DE GRUYTER
OPEN

mper

A QUALITATIVE APPROACH FOR ASSESSING RESILIENCY IN SUPPLY CHAINS

Hassan Nikookar, Josu Takala, Daniel Sahebi, Jussi Kantola

University of Vaasa, Department of Production, Vaasa, Finland

Corresponding author:
Hassan Nikookar
University of Vaasa
Department of Production
Wolffintie 34, 65200, Vaasa, Finland
phone: (+358) 417420276
e-mail: Hassan.nikookar@uva.fi

ABSTRACT
The ultimate goal of this study is to develop a comprehensive and competitive management system to enhance resilience capability of supply chains. In addition, the study aims to identify and eliminate barriers affecting resilience by identifying the factors may cause trouble in the near future. The theoretical framework was established to summarize the significant finding in the area of resilient supply chain and as a guideline for the empirical part. A qualitative approach based on multi criteria decision making process has been adopted in order to gather data through in-depth interviews. The developed method to evaluate resilience capability through supply chains piloted in a sample of five companies involved in an automotive supply chain.

KEYWORDS
resilience supply chain, disruption, case study, sense and response, automotive industry.

Introduction

A supply chain (SC) is defined as a virtual network that connects various agents, from the supplier's supplier to the customer's customer, through various activities so that the smooth flow of materials or services, money and information stem from effectively manage of them [1]. Supply Chain Management (SCM) mainly deals with the selection of strategies and methodologies to facilitate the optimal flow of material from raw material suppliers through to the end-users [2]. In today's business environment, not only supply chain management is counted as a strategic necessity to enhance company's competitiveness and the better attainment of organizational objectives [3] but also it is frequently discussed that in current business environment SCs compete instead of companies; Success or failure of SCs is mainly determined by the marketplace [4].

In the globalized business environment, with supply chains traversing diverse countries or even continents, it is inevitable that disruptive events would

jeopardize the smooth flow of material in supply chain even if they occur in a remote place [5]. Due to the network structure of the SCs, all disruptions are being propagated and amplified, causing drastic negative effects on the supply chain abilities to meet its given undertakings. These fluctuations may result in a significant escalation of financial losses [6].

In addition, escalating pressure on margins have increased the tendency of companies toward employing lean and agile strategies aiming at reducing costs, through process improvement and waste elimination [4].

Whereas these low-cost solutions help companies beneficially, they may lead to more vulnerable supply chains [7]. Consequently, it is clear that the main factors to survive in the market fluctuations are not only the low cost, high quality, and short delivery time; but also overcoming disturbances that may jeopardize their performance, i.e., they must be resilient [8]. Being resilient in supply chain context is also considered as a prominent feature due to the fact that companies will not be able to maintain their level of

productivity in the case of a disruption in their supply chains. Therefore, interest in supply chain disruptions and respective negative consequences has been growing in the last years. Despite the fact that cost minimization or optimization of services had been the main objective in supply chain design, Current knowledge of market highlights resilience as the most crucial factor [9, 10].

Despite valuable works regarding resilient supply chain, much of the conducted research address resources of uncertainty in a supply chain and prepare several theoretical foundations to supply chain resilience [11–13]. However, a method to identify and analyze factors that influence resilience capability of supply chain is needed [14]. It seems that companies are eager to identify their weak points strongly related to their resiliency capability so that they would be able to improve their capabilities to overcome probable disruptions. Consequently, this article aims to propose an approach to evaluate and quantify the resilience level of the supply chain and identifying potentials for improving resilience in the supply chain. As it is frequently discussed that we can control what we can measure, this approach may help managers to explore supply chain threats from resiliency point of view to achieve more reliable supply chain.

In the following section, a literature review on resilient paradigm from SCM pointing at identifying resilient attributes in supply chain process is presented. Subsequently, some insights into sense and respond philosophy as the foundation of proposed assessment model will be discussed. Next, an assessment model is developed to evaluate SC's resilience capability. A case study is presented to illustrate how proposed measure helps companies make wise decision to enhance supply chain resilient. Finally main conclusions are drawn.

