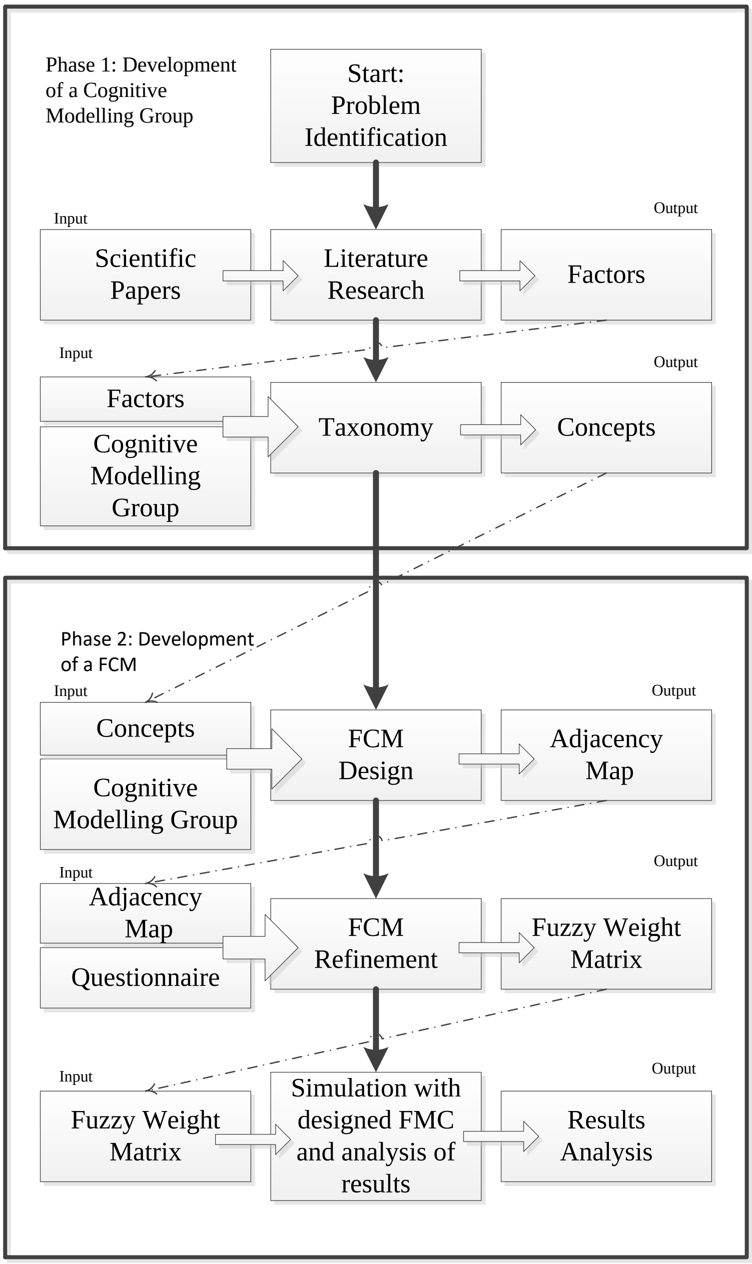

Phase 1: Development of a Cognitive Modelling Group
Start: Problem Identification
Input
Scientific Papers
Literature Research
Output
Factors
Input
Factors
Cognitive Modelling Group
Taxonomy
Output
Concepts
Phase 2: Development of a FCM
Input
Concepts
Cognitive Modelling Group
FCM Design
Output
Adjacency Map
Input
Adjacency Map
Questionnaire
FCM Refinement
Output
Fuzzy Weight Matrix
Input
Fuzzy Weight Matrix
Simulation with designed FMC and analysis of results
Output
Results Analysis

Figure 3.

