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Planning for disruptions in supply chain networks

Ahmad Jafarnejad Chaghooshi[a], Mansour Momeni[a], Behzad Abdollahi[a*], Hossein Safari[a] and Isa Nakhai Kamalabadi[b]

[a]*Department of Industrial Management, Faculty of Management, University of Tehran, Iran*
[b]*Department of Industrial Engineering, University of Kurdistan, Sanandaj, Iran*

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A B S T R A C T

The nature and complexity of today's supply chains have predisposed them to various risks, which are described under different terms, including disturbances, uncertainties and riots. Under these conditions, organizations are required to manage their supply chain in a way that is responsive to changes. The purpose of this study is to analyze the relationships between the strategies of coping with disturbances in supply chain networks. This is an applied research and using the research literature, 41 factors are selected for the solutions of coping with risk in supply chain networks. Then, these factors are entered in a questionnaire and presented for some supply chain experts. After that, Interpretative Structural Modeling (ISM) and Fuzzy MICMAC are implemented to rate the solutions of coping with risk in supply chain networks. The results show that the establishment of a supply chain continuity system at the seventh level is the basis of agility in the supply chain. The proper and efficient design of processes in the supply chain network will lead to proper operation in management solutions and appropriate synchronization in the supply chain networks. Using appropriate management solutions in synchronization leads to the integration and proper sharing of information within a supply chain network and between various supply chains and government. Additionally, using the synchrony and integration of supply chain networks, it is possible to design the proper supply chain network and appropriate communication between employees and network elements.

1. Introduction

Undoubtedly, in today's world, attention to sustainable development and efficient utilization of resources is one of the requirements of any structure. Limited resources and growing demand in most industries have led many organizations to seek their own supply chain design, and put it in their vast policies and take organizational decisions based on it. Most organizations believe that if they do not have such a belief, they will be removed from the competition cycle in today's world, and there will be no place for them. The possibility of occurring unpredictable events in a supply chain network is more than before as much as today's supply chain networks are becoming more globalized and complex in the structures (Foroughi et al., 2006).

* Corresponding author.
E-mail address: b.abdollahi@ut.ac.ir (B. Abdollahi)

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The current competitive market is characterized by high levels of volatility and uncertainty. As a result, supply chains are more vulnerable and business continuity is riskier (Azevedo et al., 2008). Actually, the actions taken in a supply chain have inherent risks for the occurrence of an unexpected disturbance. On the other hand, globalization of supply chains, shorter product lifecycles, increasing customer requirements, etc., have made businesses more aware of the adverse financial and operational side effects of supply chain disturbances. Disturbances such as the loss of an important supplier, fire in a manufacturer's factory, complex and irregular demand, natural disasters, terrorism, etc., have the potential to negatively influence on income and expenses. In recent years, with the emergence of various events such as the September 11 attacks, Katrina hurricane, earthquakes in Japan and Taiwan, etc., there is an increasing concern for the vulnerability of supply chain disturbance (Christopher & Towill, 2002). In this situation, organizations are required to manage their supply chain in a way that is responsive to changes.

Over the past few years, a newer axis has been activated in the literature of supply chain management as Supply Chain Risk/Disruption Management (SCRM/SCDM). The primary purpose of this research axis is to consider the risks of treating supply chains (i.e., natural or man-made disruptions in designing the network and solving other chain problems at the medium-term and operational levels) (Ponis & Koronis, 2012).

The destructive and devastating effects of large and varied disruptions are reported by many researchers (Eskew, 2004; Hendricks et al., 2009; Hendricks & Singhal, 2003, 2005). Given these documents and evidences collected by the researchers, it is still difficult for many organizations to justify costly strategies as well as investment to reduce the risk of disturbances. Therefore, our goal in this research is to provide solutions to control and manage these disruptions in the way that they remain efficient under normal conditions, and resilience in the occurrence of disaster situations. Most of the companies, however, have prepared themselves against Low impact-High frequency risks, and most of them ignore High impact-Low frequency risks (Chopra & Sodhi, 2004).

The nature and complexity of today's supply chains have predisposed them to various risks, which are under various terms including disturbances, uncertainties and riots (Hishamuddin et al., 2013). Disruptions in the supply chain disrupt the flow of goods, delay the delivery of goods to the customer, loose the profit, and increase cost. Disruptions can have a small nature, such as short-term breakdowns of machinery or a large nature such as tsunami and other natural disasters (Bradley, 2014, Hishamuddin, et al., 2013). Experts believe that supply chain disruptions are expanding, and by the increasing globalization of companies, they are more exposed to the risks associated with these disruptions (Bradley, 2014, Handfield et al., 2007, Sheffi & Rice Jr, 2005).

The existence of a flexible supply chain is one of the most important aspects of coping with risks in the supply chain networks. To efficiently and effectively deal with network risks, supply chain management should be aware of the importance of solutions as well as prioritizing the solutions of risks, and it will be able to devote more time and energy to solutions with a higher priority. In fact, this research is looking for a management model and framework providing a collection of strategic management solutions for managing, so that it could select the proper solutions to improve the competitive advantage in local and global markets regarding the environmental and internal conditions of its organization, and the best decision would be made by observing the results of the model analysis, and the optimal strategy would be used to reduce maximum effects of disturbances in the supply chain. This study was conducted at a chemical and pharmaceutical company named BehbanShimi Comapany (BSCO). BehbanShimi Comapany is one of the most reputable and largest factories of antiseptic and disinfectant products, and exclusive cleaners in the Middle East region in 2002.

2. Literature review

According to Azevedo et al. (2008), supply chain disability, at a moment, in responding to disturbances, and thereby achieving its goals, has been defined as supply chain vulnerability. When the companies are involved in the disturbances caused by sudden and unforeseen events, such as political and economic crises or environmental disasters, disrupted conditions emerge in the supply chain (Ponomarov & Holcomb, 2009). Various definitions of disruption are also provided by the researchers. For example, Wu et al. (2007) described disruption as an unexpected event in the supply chain. Black hurst et al. (2011) defined disruption as a quantitative or qualitative deviation from what is normal or expected.

Supply chain disturbances disrupt the flow of goods, delay the delivery of goods to the customer, lose profit, and increase cost. Disruptions can have small nature, such as short-term breakdowns of machinery or large nature such as tsunami and other natural disasters (Bradley, 2014, Hishamuddin, 2013). Experts believe that supply chain disruptions are on the rise, and by increasing the globalization of companies, they are more exposed to the risks associated with these disruptions (Bradley, 2014, Handfield et al, 2008, Sheffi, 2003). Christopher and Towill (2002), reviewed and studied the literatures and claimed that the implementation of risk management in the supply chain is still in its early stage, over the past years, organizations have begun to take steps to make progress in this field. An appropriate classification of supply chain disruptions can raise awareness and understanding of decision makers about the impact of events on supply chains. Disruptions have a negative impact on performance, profitability, operating income, cost structure, properties, and supplies (Hendricks & Singhal, 2005).