Theoretical research background

Resilient supply chain

In current business environment, which is characterized as increasing interdependencies among companies, disruptive events adversely affect the company ability to deliver products and services to the market [15]. Jin and Zhu discuss that disturbances have undesirable impact on financial performance both in the short-term and in the long-term, sales, costs, inventories of individual companies and the whole supply chain [16]. In addition, according to Hendricks and Singhal disturbances also negatively

affect the satisfaction level of the downstream supply chain members as well as ultimate costumer [17].

Traditionally supply chains try to resist disruptions; however new concentration is on finding ways for efficiently response to disruptions. Supply chains based on their behavior in the face of disturbances can be classified into two groups as following [18]:

- Resistant supply chains: is a highly controlled supply chain which can resist to minor disturbances and have the ability to rapidly recover.
- Resilient supply chains: can operate within a broad range of possible state and have the capability to recover to its original state or even a desired state after a disruption occurrence.

Broadly speaking, resilience means recovering to initial state after disturbances. The term "Resilience" is commonly used in most areas of research ranging from engineering sciences to social sciences. In metallurgy, resilience is defined as the ability of a substance to absorb and store energy and release it without any deformation [19]. The ability of an ecosystem to keep its identity in the face of any changes or shocks is called resilience [20]. In social science Ganor and Ben-lavy define resilience as a feature of a community that prepares the ability of the community to deal with long-term stress [21]. The concept is expanded to the supply chain management and several authors propose different definitions for resilience in the area of supply chain management. According to [22], resilience is the company's ability to react to disruptive events and maintain normal activities following a disruption. Christopher and Peck define resilience as the ability of a company to bounce back from any disruptive situation [23]. Resilience is also viewed as the ability of any members of a supply chain to cope with disruptive events [24]. Research is going further and resilience definition is shifting to more detailed ones. Ponomarrov and Holcomb explain that the resilience is the capability of supply chain and not just individual companies to be prepared for disruption, whether natural or man-made, respond to and also recover from them. The point which is explicit in mentioned definitions is that the resilience provides the capability to cope with disruptions but it does not stop disruptions occurrence.

Resilience practices

In new operating environment, a broad range of responses to supply chain disruptions can be observed. The majority of which is counted as reactive. However, in few cases, companies enhanced resilient capability in response to disruptive events [22]. Resilient capability helps companies to be prepared for and respond to unexpected disruptions ahead [25].

When the supply chains are investigated, important practices can be indentified that can lead to improve resilience in the supply chain. Implementing these practices efficiently would affect the resilience capability of the SC posetively.

Of all the ways to achieve resilience capability in supply chain context, two strategies, namely, redundancy and flexibility hold the greatest significant. Resilience would be enhanced through proper utilization of practices contributing to these strategies [10]. According to Carvalho, Maleki, and Cruz-Machado [26], the main goals of the resilient practices can be captured as following: to recover to original state or even desired state of the disrupted supply chain within reasonable time and cost as well as softening the impact of disturbances.

Redundancy entails maintaining extra resources and capacity in the supply chain to deal with unexpected disruptions. According to [22], companies may pursue practices such as "Managing inventory", "Maintaining production lines or facilities in excess of capacity requirement", "Committing to contracts for material supply", and " Maintaining dedicated transportation fleet" to implement redundancy strategy in their supply chains and appropriately respond to disruptions.

Table 1
Supply chain resilient praactices.

Resilient Practices	References				
	Rice and Caniato (2003)	Christopher and Peck (2004)	Tang (2007)	Sodhi and Tang (2012)	Soni et al. (2014)
Managing inventory	√				
Maintaining production lines or facilities in excess of capacity requirement	√				
Committing to contracts for material supply	√				
Maintaining dedicated transportation fleet	√				
Developing multi skilled work force	√				
Designing production systems that can accommodate multi products and real time changes	√				
Adopting sourcing strategies that permit transparent switching of suppliers	√				
Improving velocity of supply chain through "End-to-end time" reduction		√			
Strategic use of slack		√			
Developing visibility throughout the supply chain		√			√
Developing collaboration among supply chain member		√			√
Streamline the processes		√			
Silent product rollover		√			
Postponement			√		
Strategic stock			√		
Flexible supply base			√		
Make-and-Buy			√		
Flexible transportation			√		
Dynamic pricing and promotion in the case of disruption occurrence			√		
Assortment planning			√		
Risk management culture		√			√
Flexible contracts				√	√
Flexible manufacturing process				√	√
Improving agility		√			√
Information sharing					√