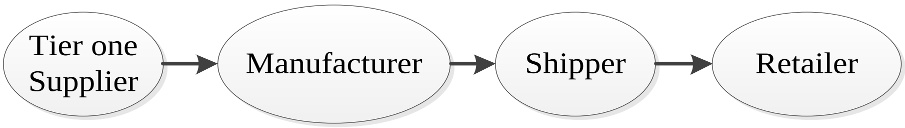
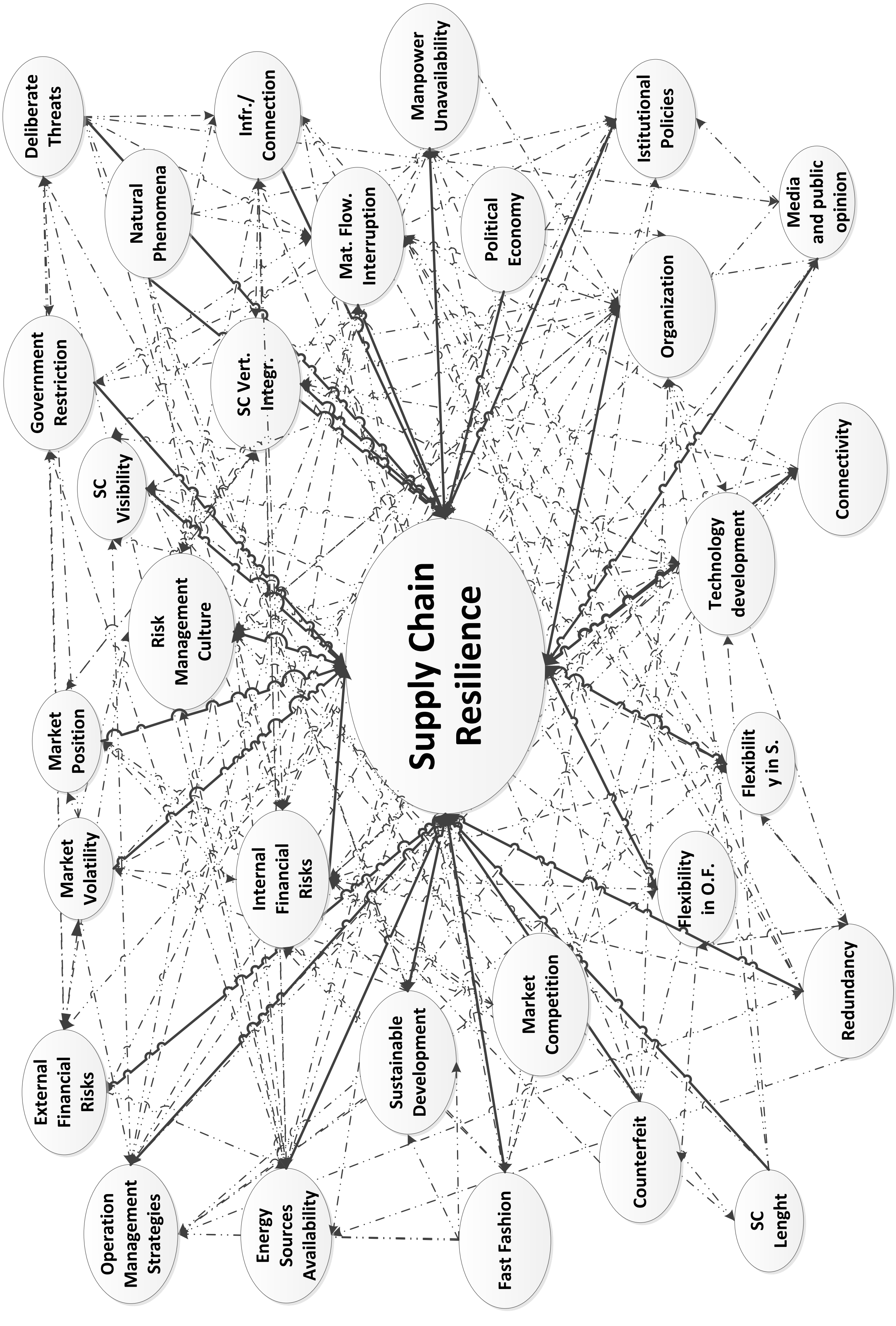


Figure 4.



Dashed lines = interconnections between concepts;
Full lines = interconnections between concepts and the top event (i.e. Supply Chain Resilience)

Figure 5.

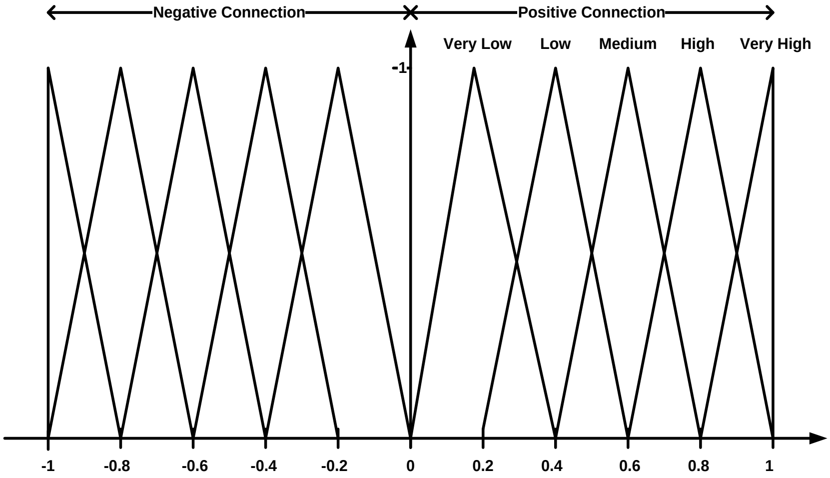


Figure 6.