Qi and Lee (2015) studied risk reduction in the supply chain by considering the transportation expediting, and they showed how the expedited transportation influence on the strategies of optimal reduction, and they concluded that the optimal risk reduction strategy of a company is sensitive to the ability of company to expedite the transportation. These factors highlight the importance of attention to the expedited transportation in the reduction of supply chain risk, and suggest ideas to develop new transport modes with the practical expediting of transportation. Sawik (2013) tried to achieve a minimum cost of suppliers' protection, emergency inventory pre-positioning, parts ordering, purchasing, transportation and shortage and to mitigate the impact of disruption risks by minimizing the potential worst-case cost. As a result, a resilient supply portfolio is identified with protected suppliers capable of supplying parts in the face of disruption events. A mixed integer programming approach is proposed to determine risk-neutral, risk-averse or mean-risk supply portfolios, with conditional value-at-risk applied to control the risk of worst-case cost.

In the sixth principle of ten principles presented for the management of disruption in supply chain, Kleindorfer and Saad (2005) noted that the traditional path to increase supply chain robustness, namely the use of reliability theory and process improvement, including redundancy and appropriate back-up systems, which back-up systems can be made available in either physical form, virtual form, or both. In other words, redundancy as an increase in capacity enables the organization to continue its activities in the presence of disruptions (Jüttner & Maklan 2011). In fact, this factor is a shield against disruptions (Wicher & Lenort, 2013) and allows a level of sustainable production for the organization (Pettit et al, 2010; Pettit et al., 2013). In their ninth principle, Kleindorfer and Saad (2005) also emphasized on the flexibility and the mobility of resources to reduce risk and increase the speed of response to disruptions. In addition, Chopra and Sodhi (2004) emphasized that the severity of the disruption in supply chain network would be reduced by using the diversity strategy, and it would be better for supply chains not to be focused on a geographic location.

Given the literature review, 41 solutions were identified and provided to the experts of the company. Considering the company's disruptions and the importance of each of these strategies, it was agreed to examine all the solutions presented in Table 1.

Table 1
Solutions of Coping with Disruptions

code	Solutions of Coping with Disruptions	authors
1	Pre-Positioned emergency inventory	Sheffi & Ross, 2005; Sheffi, 2003; Christopher & Peck, 2004 ; Christopher & Peck, 2004; Kleindorfer & Saad, 2005; Chopra & Sodhi, 2004; Pettit et al., 2010, 2013; Wicher & Lenort, 2013; Khan & Haleem, 2015
2	Excess capacity and Reserved capacity	Sheffi et al. 2003; Sheffi & Rice Jr, 2005; Chopra & Sodhi, 2004; Perttit et al., 2010, 2013; Wicher & Lenort, 2013
3	Strategic stock	Christopher & Peck, 2004;Tang, 2006b; Lee, 2004;Kleindorfer & Saad, 2005; Sheffi & Rice Jr, 2005; Iakovou et al., 2007, Pettit et al., 2010, 2013; Wicher & Lenort, 2013; Hendricks et al., 2009
4	Standardize Process	Sheffi et al., 2003; Sheffi & Rice Jr, 2005; Tang & Tomlin, 2008; Tang, 2006b; Wicher & Lenort, 2013
5	Identical plant design/process and facility	Sheffi et al., 2003; Sheffi & Rice Jr, 2005; Tang & Tomlin, 2008; Tang, 2006b, Lee 2004; Kleindorfer & Saad, 2005
6	Interchangeable and generic parts in diver products	Sheffi et al., 2003; Sheffi & Rice Jr, 2005; Tang & Tomlin, 2008; Tang, 2006b, Lee 2004; Kleindorfer & Saad, 2005
7	Multi-skill and interchangeable labor forc	Sheffi, 2003; Sheffi & Rice Jr, 2005; Tang & Tomlin, 2008; Tang, 2006b; Pettit et al., 2010, 2013
8	Flexible Manufacturing System (FMS)	Sheffi, 2003; Sheffi & Rice Jr, 2005; Tang & Tomlin, 2008
9	Postponement	Manuj & Mentzer, 2008; Tang & Tomlin, 2008; Tang, 2006b; Tang 2006a; Sheffi 2003; Sheffi & Rice Jr, 2005; Lee, 2004; Wicher & Lenort, 2013
10	Revenue management via Dynamic Pricing	Tang & Tomlin, 2008; Tang, 2006b; Tang 2006a; Sheffi 2003; Sheffi & Rice Jr, 2005
11	Assortment planning	Tang, 2006a, 2006b
12	Silent product rollover (Substitutable products)	Tang, 2006a, 2006b
13	Flexible Supply Base (Multiple sourcing)	Sheffi, 2003; Iakovou et al., 2007; Wicher & Lenort, 2013; Chopra & Sodhi, 2004; Manuj & Mentzer, 2008; Sheffi et al., 2005; Christopher & Peck, 2004; Tang, 2006; Kleindorfer & Saad, 2005
14	Single source for an item or service into each site	Christopher & Peck, 2003, 2004
15	Having a deep and close relationship with key suppliers	Sheffi, 2003; Tang, 2006
16	Suppliers risk awareness	Christopher & Peck, 2003, 2004
17	Aligning incentives and revenue sharing policies in a supply chain	Tang & Tomlin, 2008; Tang, 2006b; Tang 2006a; Sheffi 2003; Sheffi & Rice Jr, 2005; Christopher & Peck, 2003, 2004
18	Long-term and Supplier contract flexibility	Tang, 2006b; Sheffi 2003; Manuj & Mentzer, 2008; Sheffi & Rice Jr, 2005
19	Economic Supply incentive	Tang, 2006b; Lee, 2004
20	Vertical relatedness and Developing in-house capacity to produce inputs	(Christopher 2004 Cranfield practical guide),(Christopher and Peck 2004),(Tang 2006b),(Hendricks, Singhal, and Zhang 2009)
21	Multi-modal transportation	(Kleindorfer and Saad 2005; Lee 2004)
22	Multi-carrier transportation	(Kleindorfer and Saad 2005)
23	Multiple routes	Tang 2006b; Ishfaq, 2012
24	Diversification strategy	Christopher & Peck, 2003, 2004; Kleindorfer & Saad, 2005; Sheffi, 2003; Tang 2006b; Choi & Hong, 2002; Choi & Krause, 2006; Craighead et al. 2007; Falasca et al., 2008; Hendricks et al., 2009; Manuj & Mentzer, 2008a; Sheffi et al. 2003
25	Distributed Power	Sheffi, 2003; Sheffi & Rice Jr, 2005; Christopher & Peck, 2003, 2004; Pettit et al., 2013; Pettit et al., 2010, Fiksel 2003
26	Continuous Communication among informed employee	Sheffi, 2003; Sheffi & Rice Jr, 2005; Christopher & Peck, 2003, 2004; Pettit et al., 2013; Pettit et al., 2010, Fiksel 2003; Peck, 2005
27	Passion for work	Sheffi, 2003; Sheffi & Rice Jr, 2005
28	Establish supply chain continuity team	Christopher & Peck, 2003, 2004
29	Information sharing among Nodes of network	Christopher & Peck, 2003, 2004; Tang, 2006b; Kleindorfer & Saad, 2005; Lee, 2004; Fiksel, 2003; Peck, 2005; Christopher et al., 2003; Pettit et al., 2010, 2013; Wicher & Lenort, 2013; Sheffi 2003; Ivanov et al., 2014
30	Communicational and Technological Tools	Sheffi et al., 2003; Sheffi & Rice Jr, 2005;Peck, 2003; Kleindorfer & Saad, 2005; Tang 2006b; Hendricks et al., 2009; Pettit et al., 2010, 2013; Manuj & Mentzer, 2008a; Christopher & Peck 2003, 2004; Ivanov et al., 2014
31	Business Intelligence (BI)	Christopher & Peck, 2003, 2004; Ivanov et al., 2014; Pettit et al., 2013; Pettit et al.,2010
32	Collaborative relationships among supply chain partners	Christopher & Peck, 2004; Tang, 2006b; Lee, 2004; Christopher & Peck, 2003; Peck, 2005; Sheffi, 2003; Sheffi & Rice Jr, 2005; Wicher & Lenort, 2013
33	Common planning, forecasting and replenishment (CPFR)	Christopher & Peck, 2004; Tang, 2006b; Lee, 2004; Sheffi, 2003; Christopher & Peck, 2003; Peck, 2005; Sheffi, 2003; Sheffi & Rice Jr, 2005; Fiksel, 2003; Pettit et al., 2013; Pettit et al., 2010; Faisal et al., 2006
34	Governmental cooperation (customs) to cope with terrorist acts	Pettit et al., 2010, 2013; Tang 2006ab; Kleindorfer & Saad, 2005; Manuj & Mentzer, 2008a; Sheffi, 2001
35	Process improvement	Christopher & Peck, 2004; Tang 2006ab; Sheffi et al., 2003; Sheffi & Rice Jr, 2005; Pettit et al., 2013; Pettit et al., 2010; Christopher & Peck 2003
36	Streamlined and Simplified Designing of Processes	Christopher & Peck, 2003, 2004; Sheffi, 2003; Sheffi & Rice Jr, 2005