In contrast to redundancy, flexibility underscores organizational capabilities to respond to unexpected disruptions. It mainly entails establishing capability within individual companies and the whole supply chain through prior investment in tangible and intangible assets. This means that the company would reutilize existing resources in one division to make up for the missed resources in other divisions. In this line, Rice and Caniato present "developing multi skilled work force", "designing production systems that can accommodate multi products and real time changes", and "adopting sourcing strategies that permit transparent switching of suppliers" as practices which can improve flexibility through supply chain [22].

In connection with improving resilience, [23] discuss that improving agility, supply chain collaboration, and risk management culture underpin resilience in supply chains. "Strategic use of slack", developing visibility throughout the supply chain, developing collaboration among supply chain members, improving velocity of supply chain through "End-to-end time" reduction and try to streamline the processes are some practices result in improving mentioned features and consequently increasing supply chain resilience.

Anecdotal evidence shows that many companies are not willing to spend lots of money to adopt costly strategies for mitigating bad effects of disruptive events in their supply chains that may not occur. Hence, robust strategies would be good alternative as they help firms to reduce cost and enhance service quality in normal situation as well as they support companies during disruptions. To Tang [27] the utilization of robust supply chain strategies lead to enhance the organization's resilience when facing disruptive events. Eight robust practices are introduced to improve robust as well as resilience of companies as following: Postponement, Strategic stock, Flexible supply base, Make-and-Buy, Flexible transportation, Dynamic pricing and promotion in the case of disruption occurrence, Assortment planning, and Silent product rollover. This lsit has been extended by adding two new practices, namely flexible contracts and flexible manufacturing process [28].

In another research conducted by Hanna, Skipper, and Hall [15] improving collaboration among supply chain members, visibility of supply chain, risk management culture, and information sharing have been proposed as ways that can improve resilience of the supply chain. Table 1 illustrates supply chain practices contributing to improvement of resilience capability of the supply chains.

Supply chain in automotive industry

The most important feature of supply chain in automotive industry is that there are numerous sorts of raw materials. Since manufacturing process of vehicles needs a lot of components, therefore, relationships with hundreds of first tier supplier as well as thousands of second and third tier suppliers must be established and arranged in a normal automotive supply chain. Thun and Hoenig argue that in automotive industry, the majority of product aspects are determined, designed, and developed by OEMs [29]. The industry, unlike any other industry, is dominated by limited number of OEMs and they rule smaller firms especially suppliers with an iron fist.

According to a research conducted by Sturgeon, Memedovic, Van Biesebroeck, & Gereffi [30] the automotive industry is also influenced by globalization. They argue that today's OEMs supply needed materials and components from all over the globe then they will be able to produce vehicles in their own factory. End products are shipped to dealers who are in charge of distributing vehicles and deliver them to end costumer. Each of OEM's supply chains is constituted by several kinds of suppliers including direct, indirect and integrator suppliers which are responsible to delivery raw material, parts, and complex components to the manufacturer.

The normal supply chain paradigms used in automotive industry are just in time or just in sequence systems. These systems are used due to imbalanced distribution of power through the supply chain. As already mentioned having dominate authority in the supply chain from OEMs provide a good base for applying these systems in the supply chain. Holweg, Disney, Hines, and Naim [31] state that although in automotive industry just in time system and just in sequence system are used but lead time of the initial components is about 40 days of which just 15% of the time is used to produce components. They also report that big changes in pricing policies have happened. Previously suppliers were in competition with each other for reducing price but nowadays this policy is replaced by partnership and collaboration instead of competition.