Figure captions

Figure 1: Example of fuzzy sets union with max(a,b) operator

Figure 2: The defuzzification method using the COG approach

Figure 3. Research approach

Figure 4. Fashion SC

Figure 5. Cognitive Map

Figure 6: Membership function for the fuzzy weights

TABLES

Tables' captures

Factors	Cross-sectorial research studies																																	Fashion sector research studies																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
Lean Production/Agile Manufacturing	X	X		X																												X		X					X																		X	
Portfolio Diversification	X																																																									
Financial Reserves and Liquidity	X																																																							X		
Price Margin	X																																																									
Market Share	X													X																															X													
Brand Equity	X											X																																	X						X							
Customer Relationships	X														X																		X			X																						
Supply Chain Visibility	X			X	X			X	X		X								X	X									X			X																										
Collaboration	X			X				X			X						X			X												X			X											X							X					
Theft	X																																																									
Terrorism	X		X					X						X	X	X											X																					X										
Political Economy Change	X																																																	X								
Cross-Training	X																																																									
Substitute Leadership/Empowerment	X																																																									
Learning/Benchmarking	X																																																									
Technological Innovation	X																																		X													X										
Modular Product Design	X																																																									
Supplier Contract Flexibility	X																													X		X																										
Alternate Distribution Channels	X																																																									
Information Sharing																													X			X																										
Multi-Sourcing	X																											X																														
Lack of Credit		X																									X																															
Natural Disaster		X			X	X									X	X							X				X																															
Economic Crises		X	X											X	X	X																						X			X						X		X	X								
Risk Management Culture	X			X	X			X						X	X				X				X																																			
Domino Effect						X	X																																																			
Awareness of Disturbances								X																																																		
War								X						X																																												
Flexibility				X				X			X		X				X			X												X																										
Redundancy								X									X		X																																							
Planning and Control									X																																																	
Management Methods									X																																																	
Power and Leadership Culture									X																																																	
Warning Capability										X																																																
Supply Chain Length				X						X						X																																									
Product Recall												X																																													
Social Media												X																																													
Recovery Planning System														X																																												
Measures applied after terrorist attack														X																																											
Workforce Availability Constraint														X		X											X																															
Multimodal Transportation														X																																											
Challenging Political Context															X																							X							X					X								
Disaster Management																X																																									
Research Planning																X																																									
Infrastructural Disruptions																X																																							X			
Media Influence																X																																									
Security People in Leadership																	X																																								
Business Continuity Planning						X											X																																								
Intensive Training in Risk Management																	X																																								

(see in the next page the remaining part of table 1)

	Cross-sectorial research studies																																	Fashion sector research studies																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58
Sound Strategy																	X																																									
Organizational Capabilities																	X																																									
Assess Effect of Disruptions																		X																																							
Knowledge Assessment																			X																																						
Strikes	X																																																									
State Aid																					X	X																																				
Cyber-Attack/Data Breach																							X				X																															
Embargoes																							X																											X								
It/Communication Outage																							X				X																															
Transport/Network Disruptions																							X				X																															
Supply Chain Connectivity																													X		X																											
Product Quality Accident																							X				X																															
Investment																																	X																									
Expected Net Present Value																																	X																									
Scale Complexity																													X																													
Loss of Talent/Skills																							X				X																															
Energy Scarcity																							X				X								X																							
New Laws/Regulation	X																						X																																			
Delivery Complexity																													X																													
Collaborative Communication																								X										X							X									X		X	X					
Mutually Created Knowledge																								X																																		
Supply Chain Integration	X																									X															X											X						
Restoration Budget																												X																														
Technical Resource Restoration																												X																														
Node Complexity																														X			X																									
Sources Criticality																														X																												
Currency Exchange Rate Volatility																											X																															
Product Differentiation/Fast Fashion																													X																													
Density																														X			X																									
Insolvency in the supply chain																											X																															
Establish Relationship with Suppliers																																		X																X								
Node Criticality and Reliability																														X			X																									
Availability																															X																											
Flow Complexity and Reliability																																X			X																							
Accessibility																															X																											
Market Competition																																		X		X						X	X		X						X							
Lead time reduction																																X																										
Cluster Reliability																														X																												
Flexible Transportation																																X																										
Network Centralization																																	X																									
Environmental Protection Policies																																			X																							
Quantity of inbound and outbound flows																																	X																									
Intensity of inbound and outbound flows																																	X																									
Supply Chain Robustness																													X																													
Surplus Inventory/Strategic Stock																												X				X																										
Demand Unpredictability																																				X	X	X	X			X		X		X		X	X		X	X				X	X	
Counterfeits																									X											X																						
Short Product Life Cycles																																					X			X		X	X	X		X					X			X				X
Geographical Segregation																												X																														

Product Variety																																					X					X	X	X							X							
Sustainable Development																											X		X					X	X	X				X					X				X	X								
Tighter Constraint on Capital																																									X																	
Rerouting																												X																														
Joint Goals Setting																								X																	X																	
HR Capabilities in New Technologies																								X																		X																
Physical Protection																												X																														
Weaker Cash Flows																																																							X		