Table 1
Solutions of Coping with Disruptions (Continued)

code	Solutions of Coping with Disruptions	authors
37	Use of parallel processes instead of series processes	Christopher & Peck, 2003, 2004; Sheffi, 2003; Sheffi & Rice Jr, 2005
38	Use of E-based processes instead of paper-based ones	Christopher & Peck, 2003, 2004
39	Synchronization of schedules based on shared information	Christopher & Peck, 2004
40	Increase of the speed of recovery by increasing preparedness and anticipation against disturbances	Christopher & Peck 2004; Tang 2006ab; Kleindorfer & Saad, 2005; Pettit et al., 2013; Pettit et al., 2010; Sheffi, 2003; Fiksel, 2003; Sheffi & Rice Jr, 2005; Christopher & Peck, 2003; Lee, 2004
41	Six sigma	Christopher & Rutherford, 2004; Kleindorfer & Saad, 2005

3. Research Methodology

Based on the studies conducted in this research, all solutions of coping with risk and supply chain events are placed in 41 factors. This research is based on the positivist paradigm, and it is an applied case in terms of the type and purpose of the research because it aims to use the results of its findings to solve a particular problem in the organization. It is descriptive-analytical one in terms of the method of data collection. Because the researcher has tried to describe the attitudes, thoughts or the characteristics of society by using the questionnaire, the research is quantitative one, and in the field of case study, its aim is the theoretical test. ISM technique and Fuzzy MICMAC analysis were used to classify factors. Mental, non-structured, and non-obvious models can be transformed into clear and well-defined models by ISM (Attri et al., 2013), but ISM model cannot detect indirect relationships between the presented methods. Therefore, Fuzzy MICMAC technique is used to explore the indirect relationships between the proposed solutions (Khan & Haleem, 2015). ISM method is one of the most widely used models in the theories of making decision and management due to its advantages. Using the proposed process in this method and the systematic approaches of this method, we can reduce 50 to 80 percent of the calculations related to examine the relationships between solutions, and using the graph generated by this method, we can effectively and efficiently examine the relationship between the elements of a system (Singh et al., 2016). The ISM and fuzzy MICMAC provide a deep insight into the relationships between risk management strategies by using the systematic steps. Using the ISM technique, Singh et al. (2016) presented a model for examining key factors in a responsive supply chain. Using the ISM and Fuzzy MICMAC methods, Goran and Kant in 2013 explored the relationships between empowering a supply chain and recognizing the stimulus and dependent enablers in supply chain management. Using fuzzy ISM and MICMAC techniques, Kumar et al. (2015) investigated the dynamical relationships between enablers in the process of suppliers' making decisions, and identified the stimulus and related enablers in this process. Interpretative structural modeling suggests that experts' opinions should be used based on various managerial techniques such as brain storming, nominal group, etc., to develop content relationships among variables. As a result, in this research, the opinions of 11 experts were used to determine the content relationships among the solutions of coping with supply chain disruptions in Behban Shimi Company (BSCO), all of them have worked in infection control industry for at least 7 years. For each pair of criteria, experts were asked to comment on the relationship between each two criteria.

4. Findings

SSIM Matrix (Structural Self Interaction Matrix)

The relation of "lead to" has been chosen to examine the textual relationships. To develop the textual relations between risk management strategies in a supply chain, experts' opinions should be used based on various managerial techniques such as brain storms, nominal grouping, engineering the ideas, and so on. In this research, 11 experts in the supply chain field in Behban Shimi Company (BSCO), including seven specialists in the field of supply chain risk management as well as four academic specialists have been used. The results are summarized in Table 2.