Building the method

Since resilience capabilty of a supply chain will be improved throughout proper utilization of resilient supply chain practices, therefore, the evaluation of implementation performance of these practices throughout the supply chain is counted as an efficient approach to assess the resilience level of the supply chain. On the other hand, as the disruption

may occur in everywhere throughout the chain and due to network nature of the supply chain the negative effects of these disruptive events may be amplified and propagated throughout the supply chain, therefore, the investigation must be concentrated on all supply chain parties.

The research has been conducted in three steps including:

1. Identifying practices and attributes affecting resilience of the focal supply chain.
   Tools: Personnel interview, Literature review;
2. Preparing Questionnaire;
3. Analysis of gathered data, comparison with observation, and conclusion.

23 supply chain practices were identified in the literature, which improve resilience capability of a supply chain. During different interviews with 5 managers of case companies who are directly responsible for formulating supply chain strategies as well as following them, it was revealed that 20 of identified practices in the literature listed in Table 2 have more influence on and are more suitable for their business. They mentioned that utilization of these practices can enhance the resilience capability of the whole supply chain.

Table 2

Supply chain resilient practices utilized in the case study.

1.	Managing inventory
2.	Maintaining production lines or facilities in excess of capacity requirement
3.	Improving velocity of supply chain through "End-to-end time" reduction
4.	Risk management culture
5.	Developing multi skilled work force
6.	Streamline the processes
7.	Information sharing
8.	Committing to contracts for material supply
9.	Strategic use of slack
10.	Postponement
11.	Flexible supply base
12.	Dynamic pricing and promotion in the case of disruption occurrence
13.	Developing collaboration among supply chain member
14.	Developing visibility throughout the supply chain
15.	Improving agility
16.	Managing inventory
17.	Adopting sourcing strategies that permit transparent switching of suppliers
18.	Designing production systems that can accommodate multi products and real time changes
19.	Flexible transportation
20.	Maintaining dedicated transportation fleet

Sense and respond

The method used in this study derived from "Sense & Respond" philosophy which offers tools to deal with future uncertainty. "Sense & Respond" is utilized to assess the performance of resilient practice implementation in the supply chain. The main idea behind "Sense & Respond" methodology is being prepared against threats and converting them to opportunities by sensing the environment and organizations for ongoing or unexpected changes leading to the threats.

Based on this idea, Rautiainen and Takala have proposed a questionnaire method that can assess customer satisfaction and reveals critical attributes in regards with customer satisfaction from the system [32]. Ranta and Takala use "Sense & Respond" to identify critical factors affecting service quality in a company [33]. In another study, "Sense & Respond" was applied to assess the performance of the supply chain strategy implementation within European vs. Asian companies [34]. Nikookar, Sahebi and Takala discuss that the method can be implemented at either an individual firm or a group of firms regardless of its size and complexity [35].

Questionnaire

The most reliable and convenient tool to gather data in qualitative research is using questionnaire. In our research a questionnaire has been formed from resilient practices identified in prior stage and the study is going to evaluate their implementation performance in the supply chain. It was developed same way as it is proposed in Sillanpää et al. study [34]. In order to increase the validity and the reliability, a short and clear questionnaire has been formed. The easier the questionnaire is to complete the more valid the answers are. Table 3 illustrates the way how the questionnaire was formed. The implementation of practices is evaluated by expectation and experience with the scale of 1 to 10. Respondents are also asked to assess direction of development, past and future, and compare the focal supply chain with other competitors by choice of worse, same, or better.

The information extracted from questionnaires is then analyzed by the means of eight indices as following:

- Average of expectations;
- Average of experiences;
- Importance index;
- performance index;
- Gap index;
- Direction of development (past);
- Direction of development (future);
- Balanced Critical Index (BCFI).

Table 3
The format of questionnaire.