(1) Pettit (2008); (2) Mensah and Merkuryev (2014); (3) Annarelli and Nonino (2016); (4) Soni et al. (2014); (5) Bruno and Clegg (2015); (6) Stolker et al. (2008); (7) Scheffer et al. (2012); (8) Christopher and Peck Helen (2004); (9) Cooper et al. (1997); (10) Craighead et al. (2007); (11) Jüttner and Maklan (2011); (12) Hsu and Lawrence (2016); (13) Lengnick-Hall et al. (2011); (14) Tang (2006); (15) Bueno-Solano and Cedillo-Campos (2014); (16) Boin et al. (2010); (17) Rice and Caniato (2003); (18) Kristianto et al. (2014); (19) Scholten et al. (2014); (20) Johnson et al. (2013); (21) Klibi and Martel (2012); (22) Boekholt et al. (1999); (23) Green (2015); (24) Scholten and Schilder (2015); (25) Stevenson and Busby (2015); (26) van der Vaart and van Donk (2008); (27) Supply Chain Resilience Report (2016); (28) Hosseini and Baker (2016); (29) Brandon Jones et al. (2014); (30) Adenso Diaz et al. (2012); (31) Zhao et al. (2011); (32) Azevedo et al. (2016); (33) Cardoso et al. (2015); (34) Turker and Altuntas (2014); (35) Li et al. (2014); (36) Macchion et al. (2015); (37) Mehrjoo and Pasek (2014); (38) Venkatesh et al. (2015); (39) Čiarnienė et al. 2014); (40) Caniato et al. (2012); (41) Li et al. (2016); (42) Dewi et al. (2015); (43) Vaagen and Wallace (2008); (44) Martino et al. (2016); (45) Martino et al. (2015); (46) Şen (2008); (47) Torstensson and Pal (2013); (48) Wang et al. (2012); (49) Li et al. (2015); (50) Abylaev et al. (2014); (51) Mehrjoo and Pasek (2016); (52) Ait-Alla et al. (2014); (53) Guercini and Runfola (2010); (54) Choy et al. (2009); (55) Marmo (2010); (56) Pal et al. (2014); (57) Escalona Orcao and Ramos-Pérez (2015); (58) Shen et al. (2014)

Table 1. Factors affecting SCR in literature

Supply chain players	Typology	Location	Description	Company size
Tier one supplier	Leather supplier	Italy	Company that offers all types of leather needed to produce goods to the next actor in the SC	As of 2016, it had more than 1000 employees and a revenue of € 350 million
Manufacturer	Global apparel manufacturer	Spain	Product industrialization and production	As of 2016, it had approximately 1,200 employees and a revenue of €400 million
Shipper	Global transportation and logistics company	Italy	Provides sea freight and airfreight transport, contract logistics, and overland services.	As of 2016, it had more than 1,000 offices in over 100 countries, with over 63,000 employees.
Retailer	National Clothing Retailer	Italy	Multi-brand company providing finished products to consumers	As of 2016, it had approximately 6,600 employees and their revenue was over € 1.34 billion

Table 2. Supply chain players

Code	Concept	Description	Factors involved
C1	Operation Management strategies	All practices connected to Operation Management	Lean production practices, Agility, Lead time reduction, Management Methods, Planning and Control
C2	External Financial Risk	Risks linked to the financial sector in which the SC operates	Lack of Credit, Economic Crises, Currency exchange rate volatility, weaker cash flow
C3	Internal Financial Risk	Risks linked to the financial situation of the enterprises.	Portfolio diversification, Financial reserves and liquidity, Price margin, Tighter constraints on the capital, insolvency in the SC, Expected Net Present Value, Restoration Budget
C4	Market Volatility	Uncertainties linked to market developments	Demand unpredictability