Table 2
SSIM matrix of the solutions of coping with risk in a supply chain

code	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
1		O	X	O	O	O	O	O	O	O	O	O	O	O	O	O	A	O	V	O	O	O	O	A	A	A	O	A	A	A	A	A	A	A	A	A	A	A	O	X	A
2			O	A	A	O	A	O	O	A	A	O	O	O	A	X	A	X	V	A	O	O	O	A	A	O	O	A	A	A	A	A	A	A	A	A	O	A	O	O	A
3				O	O	O	O	O	O	O	O	O	O	O	O	O	A	O	V	O	O	O	O	A	A	A	O	A	A	A	A	A	A	A	A	A	A	A	O	X	A
4					V	V	V	V	V	X	X	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	A	V	V	X	A	A	A	A	X	V	A	V	V	V
5						V	X	V	V	A	A	V	V	V	V	V	X	V	V	X	V	V	V	X	X	V	V	A	X	X	A	A	A	A	A	A	V	A	V	V	X
6							O	X	X	A	A	O	V	V	O	O	A	O	V	A	V	V	V	A	A	O	O	A	A	A	A	A	A	A	A	A	O	A	O	V	A
7								V	V	A	A	V	V	V	V	V	X	V	V	X	V	V	V	X	X	V	V	A	X	X	A	A	A	A	A	A	V	A	V	V	X
8									X	A	A	O	V	V	O	O	A	O	V	A	V	V	V	A	A	O	O	A	A	A	A	A	A	A	A	A	O	A	O	V	A
9										A	A	O	V	V	O	O	A	O	V	A	V	V	V	A	A	O	O	A	A	A	A	A	A	A	A	A	O	A	O	V	A
10											X	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	A	V	V	X	A	A	A	A	X	V	A	V	V	V
11												V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	V	A	V	V	X	A	A	A	A	X	V	A	V	V	V
12													O	O	O	O	A	O	O	O	O	O	O	A	A	O	V	A	A	A	A	A	A	A	A	A	X	A	V	O	A
13														O	O	O	A	O	V	O	O	O	O	A	A	A	O	A	A	A	A	A	A	A	A	A	A	A	O	O	A
14															O	O	A	O	V	O	O	O	O	A	A	A	O	A	A	A	A	A	A	A	A	A	A	A	O	O	A
15																V	A	V	V	A	O	O	O	A	A	O	O	A	A	A	A	A	A	A	A	A	O	A	O	O	A
16																	A	X	V	A	O	O	O	A	A	O	O	A	A	A	A	A	A	A	A	A	O	A	O	O	A
17																		V	V	X	V	V	V	X	X	V	V	A	X	X	A	A	A	A	A	A	V	A	V	V	X
18																			V	A	O	O	O	A	A	O	O	A	A	A	A	A	A	A	A	A	O	A	O	O	A
19																				A	O	O	O	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
20																					V	V	V	X	X	V	V	A	X	X	A	A	A	A	A	A	V	A	V	V	X
21																						X	A	V	V	O	O	V	V	V	V	V	V	V	V	V	O	V	O	O	V
22																							A	V	V	O	O	V	V	V	V	V	V	V	V	V	O	V	O	O	V
23																								A	A	A	A	A	A	A	A	A	A	A	A	A	O	A	A	A	A
24																									X	V	V	A	X	X	A	A	A	A	A	A	V	A	V	V	X
25																										V	V	A	X	X	A	A	A	A	A	A	V	A	V	V	X
26																											V	A	A	A	A	A	A	A	A	A	X	A	V	O	A
27																												A	A	O	A	A	A	A	A	A	A	A	X	O	O
28																													v	v	v	v	v	v	v	v	v	v	v	v	v
29																														X	A	A	A	A	A	A	V	A	V	V	X
30																															A	A	A	A	A	A	V	A	V	V	X
31																																A	A	A	A	X	V	A	V	V	V
32																																	X	O	X	V	V	O	V	V	V
33																																		O	X	V	V	O	V	V	V
34																																			O	V	V	X	V	V	V
35																																				V	V	X	V	V	V
36																																					V	A	V	V	V
37																																						A	V	O	A
38																																							V	V	V
39																																								O	O
40																																									A
41																																									

Reachability Matrix

The developed SSIM matrix is converted to a zero and one matrix, which will henceforth be called the Reachable Matrix. In order to convert the SSIM matrix to reachable matrix, the elements V, A, X, and O in the SSIM matrix must be converted to zero and one by the following rules:

Table 3
Final Reachable Matrix

code	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
1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
4	0	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	0	1	1	0	1	1	1
5	0	1	0	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0	1	0	1	1	1
6	0	0	0	0	0	0	0	1	1	0	0	0	1	1	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
7	0	1	0	0	0	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0	1	0	1	1	1
8	0	0	0	0	0	0	0	0	1	0	0	0	1	1	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
9	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
10	0	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	0	1	1	0	1	1	1
11	0	1	0	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	0	0	0	0	1	1	0	1	1	1
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	1	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	1	1	1	0	0	1	0	1	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0	1	0	1	1	1
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	0	1	0	0	0	1	0	1	1	0	0	0	0	0	1	1	0	1	1	0	1	1	1	1	1	1	1	0	1	1	0	0	0	0	0	0	1	0	1	1	1
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	0	1
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	1	1	1	1	1	1	1	1	0	1	0	0	1
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
24	1	1	1	0	0	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	1	0	1	1	1	0	1	1	0	0	0	0	0	0	1	0	1	1	1
25	1	1	1	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	1	1	0	1	1	0	1	1	0	0	0	0	0	0	1	0	1	1	1
26	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1
29	1	1	1	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	0	1	0	0	0	0	0	0	1	0	1	1	1
30	1	1	1	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	1	0	0	0	0	0	0	0	1	0	1	1	1
31	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	0	0	0	0	0	1	1	0	1	1	1
32	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	0	1	0	1	1	1	0	1	1	1
33	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	0	0	1	1	1	0	1	1	1
34	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	0	0	0	0	1	1	1	1	1	1
35	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	1	1	0	0	1	1	1	1	1	1
36	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	0	0	0	0	0	1	0	1	1	1
37	1	0	1	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
38	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	1	0	1	1	1	0	0	1	1	1	1	0	1	1	1
39	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
40	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
41	1	1	1	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	1	1	0	0	1	1	1	1	0	0	1	1	0	0	0	0	0	0	1	0	0	1	0

Matrix classification

Using final reachability matrix, the reachability set and antecedent set of each solution are identified. Reachability set contains all the elements obtained through an element (plus the same element) and the antecedent set is a solution or element containing all the solutions leading to this solution (plus the same element). Therefore, the intersection set of these two sets is identified for all solutions. The element, in which the reachability set and the intersection set are the same, is equal to the upper element of the ISM hierarchical structure. The upper element of the ISM technique would not help to get any solution above itself. When the upper element is detected, this element is removed from the set of elements, then the next levels of the ISM graph are identified by using similar technique. These identified levels help to create an oriented graph in the final model of ISM. In the following, the tables of calculations related to identify the different levels of solutions of coping with risk in a supply chain.