Attribute	Scale: 1 = low, 10 = high		Direction of development, expectations (future)			Direction of development, experiences (past)			Competitor		
	Expectations (1–10)	Experience (1–10)	Worse	Same	Better	Worse	Same	Better	Worse	Same	Better
Attribute 1											

Figure 1 presents the formulas which are used in the calculation of above indices.

$$Importance\ index = \frac{Average\ of\ expectation}{10},$$

$$Gap\ index = \frac{Average\ of\ expectation - Average\ of\ experience}{10} - 1,$$

$$Development\ index = |(better - worse) * 0.9 - 1|,$$

$$Performance\ index = \frac{Average\ of\ experience}{10},$$

$$SD\ expectation\ index = \frac{std\{expectation\}}{10} + 1,$$

$$SD\ experience\ index = \frac{std\{experience\}}{10} + 1,$$

$$BCFI = \frac{SD\ expectation\ index * SD\ experience\ index * Performance\ index}{Importance\ index * Gap\ index * Development\ index} - 1,$$

Fig. 1. "Sense&respond" equations [34].

The BCFI has been proposed to prepare a comprehensive overview on the performance of business process [33]. The idea behind the BCFI is to develop a reliable and quick tool to sense in advance and adequately respond to changes. Whereas the method, for the first time, was used to assess customer satisfaction and determine which attribute of the business process needs to be enhanced and which is in a stable situation but the application of this method in over than 60 cases, including a big categories of businesses, confirms that the methodology can be utilized in every business processes [33]. The method helps de-

cision makers within the organization to find out the implementation performance of which resilient practice should be monitored and improved by revealing the criticality level of it.

Case study

A sample of five companies involved in an automotive supply chain was determined to be investigated during this work. The target supply chain in this study is constituted by one manufacture and four first tier suppliers which are located in several parts of Iran. Those suppliers are responsible for supplying manufacturer with wire harness, exhaust, CNG conversion kit, and piston.

The manufacturer is a subsidiary of the greatest OEM in Iran. Similar to other OEMs in automotive industry, the parent company is in charge of designing and developing all products and subsidiaries located in different parts of the country only produce vehicles according to dictated production plans. In this case the responsibility of sourcing belongs to especial subsidiary of OEM, which has the responsibility of sourcing, making contract, and delivering parts and components to plants being responsible to produce vehicles. The OEM produces 12 different types of vehicles from which 4 models are produced by focal plant, which is called in this work manufacturer.

The recent strategy of the company is concentrated on producing customized vehicles based upon end user preferences, simultaneously, reducing cost to achieve price reduction. This policy has been adopted by the OEM for improving customer satisfaction.

In automotive industry, OEMs have authority to make decision regarding to the majority of product features. In the focal supply chain the OEM is in charge of sourcing raw materials and components needed in production process. An especial department located in headquarters of the OEM determines important factors influencing supplier selection process. Since there are strict regulations and standards in automotive industry in regards to safety and environmental issues. Therefore, OEMs not only control first tier suppliers but also they do control second tier supplier i.e. the suppliers of suppliers.

In our case study first tier suppliers and also the suppliers of them i.e. second tier suppliers are regularly audited according to particular predefined instructions by OEM.

The manufacturer in this case has established a long-term relationship with approximately 465 suppliers and in some cases they intend to develop partnership relations. The main goal of the company in developing long-term relationship with its suppliers is to ensure that all components and raw materials correspond exactly to orders.

In order to increase the reliability of supply chain, a new policy is being applied to almost every first tier suppliers. The order quantity is determined based on regular audits, price, and the geographical proximity of suppliers. This new policy has more pressure on suppliers than before due to the fact they must increase their quality in parallel with cost reduction.

Results and discussion

Information was collected by the resilient evaluation questionnaire which was especially developed and tested in the supply chain case to assess its resilience. First of all, the researchers investigate resilient features and current situation through literature review, observation, and interview. The questionnaire has been established based on findings of first step. The questionnaire measure the performance implementation of 20 resilient practices taking respondents' expectation and experience, their impressions of direction of development and other competitors into account.

The respondents were determined so that all the managers who are contributing to supply chain processes in four case companies, being questioned. From 40 distributed questionnaires, 25 answered questionnaires are useable (62.5%). According to response rate, the questionnaire is very successful because over the half of the distributed questionnaires have been fully answered and returned.