C5	Market Position	Status of a company or its products in specific markets	Market share, Brand equity, Customer relationships
C6	Risk Management culture	All of the risk management branches: prevention techniques, risk evaluation, reduction of action plans to face sudden disturbances	Risk management culture, Recovery Planning System, Disaster Management, Research Planning and Control, Security people in leadership, Business Continuity planning, Intensive training/education in risk management, Sound strategy, Awareness of Disturbances, Assess effect of disruptions, Knowledge assessment
C7	SC Visibility	Knowledge of the state of the operations along the SC	SC Visibility, Collaboration, Collaborative Communication, Long-term Relationship with suppliers, Warning capability, joint goal setting, mutually created knowledge, Creating total supply chain visibility, Information Sharing
C8	SC Vertical Integration Degree	SC is defined as completely vertically integrated when all activities from the raw material to the finished products are carried out by the same company	SC Integration
C9	Deliberate threats	Intentional attacks aimed at disrupting operations or causing human or financial harm	Theft, Terrorism, War, Cyber attack/data breach
C10	Natural phenomena	An environmental danger with which risk of damage to people or things is associated	Natural disasters: earthquakes, flooding, tsunami, adverse weather
C11	Government restrictions	National policies that apply to all sectors of free trade	Measures after terrorist attack, Embargoes, Challenging political context
C12	Loss of infrastructure and/or connection	Physical loss of infrastructures: productive plants, physical connections (roads), telecommunications	Infrastructural Disruptions, IT/Communication outage, Transport/network disruptions, Physical Protection, Node Reliability, Technical Resource Restoration
C13	Materials flow interruption	Interruption of the normal flux of materials or final products	Product recall, Product quality accident, Surplus Inventory, Quantity and Intensity of inbound and outbound flows, Flow Complexity
C14	Manpower unavailability	Unavailability of human resources to carry on normal activities inside the SC	Workforce availability constraint, Strikes, Loss of talent/skills, Availability
C15	Energy sources availability	Availability of energy sources to carry on normal activities within the SC	Energy scarcity
C16	Political Economy	Level of intervention of public bodies on economy with the aim of modifying the macroeconomic system to reach the objectives	Political economy change, State aid
C17	Institutional Policies	Formal restrictions regarding products in the fashion sector	New laws/regulation, environmental protection policies
C18	Media and public opinion response towards the SC	Refers to the level of interest of the press regarding events related to the SC	Social media, media influence
C19	Organization	Human resource structures, policies, skills and culture	Cross-training, Substitute leadership/empowerment, Learning/benchmarking, Organizational Capabilities, power and leadership culture, management methods
C20	Connectivity	Degree of dependence on other players	Connectivity, Supply Chain Connectivity, Domino effect, Node Complexity, Node Criticality, Accessibility
C21	Technology Development	Set of technological know-how and resources	Technological innovation, improved HR capabilities in new technologies
C22	Flexible sourcing	Ability to quickly change inputs or the mode of receiving inputs	Flexibility, Modular product design, Multimodal Transportation, Supply Contract Flexibility, Multi-sourcing Flexible sourcing, Backup Supplier Contracting, Flexible transportation, Suppliers Complexity, Sources Criticality, Rerouting
C23	Flexibility in order fulfillment	Ability to quickly change outputs or the mode of delivering outputs	Flexibility, Alternate distribution channels, Multimodal Transportation, Flexible supply base, Flexible transportation,

			Delivery Complexity, Flow Complexity and Reliability, Rerouting, Cluster Reliability
C24	Redundancy	How much has been invested in resources compared to how much was needed	Redundancy, Investment
C25	SC Lenght	Refers to how many players are part of the SC	SC Length, Network Centralization, Geographical Segregation, Density, Scale Complexity
C26	Market Competition	Presence of competitors in the fashion industry market	Market Competition
C27	Fast Fashion	Capability to adapt quickly to current and emerging trends of the fashion market	Short product life cycles, product variety, product differentiation/Fast Fashion
C28	Sustainable development	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs	Sustainable development, Environmental Dynamism
C29	Counterfeit	Sale of products that imitate the originals at low price and that represent a major risk	Counterfeits
C30	Supply Chain Resilience	The ability of a system to return to its original state or move to a new, more desirable state after being disturbed (Christopher and Peck, Helen, 2004)	Top Event