Table 4

Matrix classification

Code	Reachability Set	Antecedent Set	Intersection Set
1	1,3,19,40	1,17,24,25,26,28,29,30,31,32,33,34,35,36,37,38,40,41	1,40
2	2,16,18,19	2,4,5,7,10,11,15,17,20,24,25,28,29,30,31,32,33,34,35,36,38,40,41	2
3	3,19,40,0	3,1,17,24,25,26,28,29,30,31,32,33,34,35,36,37,38,40,41	3, 40
4	4,2,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21, 22,23,24,25,26,27,28,29,30,31,36,37,39,40,41	4,28,31,32,33,34,35,36,38,0	4,31,36
5	5,2,6,7,8,9, 12,13,14,15,16,17,18,19,20,21, 22,23,24,25,26,27,28,29,30,37,39,40,41	5,4,10,11,25,28,29,30,31,32,33,34,35,36,38,41	5,25,29,30,41
6	6,8,9,13,14,19,21,22,23,40	6,4,5,10,11,17,20,24,25,28,29,30,31,32,33,34,35,36,38,41	6
7	7,2,8,9, 2,13,14,15,16,17,18,19,20,21, 22,23,24,25,26,27,28,29,30,37,39,40,41	7,4,5,10,11,24,25,28,29,30,31,32,33,34,35,36,38,41	7,24,25,29,30,41
8	8,9,13,14,19,21,22,23,40	8,4,5,6,7,10,11,17,20,24,25,28,29,30,31,32,33,34,35,36,38,41	8
9	9,13,14,19,21,22,23,40	9,4,5,6,7,8,10,11,17,20,24,25,28,29,30,31,32,33,34,35,36,38,41	9
10	10,2,5,6,7,8,9, 11,12,13,14,15,16,17,18,19,20,21, 22,23,24,25,26,27,28,29,30,31,36,37,39,40,41	10,4,28,31,32,33,34,35,36,38	10,31,36
11	11,2,5,6,7,8,9, 12,13,14,15,16,17,18,19,20,21, 22,23,24,25,26,27,28,29,30,31,36,37,39,40,41	11,4,10,28,31,32,33,34,35,36,38	11,31,36,
12	12,27,37,39	12,4,5,7,10,11,17,24,25,28,29,30,31,32,33,34,35,36,37,38,41	12,37
13	13,19	13,4,5,6,7,8,9,10,11,17,24,25,26,28,29,30,31,32,33,34,35,36,37,38, 41	13
14	14,19	14,4,5,6,7,8,9,10,11,17,24,25,26,28,29,30,31,32,33,34,35,36,37,38, 41	14
15	15,2,16,18,19	15,4,5,7,10,11,17,20,24,25,28,29,30,31,32,33,34,35,36,38,41	15
16	16,18,19	16,2,4,5,7,10,11,15,17,20,24,25,28,29,30,31,32,33,34,35,36,38,41	16
17	17,1,2,3,6,8,12,13,14,15,16,18,19,20,21,22,23,24, 25,26,27,29,30,39,40,41	17,4,5,7,10,11,24,25,28,29,30,31,32,33,34,35,36,38,41	17,24,25,29,30,4 1
18	18,19	18,2,4,5,7,10,15,16,17,20,24,25,28,29,30,31,32,33,34,35,36,38,41	18
19	19	19,1,2,3,4,5,6,7,8,9,10,11,13,14,15,16,17,18,20,24,25,26,27,28,29, 30,31,32,33,34,35,36,37,38,39,40,41	19
20	20,2,6,8,9,15,16,18,19,21,22,23,24,25,26,27,29,30, 37,39,40,41	20,4,5,7,10,11,17,24,25,28,29,30,31,32,33,34,35,36,38,41	20,24,25,29,30,4 1
21	21,22,24,25,28,29,30,31,32,33,34,35,36,38,41	21,4,5,6,7,8,9,10,11,17,20,23	21
22	22,24,25,28,29,30,31,32,33,34,35,36,38,41	22,4,5,6,7,8,9,10,11,17,20,21,23	22
23	23,21,22	23,4,5,6,7,8,9,10,11,17,20,24,25,26,27,28,29,30,31,32,33,34,35,36, 38,39,40,41	23
24	24,1,2,3,6,7,8,9,12,13,14,15,16,18,19,20,23,25, 26,27,29,30,37,39,40,41,0	24,4,5,7,10,11,17,20,21,22,25,28,29,30,31,32,33,34,35,36,38,41	24,7,17,20,25,29 ,30,41
25	25,1,2,3,5,6,7,8,9, 12,13,14,15,16,17,18,19,20,23, 24,26,27,29,30,37,39,40,41	25,4,5,7,10,11,17,20,21,22,24,28,29,30,31,32,33,34,35,36,38,41	25,5,7,17,20,29, 30,41
26	16,1,3,13,14, 19,23,27,39	26, 4,5,7,10,11,17,20,24,25,28,29,30,31,32,33,34,35,36,38,41	26
27	27,19,23,39	27,4,5,7,10,11,12,17,20,24,25,26,28,29,31,32,33,34,35,36,37,38,39	27,39
28	28,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19, 20,23,24,25,26,27,29,30,31,32,33,34,35,36,37,38,3 9,40,41	28,21,22,0	28
29	29,1,2,3,5,7,8,9,12,13,14,15,16,17,18,19,20,23, 24,25,26,27,30,37,39,40,41	29,4,5,7,10,11,17,20,21,22,24,25,28,30,31,32,33,34,35,36,38,41	29,5,7,17,20
30	30,1,2,3,5,6,7,8,9,12,13,14,15,16,17,18,19,20,23 ,24,25,26,29,37,39,40,41	30,4,5,7,10,11,17,20,21,22,24,25,28,29,31,32,33,34,35,36,38,41	30,5,7,17,20
31	31,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19, 20,23,24,25,26,27,29,30,36,37,39,40,41,	31,4,10,11,21,22,28,32,33,34,35,36,38	31,4,10,11,36
32	32, 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19 ,20,23,24,25,26,27,29,30,31,33,35,36,37,39,40,41	32,21,22,28,33,35	32,33,34

Table 4
Matrix classification (Continued)

Code	Reachability Set	Antecedent Set	Intersection Set
33	33, 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19 ,20,23,24,25,26,27,29,30,31,32,33,34,35,36,37,39,4 0,41	33,21,22,28,32,35	33,32,35
34	43,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19 ,20,23,24,25,26,27,29,30,31,32,35,36,37,39,40,41	34,21,22,28,38	34,38
35	35,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19 ,20, 23,24,25,26,27,29,30,31,32,33,36,37,38,39,40,41	35,21,22,28,32,33,38	35,32,33
36	36,1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19 ,20,23,24,25,26,27,29,30,31,37,39,40,41	36,4,10,11,21,22,28,31,32,33,34,35,38	36,4,10,11,31
37	37,1,3,12,13,14,19,27,39	37,4,5,7,10,11,12,17,20,24,25,28,29,30,31,32,33,34,35,36,38,41	37,12
38	38, 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19 ,20, 23,24,25,26,27,29,30,31,34,35,36,37,39,40,41	38,21,22,28,34,35	38,34,35
39	39,19,23,27	39,4,5,7,10,11,12,17,20,24,25,26,27,28,29,30,31,32,33,34,35,36,37 ,38	39,27
40	40,1,3,19,23	40,1,3,4,5,6,7,8,9,10,11,17,20,24,25,28,29,30,31,32,33,34,35,38,41	40,1,3
41	41,1,2,3,5,6,7,8,9,12,13,14,15,16,17,18,19,20,23,24 ,25,26,29,30,37,40	41,4,5,7,10,11,17,20,21,22,24,25,28,29,30,31,32,33,34,35,36,38	5,7,17,20

Due to prolongation, other repetitions have been not mentioned.

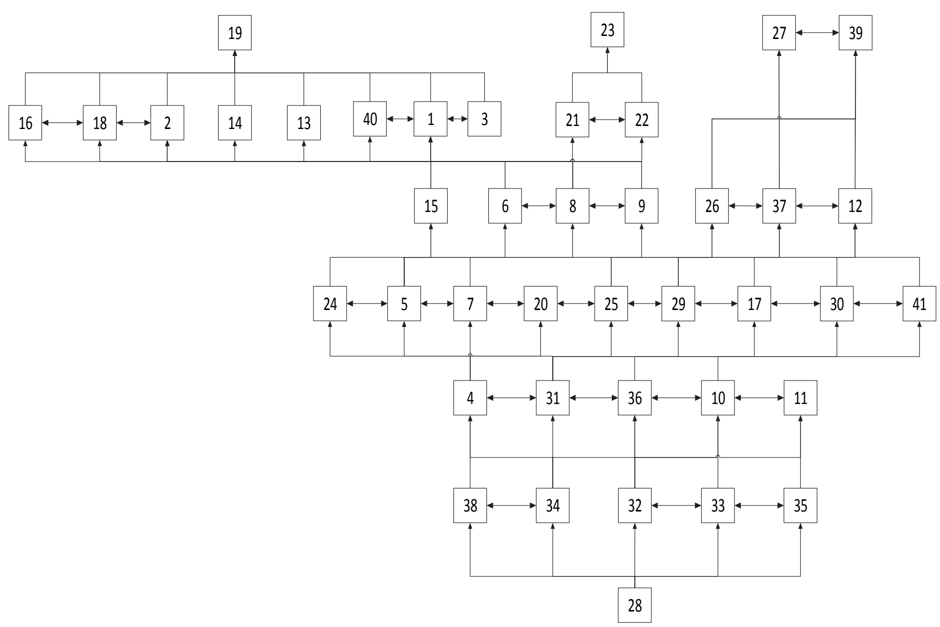

Fig. 1. Designing ISM graph

Fuzzy MICMAC analysis

The main steps in the Fuzzy MICMAC analysis technique are as follows:

Step 1- start the process of decision-making

Identifying the goals of decision making and initiating the decision-making process by collecting important information and identifying the range of solutions and objectives, as well as reviewing and selecting and monitoring the decision-making objectives to ensure that the goals are implemented in this part (Opricovic & Tzeng, 2003).