Table 3. Taxonomy analysis: concept definitions

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23	C24	C25	C26	C27	C28	C29	C30
C1	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.32	0.00	0.00	0.00	0.00	-0.22	0.00	0.00	0.00	0.00	0.00	0.57	0.49	0.00	0.49	0.74	-0.46	-0.49	0.00	0.00	0.00	0.00	0.74
C2	0.00	0.00	0.65	0.51	0.00	0.69	0.00	0.00	0.00	0.00	0.43	0.00	0.00	0.00	-0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.58
C3	0.28	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.00	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.62
C4	0.43	0.63	0.60	0.00	-0.37	0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.48
C5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68
C6	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.31	0.00	0.00	0.00	0.00	0.00	0.58	0.65	0.00	0.00	0.00	0.62	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62
C7	0.00	0.00	-0.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.54
C8	0.00	0.00	0.00	0.00	0.55	0.00	0.66	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.57
C9	0.00	0.65	0.57	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.63	0.71	0.66	0.00	-0.68	0.00	0.00	0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.54
C10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	0.75	0.00	-0.65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.48	0.00	-0.72
C11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.63
C12	0.00	0.00	0.68	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.65
C13	0.00	0.00	0.62	0.00	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.65
C14	0.00	0.00	0.00	0.00	0.00	0.46	0.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.65
C15	0.00	0.00	0.00	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.52	-0.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.55
C16	0.00	0.28	0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.66	0.00	0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.62
C17	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.57	0.00	-0.51
C18	0.00	0.00	0.00	0.65	-0.75	0.00	0.00	0.00	0.00	0.00	0.58	0.00	0.00	0.00	0.00	0.00	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.45
C19	0.00	0.00	0.00	0.00	0.00	0.45	0.65	0.51	0.00	0.00	0.00	0.00	-0.60	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.58
C20	0.00	0.00	-0.60	0.00	0.00	0.00	0.00	0.68	0.00	0.00	0.00	0.00	-0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.55
C21	0.65	0.00	-0.46	0.00	0.68	0.65	0.60	0.00	0.00	0.00	0.00	0.00	-0.55	0.66	0.65	0.00	0.00	0.00	0.57	0.48	0.00	0.62	0.55	0.54	0.00	0.00	0.00	0.49	0.00	0.48
C22	0.00	0.00	-0.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.62	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.75	0.00	0.00	0.00	0.00	0.00	0.49
C23	0.00	0.00	-0.54	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.65	0.00	0.00	0.00	0.00	0.00	0.55
C24	0.00	0.00	0.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.46	-0.71	0.54	0.48	0.00	0.00	0.00	0.00	0.00	0.00	-0.58	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.62
C25	0.00	0.00	0.58	0.00	0.00	0.55	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-0.71
C26	0.65	0.00	0.60	0.65	-0.52	0.00	0.00	0.62	0.69	0.00	0.00	0.00	0.00	-0.57	0.00	0.63	0.00	0.00	0.00	0.69	0.62	0.65	0.54	0.63	0.00	0.00	0.54	0.60	0.54	-0.63
C27	0.88	0.69	0.62	0.72	-0.57	0.72	0.51	0.60	0.55	0.00	0.00	0.00	0.60	0.00	0.00	0.00	0.00	0.00	-0.52	0.00	0.63	0.62	0.55	0.57	0.00	0.65	0.00	0.60	0.00	-0.58
C28	0.00	0.00	0.58	0.00	0.46	0.00	0.00	0.00	-0.74	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00	-0.55	0.00	0.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60
C29	0.00	0.00	0.49	0.62	-0.69	0.60	0.00	0.00	0.77	0.00	0.74	0.00	0.60	0.00	0.00	0.00	0.62	0.52	0.00	0.00	0.54	0.00	0.00	0.00	0.00	0.72	0.57	-0.62	0.00	-0.54
C30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 4. Fuzzy Weight Matrix

Supply Chain - Principal paths						
#path	*Starting Node*					*IE*
1	Operation Management strategies	SCR				0.74
2	Fast Fashion	Flexible sourcing	SCR			-0.73
3	Natural phenomena	Materials flow interruption	SCR			-0.71
4	SC Length	Materials flow interruption	SCR			-0.71
5	Market Position	SCR				0.71
6	Sustainable development	Media and public opinion	Market Position	SCR		0.68
7	Media and public opinion	Market Position	SCR			0.68
8	Technology Development	Market Position	SCR			0.68
9	Counterfeit	Market Position	SCR			-0.67
10	Deliberate threats	Market Volatility	Market Position	SCR		-0.66
11	SC Visibility	Flexibility in order fulfillment	SCR			0.65
12	SC Vertical Integration Degree	Flexibility in order fulfillment	Materials flow interruption	SCR		0.65
13	Loss of infrastructure/connection	Connectivity	SCR			-0.65
14	Fast Fashion	Materials flow interruption	SCR			-0.65
15	Manpower unavailability	Materials flow interruption	SCR			-0.65
16	Connectivity	Materials flow interruption	SCR			-0.65
17	Flexibility in sourcing	Redundancy	Materials flow interruption	SCR		-0.65
18	Flexibility in order fulfillment	Materials flow interruption	SCR			-0.65
19	Flexibility in order fulfillment	Redundancy	Materials flow interruption	SCR		-0.65
20	Deliberate threats	Market Volatility	SCR			-0.64
21	Market Competition	Operation Management strategies	SCR			0.64
22	Market Competition	Manpower unavailability	Materials flow interruption	SCR		-0.64
23	Market Competition	Technology Development	Operation Management strategies	SCR		0.63
24	Market Competition	Market Volatility	Market Position	SCR		-0.63
25	Market Volatility	Internal Financial Risk	SCR			-0.63
26	SC Length	Internal Financial Risk	Materials flow interruption	Market Position	SCR	-0.61
27	Institutional Policies	Market Volatility	Market Position	SCR		-0.60