Step 2 - select the decision-making elements

A set of decision-making elements (here, the solution of coping with risk in the supply chain) are identified at this stage. An element in this set may affect other elements, or it may be affected by other elements or both cases. The existence of uncertainty in the expression variables of experts can be added according to the table above by using expression variables in the model.

Step 3 - Collect information and form SSIM matrix for Fuzzy MICMAC technique

Relationships between the various risk-management solutions in the supply chain represented by $\boldsymbol{C} = \{\boldsymbol{c_i} | \boldsymbol{i} = \mathbf{1}, \mathbf{2}, \dots, \boldsymbol{n}\}$ experts are identified in this field by collecting questionnaires given to the individuals, and then they are placed in SSIM matrix. The respondents can use a combination of the symbols presented in the ISM section (V, A, X, O) and the expression variables presented in the table above, and generally there are four options as below:

V: to show $\boldsymbol{i} \rightarrow \boldsymbol{j}$ relation, and not vice versa. The relation can be shown as below:

$$\boldsymbol{V(VH)} \quad \boldsymbol{V(H)} \quad \boldsymbol{V(L)} \quad \boldsymbol{V(VL)}$$

1- A: to show $\boldsymbol{j} \rightarrow \boldsymbol{i}$ relation, not vice versa. The relation can be shown as below:

$$\boldsymbol{A(VH)} \quad \boldsymbol{A(H)} \quad \boldsymbol{A(L)} \quad \boldsymbol{A(VL)}$$

2- X: to show $\boldsymbol{j} \rightarrow \boldsymbol{i}$ and $\boldsymbol{i} \rightarrow \boldsymbol{j}$ relation. The relation can be shown as below:

$$\boldsymbol{X(VH)} \quad \boldsymbol{X(H)} \quad \boldsymbol{X(L)} \quad \boldsymbol{X(VL)}$$

3- O: to show no relation between $\boldsymbol{i}$ and $\boldsymbol{j}$. The relation can be shown as below:

$$\boldsymbol{O(VH)} \quad \boldsymbol{O(H)} \quad \boldsymbol{O(L)} \quad \boldsymbol{O(VL)}$$

Step 4: Calculate SSIM Matrix and final Fuzzy accessibility matrix

The set of collected answers of experts is used to create SSIM matrix, and expression variables and numerical values of these variables have been replaced in the matrix. The following items would occur when creating the final accessibility matrix:

Step 5: Calculate the driving and dependence power of risk management solutions in supply chain using MICMAC Analysis

The fuzzy accessibility matrix of above table was created by collecting and forming SSIM fuzzy matrix in step four. The driving and dependence power of a solution can be calculated by summing the rows and columns, and also for a more accurate comparison, the numbers can become definite by the Fuzzy technique. Based on the obtained matrices and the mentioned points, the driving power and dependence of solution are presented in the following table.

In the Fuzzy MICMAC analysis, the solutions of coping with risk are divided into four groups. The first group is the autonomous solutions having practically poor driving power and effective power compared to the other solutions. These solutions are so-called separated from other solutions. The second group is dependent solutions. These solutions have low driving power but high dependence power, and are usually at the higher levels of ISM chart. The third group is linkage solutions. These strategies simultaneously have higher driving power and dependence power than other solutions, and changes within them would lead to changes in higher levels of ISM, and these solutions would also be affected by lower level solutions. The fourth group is the driver solutions. These have a high driving power but lower dependence than other risk management solutions, and they are usually at lower levels of ISM chart.

Step 6: Creating the Matrix of Driving and Dependence power (Analyzing MICMAC) Based on the values obtained in step 5, the following graph is provided for the driving and dependence power of each solution.

Table 5
Driving and dependence power of each solution

code	Dependence power	Driving power	code	Dependence power	Driving power	code	Dependence power	Driving power
1	14.54	3.27	15	15.90	4.60	29	16.33	19.85
2	17.89	3.81	16	17.89	3.81	30	16.33	18.72
3	14.54	3.81	17	15.22	21.39	31	10.60	23.10
4	8.89	22.87	18	17.89	3.81	32	5.58	25.04
5	14.98	20.32	19	25.36	1.37	33	5.58	25.04
6	16.57	8.41	20	15.22	18.58	34	4.52	24.16
7	14.74	19.90	21	10.35	11.77	35	6.35	25.68
8	17.23	8.41	22	10.35	11.77	36	10.10	23.10
9	17.23	8.41	23	20.51	2.47	37	16.52	7.90
10	8.13	23.23	24	13.21	17.96	38	5.31	23.64
11	8.64	23.23	25	16.33	19.85	39	17.42	3.81
12	9.11	2.19	26	16.33	8.41	40	18.97	4.60
13	18.55	2.20	27	16.76	3.81	41	11.76	13.52
14	18.55	2.20	28	2.97	27.99			

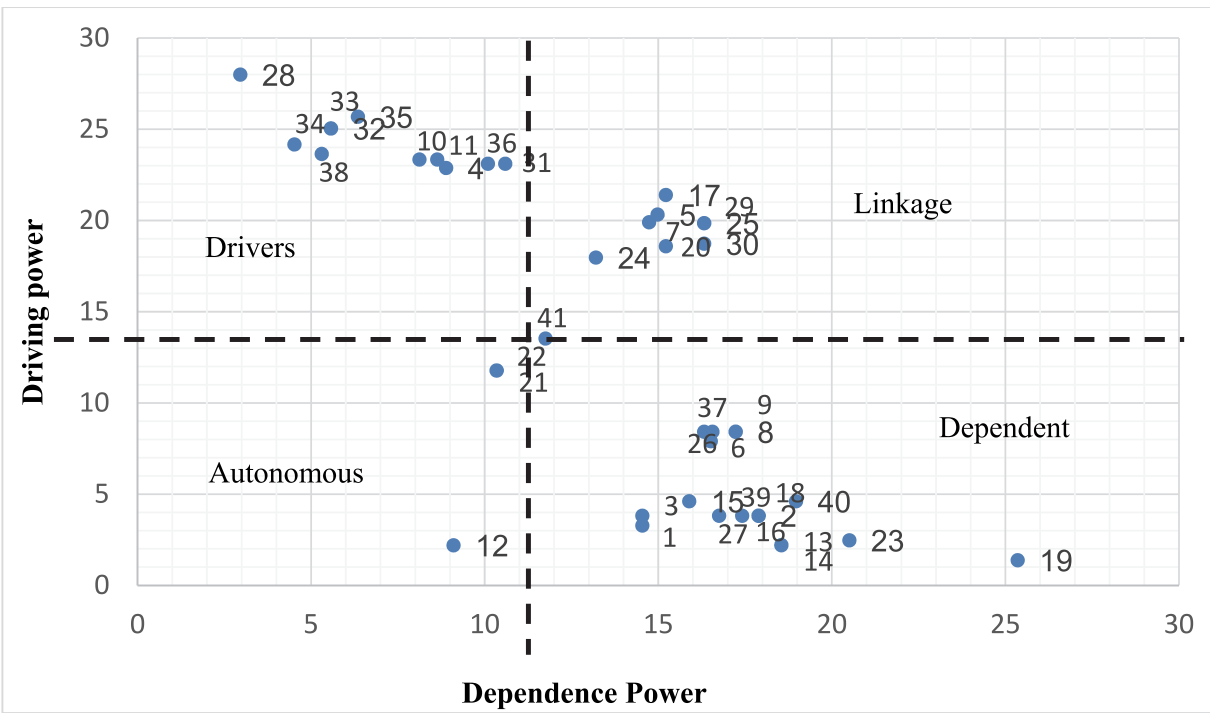

Fig. 2. Fuzzy MICMAC

5. Discussion and conclusion

The existence of a resilient supply chain is one of the most important aspects of coping with risk in supply chain networks. To effectively and efficiently deal with network risks, supply chain management should be aware of the importance of solutions as well as prioritizing the solutions of coping with risks, and it should be able to spend more time and energy to solutions with a higher priority. The purpose of this study was to analyze the relationships among the solutions of coping with disruptions in supply chain networks. This is an applied research, using the research literature, 41 factors were selected for the solutions of coping with disruptions in supply chain networks. Then, these factors were entered in questionnaire and were provided to the supply chain experts. After that Structural Interpretation Modeling (ISM) and Fuzzy MICMAC were used to categorize the solutions of coping with disruptions in supply chain networks. The findings of this study can have a significant role in managing supply chain disruptions. In fact, managers can make decisions on supply chain disruptions, by awareness and attention to the level, degree of dependency, and the power of each of them. The findings indicate that the development of the supply chain continuity system (solution 28) is at the seventh level. In fact, in the area of quality management, many organizations have concluded that the only way to achieve optimal quality is to create a culture whereby quality issues can be taken into consideration by all employees, and everyone can be involved in this subject, which led to the emergence of a comprehensive quality management system. Hence, today many organizations are trying to create a comprehensive risk management culture. These results are consistent with the research findings of Christopher and Peck (2004).

Creating a crisis and planning committee to cope with risks in supply chain systems is the most important risk management solution. The creation of this system will lead to the use of standard processes and the optimal design of processes in the supply chain. Sixth level of ISM is composed of solutions related to design processes (Solutions 35,33,32,34 and 38). By the help of electronic devices, managers will be able to know the status of activities moment by moment, so that they can take urgent action immediately as needed. This strategy increases the speed of flow of materials in the network, leading to better and faster response to unexpected changes as well as better and faster recovery and increase the competitive power of the organization. The results show that activities should be designed in parallel rather than in series as much as possible. This way of designing enables the supply chain to quickly respond to changes in demand. These results are consistent with Christopher and Peck (2004), Sheffi (2003) and Sheffi and Rice Jr (2005). The results also show that proper and efficient design of processes in the supply chain network will lead to proper operation in management solutions and appropriate coordination in the supply chain network (Fifth level). The use of appropriate management solutions in coordination will result in the integration and proper sharing of information within a supply chain and between various supply chains and the government (fourth Level). Using the coordination and integration of supply chain networks, it is possible to design a suitable supply chain network and appropriate communication between employees and network elements (third level, second and first level). Also, Fuzzy MICMAC analysis shows that solutions of established supply chain continuity team are driving and radical. In fact, these disruptions are slightly dependent on other disruptions and influence greatly on other solutions. In fact, it is a key solution, and it is considered as a foundation for managing disruptions in the supply chain, which can help the organization in managing the supply chain disruptions. Also, the solutions of Aligning incentives and revenue sharing policies in a supply chain, Communicational and Technological Tools, Information sharing among Nodes of network, Distributed Power, Diversification strategy, Vertical relatedness and Developing in-house capacity to produce inputs, Identical plant design/process and facility and Multi-skill and interchangeable labor force are located in linkage area. These solutions are also important, but not as much as driver solutions. The solutions of Multi-modal transportation, Multi-carrier transportation and Silent product rollover (Substitutable products) are located in the autonomous area, which have little impact on other solutions, and they should be addressed independently. In addition, the solutions of Pre-Positioned emergency inventory, Excess capacity and Reserved capacity, Strategic stock, Interchangeable and generic parts in divers products, Flexible Manufacturing System (FMS), Postponement and … are dependent and they should always be implemented after the drivers and linkage solutions.

For future research, the following points are recommended to respectful researchers:

- Identifying, determining relationships, and categorizing the solutions of coping with supply chain disruptions in other industries
- Identifying, determining the relationships, and categorizing the solutions of coping with supply chain disruptions in the infection control industry or other similar industries by modeling structural equations and mental mapping.

The limitations of this research can also be referred to the lack of feasibility of research results for other industries. In fact, if this research is conducted in other industries, it is necessary to re-derive the content relationships among the criteria based on the experts' ideas of intended industry supply chain.

References

Attri, R., Dev, N., & Sharma, V. (2013). Interpretive structural modelling (ISM) approach: an overview. *Research Journal of Management Sciences*, *2*(2), 3-8.

Azevedo, S. G., Machado, V. H., Barroso, A. P., & Cruz-Machado, V. (2008). Supply chain vulnerability: environment changes and dependencies. *International journal of logistics and transport*, *2*(1), 41-55.

Blackhurst, J., Dunn, K. S., & Craighead, C. W. (2011). An empirically derived framework of global supply resiliency. *Journal of Business Logistics*, *32*(4), 374-391.

Bradley, J. R. (2014). An improved method for managing catastrophic supply chain disruptions. *Business Horizons*, *57*(4), 483-495.

Choi, T. Y., & Krause, D. R. (2006). The supply base and its complexity: Implications for transaction costs, risks, responsiveness, and innovation. *Journal of Operations Management*, *24*(5), 637-652.

Choi, T. Y., & Hong, Y. (2002). Unveiling the structure of supply networks: case studies in Honda, Acura, and DaimlerChrysler. *Journal of Operations Management*, *20*(5), 469-493.

Chopra, S., & Sodhi, M. S. (2004). Managing risk to avoid supply-chain breakdown. *MIT Sloan Management Review*, *46*(1), 53.

Christopher, M. (2004). Creating resilient supply chains. *Logistics Europe*, *11*, 18-19.

Christopher, M., & Towill, D. R. (2002). Developing market specific supply chain strategies. *The international journal of logistics management*, *13*(1), 1-14.

Christopher, M., McKinnon, A., Sharp, J., Wilding, R., Peck, H., Chapman, P., ... & Bolumole, Y. (2002). Supply chain vulnerability. *Cranfield University, Cranfield*.

Christopher, M., & Rutherford, C. (2004). Creating supply chain resilience through agile six sigma. *Critical eye*, *7*(1), 24-28.

Christopher, M., & Peck, H. (2004). Building the resilient supply chain. *The international journal of logistics management*, *15*(2), 1-14.