Table 5. SC case study principal paths

Tier-One supplier - Principal paths					
#path	*Starting Node*				*IE*
1	Organization	SCR			0.93
2	Operation Management strategies	SCR			0.87
3	Manpower unavailability	Materials flow interruption	SCR		-0.87
4	Manpower unavailability	Organization	SCR		-0.85
5	Fast Fashion	Operation Management strategies	SCR		-0.83
6	Fast Fashion	Manpower unavailability	SCR		-0.81
7	Materials Flow Interruption	SCR			-0,77
8	Materials Flow Interruption	Organization	SCR		-0.73
9	External Financial Risk	Risk Management Culture	SCR		-0.73
10	External Financial Risk	Risk Management Culture	Organization	SCR	-0.70
11	Sustainable development	Media and public opinion	SCR		0.70
12	Market Volatility	Internal Financial Risk	SCR		-0.69
13	Market Competition	Operation Management strategies	SCR		0.66
14	Deliberate threats	Market Volatility	SCR		-0.66
15	Market Volatility	Internal Financial Risk	Market Position	SCR	-0.64
16	External financial risk	Internal Financial Risk	Market Position	SCR	-0.64
17	Government restrictions	Market Volatility	Market Position	SCR	-0.64
18	Fast Fashion	Materials flow interruption	SCR		-0.63
19	External Financial Risk	Government restrictions	Market Volatility	SCR	-0.63
20	Risk Management culture	Technology Development	SCR		-0.61
21	Government restrictions	Counterfeit	Market Position	SCR	-0.61
22	Government restrictions	SC Vertical Integration Degree	Internal Financial Risk	SCR	-0.61
23	Deliberate threats	External financial risk	Market Volatility	SCR	-0.61

Table 6. Tier-one supplier principal paths

Manufacturer - Principal paths						
#path	*Starting Node*					*IE*
1	Operation Management strategies	SCR				0.87
2	Market Position	SCR				0.87
3	Fast Fashion	Flexibility in order fulfilment	Manpower unavailability	SCR		-0.85
4	Fast Fashion	Flexible sourcing	SCR			-0.82
5	Market Competition	Operation Management strategies	SCR			0.80
6	Fast Fashion	External Financial Risk	SCR			-0.80
7	SC Vertical Integration Degree	Flexible sourcing	Internal Financial Risk	SCR		-0.74
8	Market Volatility	External Financial Risk	SCR			-0.73
9	Flexibility in order fulfilment	SCR				0.73
10	Technology Development	Operation Management strategies	SCR			0.70
11	Technology Development	Operation Management strategies	Flexibility in order fulfillment	SCR		0.70
12	Technology Development	SC Visibility	Flexibility in order fulfilment	SCR		0.69
13	Sustainable development	Media and public opinion	SCR			0.68
14	Sustainable development	Media and public opinion	Market Position	SCR		0.66
15	SC Vertical Integration Degree	Flexible sourcing	Fast Fashion	SCR		-0.66
16	Manpower unavailability	SCR				-0.66
17	Fast Fashion	Market Competition	Operation Management strategies	SCR		0.65
18	Fast Fashion	Materials flow interruption	SCR			-0.65
19	Loss of infrastructure/connection	Connectivity	SCR			-0.65
20	Deliberate threats	Market Volatility	SCR			-0.64
21	Government restrictions	Counterfeit	Market Position	SCR		-0.64
22	Market Competition	Manpower unavailability	Materials flow interruption	SCR		-0.63
23	Market Competition	Technology Development	Operation Management strategies	SCR		0,61
24	Government restrictions	Market Volatility	External Financial Risk	Internal Financial Risk	SCR	-0.61
25	Market Volatility	Internal Financial Risk	SCR			-0.61
26	Market Competition	Manpower unavailability	Materials flow interruption	Internal Financial Risk	SCR	-0.61
27	Deliberate threats	Market Volatility	Market Position	SCR		-0.60
28	External financial risk	Internal Financial Risk	Materials flow interruption	Market Position	SCR	-0.60
29	Government restrictions	Market Volatility	Market Position	SCR		-0.60

Table 7. Manufacturer principal paths

Shipper - Principal paths						
#path	*Starting Node*					*IE*
1	Materials flow interruption	SCR				-0.87
2	Natural phenomena	Materials flow interruption	SCR			-0.73
3	Sustainable development	Internal Financial Risk	Risk Management culture	Organization	SCR	0.69
4	Loss of infrastructure/connection	Internal Financial Risk	Risk Management culture	SCR		-0.69
5	External Financial Risk	Energy sources availability	Risk Management culture	SCR		-0.68
6	Internal Financial Risk	Risk Management culture	SCR			-0.68
7	Internal Financial Risk	Risk Management culture	Energy sources availability	SCR		-0.67
8	Internal Financial Risk	Risk Management culture	Organization	Materials flow interruption	SCR	-0.67
9	Connectivity	Materials flow interruption	SCR			-0.67
10	Market Volatility	Risk Management culture	SCR			-0.67
11	Market Volatility	Risk Management culture	Energy sources availability	Risk Management culture	SCR	-0.65
12	Government restrictions	SCR				-0.64
13	Political Economy	Connectivity	Materials flow interruption	SCR		-0.64
14	Deliberate threats	Market Volatility	SCR			-0.60
15	External Financial Risk	Loss of infrastructure/connection	Market Volatility	SCR		-0.60

Table 8. Shipper principal paths

Retailer - Principal paths							
#path	*Starting Node*						*IE*
1	Market Position	SCR					0.90
2	Fast Fashion	Flexible sourcing	SCR				-0.85
3	Natural phenomena	Materials flow interruption	SCR				-0.85
4	Manpower unavailability	SCR					-0.82
5	External Financial Risk	Risk Management culture	Manpower unavailability	SCR			-0.81
6	SC Vertical Integration Degree	Flexible sourcing	Fast Fashion	SCR			-0.78
7	Market Position	SC Vertical Integration Degree	SC Visibility	Flexibility in sourcing	Redund.	SCR	0.73
8	Manpower unavailability	Materials flow interruption	SCR				-0.72
9	Risk Management Culture	Manpower unavailability	SCR				-0.70
10	SC Vertical Integration	SC Visibility	Flexible sourcing	Redundancy	SCR		0.67
11	Technology Development	Operation Management strategies	SCR				0.67
12	SC Length	Flexible sourcing	SC visibility	SCR			-0.65
13	Operation Management strategies	SCR					0.65
14	External Financial Risk	Market Volatility	Internal Financial Risk	SCR			-0.65
15	External Financial Risk	Market Volatility	Risk Management culture	SCR			-0.63
16	Redundancy	Materials flow interruption	SCR				-0.63
17	Sustainable development	Media and public opinion	Market Position	SCR			0.63
18	Fast Fashion	Materials flow interruption	SCR				-0.62
19	Deliberate threats	Market Volatility	SCR				-0.62
20	Government restrictions	Market Volatility	External Financial Risk	Internal Financial Risk	SCR		-0.62
21	Market Volatility	Internal Financial Risk	SCR				-0.61
22	Deliberate threats	External financial risk	SCR				-0.61
23	Deliberate threats	Market Volatility	Internal Financial Risk	SCR			-0.61
24	Market Competition	Market Volatility	Market Position	SCR			-0.60
25	External financial risk	Internal Financial Risk	Materials flow interruption	Market Position	SCR		-0.60
26	Government restrictions	Market Volatility	Market Position	SCR			-0.60

Table 9. Retailer principal paths

What is the relationship weight between "Operation management strategies" and the concepts listed below?											
Concept name	Negative Connection						Positive Connection				
	Very High	High	Medium	Low	Very Low		Very Low	Low	Medium	High	Very High
External Financial Risk	-5	-4	-3	-2	-1	0	1	2	3	4	5
Internal Financial Risk	-5	-4	-3	-2	-1	0	1	2	3	4	5
Market Volatility	-5	-4	-3	-2	-1	0	1	2	3	4	5
Market Position	-5	-4	-3	-2	-1	0	1	2	3	4	5
Risk Management culture	-5	-4	-3	-2	-1	0	1	2	3	4	5
SC Visibility	-5	-4	-3	-2	-1	0	1	2	3	4	5
SC Vertical Integration Degree	-5	-4	-3	-2	-1	0	1	2	3	4	5
Deliberate threats	-5	-4	-3	-2	-1	0	1	2	3	4	5
Natural phenomena	-5	-4	-3	-2	-1	0	1	2	3	4	5
Government restrictions	-5	-4	-3	-2	-1	0	1	2	3	4	5
Loss of infrastructure and/or connection	-5	-4	-3	-2	-1	0	1	2	3	4	5
Materials flow interruption	-5	-4	-3	-2	-1	0	1	2	3	4	5
Manpower unavailability	-5	-4	-3	-2	-1	0	1	2	3	4	5
Energy sources availability	-5	-4	-3	-2	-1	0	1	2	3	4	5
Political Economy	-5	-4	-3	-2	-1	0	1	2	3	4	5
Institutional Policies	-5	-4	-3	-2	-1	0	1	2	3	4	5
Media and public opinion response towards the SC	-5	-4	-3	-2	-1	0	1	2	3	4	5
Organization	-5	-4	-3	-2	-1	0	1	2	3	4	5
Connectivity	-5	-4	-3	-2	-1	0	1	2	3	4	5
Technology Development	-5	-4	-3	-2	-1	0	1	2	3	4	5
Flexible sourcing	-5	-4	-3	-2	-1	0	1	2	3	4	5
Flexibility in order fulfillment	-5	-4	-3	-2	-1	0	1	2	3	4	5
Redundancy	-5	-4	-3	-2	-1	0	1	2	3	4	5
SC Lenght	-5	-4	-3	-2	-1	0	1	2	3	4	5
Market Competition	-5	-4	-3	-2	-1	0	1	2	3	4	5
Fast Fashion	-5	-4	-3	-2	-1	0	1	2	3	4	5
Sustainable development	-5	-4	-3	-2	-1	0	1	2	3	4	5
Counterfeit	-5	-4	-3	-2	-1	0	1	2	3	4	5
Supply Chain Resilience	-5	-4	-3	-2	-1	0	1	2	3	4	5

Table 10. Excerpt from the questionnaire provided for the managers