Christopher, M. (2003). Understanding supply chain risk: A self-assessment workbook. *Cranfield University, School of Management, Department for Transport*.

Craighead, C. W., Blackhurst, J., Rungtusanatham, M. J., & Handfield, R. B. (2007). The severity of supply chain disruptions: design characteristics and mitigation capabilities. *Decision Sciences*, *38*(1), 131-156.

Eskew, M. (2004). Mitigating supply chain risk. *CEO (April)*, 25-26.

Foroughi, A., Albin, M., & Kocakulah, M. (2006, July). Perspectives on global supply chain supply-side risk management. In *Technology Management for the Global Future, 2006. PICMET 2006* (Vol. 6, pp. 2732-2740). IEEE.

Nishat Faisal, M., Banwet, D. K., & Shankar, R. (2006). Supply chain risk mitigation: modeling the enablers. *Business Process Management Journal*, *12*(4), 535-552.

Falasca, M., Zobel, C. W., & Cook, D. (2008, May). A decision support framework to assess supply chain resilience. In *Proceedings of the 5th International ISCRAM Conference* (pp. 596-605).

Fiksel, J. (2003). Designing resilient, sustainable systems. *Environmental science & technology*, *37*(23), 5330-5339.

Gorane, S. J., & Kant, R. (2013). Supply chain management: modelling the enablers using ISM and fuzzy MICMAC approach. *International Journal of Logistics Systems and Management*, *16*(2), 147-166.

Gunasekaran, A., Lai, K. H., & Cheng, T. E. (2008). Responsive supply chain: a competitive strategy in a networked economy. *Omega*, *36*(4), 549-564.

Handfield, R. B., Blackhurst, J., Elkins, D., & Craighead, C. W. (2007). A framework for reducing the impact of disruptions to the supply chain: Observations from multiple executives. *Supply Chain Risk Management: Minimizing Disruption in Global Sourcing. Taylor and Francis, Boca Raton, FL*, 29-49.

Hendricks, K. B., & Singhal, V. R. (2005). An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm. *Production and Operations management*, *14*(1), 35-52.

Hendricks, K. B., Singhal, V. R., & Zhang, R. (2009). The effect of operational slack, diversification, and vertical relatedness on the stock market reaction to supply chain disruptions. *Journal of Operations Management*, *27*(3), 233-246.

Hendricks, K. B., & Singhal, V. R. (2003). The effect of supply chain glitches on shareholder wealth. *Journal of operations Management*, *21*(5), 501-522.

Hishamuddin, H., Sarker, R. A., & Essam, D. (2013). A recovery model for a two-echelon serial supply chain with consideration of transportation disruption. *Computers & Industrial Engineering*, *64*(2), 552-561.

Iakovou, E., Vlachos, D., & Xanthopoulos, A. (2007). An analytical methodological framework for the optimal design of resilient supply chains. *International Journal of Logistics Economics and Globalisation*, *1*(1), 1-20.

Ishfaq, R. (2012). Resilience through flexibility in transportation operations. *International Journal of Logistics Research and Applications*, *15*(4), 215-229.

Ivanov, D., Sokolov, B., & Dolgui, A. (2014). The Ripple effect in supply chains: trade-off 'efficiency-flexibility-resilience'in disruption management. *International Journal of Production Research*, *52*(7), 2154-2172.

Jüttner, U., & Maklan, S. (2011). Supply chain resilience in the global financial crisis: an empirical study. *Supply Chain Management: An International Journal*, *16*(4), 246-259.

Khan, U., & Haleem, A. (2015). Improving to Smart Organization: An integrated ISM and fuzzy-MICMAC modelling of barriers. *Journal of Manufacturing Technology Management*, *26*(6), 807-829.

Kleindorfer, P. R., & Saad, G. H. (2005). Managing disruption risks in supply chains. *Production and operations management*, *14*(1), 53-68.

Kumar, S., Gorane, S., & Kant, R. (2015). Modelling the supplier selection process enablers using ISM and fuzzy MICMAC approach. *Journal of Business & Industrial Marketing*, *30*(5), 536-551.

Lee, H. L. (2004). The triple-A supply chain. *Harvard business review*, *82*(10), 102-113.

Manuj, I., & Mentzer, J. T. (2008). Global supply chain risk management strategies. *International Journal of Physical Distribution & Logistics Management*, *38*(3), 192-223.

Opricovic, S., & Tzeng, G. H. (2003). Defuzzification within a multicriteria decision model. *International Journal of Uncertainty, Fuzziness and Knowledge-Based Systems*, *11*(05), 635-652.

Peck, H. (2005). Drivers of supply chain vulnerability: an integrated framework. *International journal of physical distribution & logistics management*, *35*(4), 210-232.

Pettit, T. J., Fiksel, J., & Croxton, K. L. (2010). Ensuring supply chain resilience: development of a conceptual framework. *Journal of business logistics*, *31*(1), 1-21.

Pettit, T. J., Croxton, K. L., & Fiksel, J. (2013). Ensuring supply chain resilience: development and implementation of an assessment tool. *Journal of Business Logistics*, *34*(1), 46-76.

Ponis, S. T., & Koronis, E. (2012). Supply chain resilience: definition of concept and its formative elements. *Journal of Applied Business Research*, *28*(5), 921.

Ponomarov, S. Y., & Holcomb, M. C. (2009). Understanding the concept of supply chain resilience. *The international journal of logistics management*, *20*(1), 124-143.

Qi, L., & Lee, K. (2015). Supply chain risk mitigations with expedited shipping. *Omega*, *57*, 98-113.

Sawik, T. (2013). Selection of resilient supply portfolio under disruption risks. *Omega*, *41*(2), 259-269.

Sheffi, Y., Rice Jr, J. B., Fleck, J. M., & Caniato, F. (2003, June). Supply chain response to global terrorism: a situation scan. In *Center for Transportation and Logistics, MIT, Department of Management, Economics and Industrial Engineering, Politecnico di Milano, EurOMA POMS Joint International Conference*.

Sheffi, Y., & Rice Jr, J. B. (2005). A supply chain view of the resilient enterprise. *MIT Sloan Management Review*, *47*(1), 41.

Kumar, P., & Singh, R. K. (2012). A fuzzy AHP and TOPSIS methodology to evaluate 3PL in a supply chain. *Journal of Modelling in Management*, *7*(3), 287-303.

Singh, R. K., Gupta, A., Kumar, A., & Khan, T. A. (2016). Ranking of barriers for effective maintenance by using TOPSIS approach. *Journal of Quality in Maintenance Engineering*, *22*(1), 18-34.

Tang, C. S. (2006a). Robust strategies for mitigating supply chain disruptions. *International Journal of Logistics: Research and Applications*, *9*(1), 33-45.

Tang, C. S. (2006b). Perspectives in supply chain risk management. *International Journal of production economics*, *103*(2), 451-488.

Tang, C., & Tomlin, B. (2008). The power of flexibility for mitigating supply chain risks. *International Journal of Production Economics*, *116*(1), 12-27.

Wicher, P., & Lenort, R. (2013). The ways of creating resilient supply chains. In *Proceedings of Carpathian logistic congress*.

Wu, T., Blackhurst, J., & O'grady, P. (2007). Methodology for supply chain disruption analysis. *International journal of production research*, *45*(7), 1665-1682.