Table 4 is presenting preliminary results. The results revealed that every practice has gap between its experiences and expectations. Ranta and Takala claim when there are many gaps, utilization of more analyzing tools are crucial [33]. Hence, Direction of development index and Importance index were calculated for each practice. Gap index was also calculated for Critical index factor (refer to Table 5, 6, and Fig. 2).

Table 4
Preliminary results.

	Average of expectation	SD Expectation Index	Average of experiences	SD Experience Index
PRACTICE 1	8.20	1.10	7.08	1.71
PRACTICE 2	8.84	1.10	8.20	1.82
PRACTICE 3	**9.16**	1.07	**5.56**	1.56
PRACTICE 4	**8.80**	1.09	**6.16**	1.62
PRACTICE 5	7.48	1.07	6.92	1.69
PRACTICE 6	9.44	1.07	9.12	1.91
PRACTICE 7	**7.36**	1.06	**4.36**	1.44
PRACTICE 8	8.36	1.06	8.24	1.82
PRACTICE 9	9.44	1.06	8.76	1.88
PRACTICE 10	7.12	1.07	7.16	1.72
PRACTICE 11	7.04	1.08	7.12	1.71
PRACTICE 12	9.28	1.07	9.28	1.93
PRACTICE 13	**9.72**	1.05	**6.80**	1.68
PRACTICE 14	**8.56**	1.12	**5.40**	1.54
PRACTICE 15	7.12	1.11	7.96	1.80
PRACTICE 16	**9.64**	1.06	**6.64**	1.66
PRACTICE 17	7.84	1.09	9.48	1.95
PRACTICE 18	6.88	1.07	7.32	1.73
PRACTICE 19	6.60	1.06	6.28	1.08
PRACTICE 20	9.16	1.06	9.24	1.07

Table 5
Importance Index, Direction of Development Index, and Gap Index.

	Importance Index	Direction of development	Gap Index
PRACTICE 1	0.82	0.98	1.15
PRACTICE 2	0.88	0.99	1.08
PRACTICE 3	0.92	**1.03**	1.47
PRACTICE 4	0.88	**1.02**	1.34
PRACTICE 5	0.75	0.40	1.07
PRACTICE 6	0.94	0.48	1.04
PRACTICE 7	0.74	**1.48**	1.39
PRACTICE 8	0.84	0.52	1.02
PRACTICE 9	0.94	0.40	1.09
PRACTICE 10	0.71	0.84	0.99
PRACTICE 11	0.70	0.40	0.99
PRACTICE 12	0.93	0.60	1.00
PRACTICE 13	0.97	**1.44**	1.38
PRACTICE 14	0.86	**1.24**	1.41
PRACTICE 15	0.71	0.40	0.89
PRACTICE 16	0.96	0.72	1.39
PRACTICE 17	0.78	0.56	0.79
PRACTICE 18	0.69	0.60	0.94
PRACTICE 19	0.66	0.68	1.04
PRACTICE 20	0.92	0.60	0.99

Table 6
Result of BCFI.

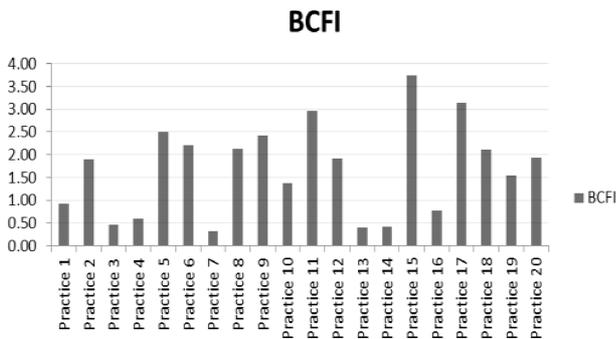|	**BCFI**		**BCFI**
PRACTICE 1	0.93	PRACTICE 11	2.97
PRACTICE 2	1.89	PRACTICE 12	1.91
PRACTICE 3	**0.47**	PRACTICE 13	**0.39**
PRACTICE 4	0.60	PRACTICE 14	**0.42**
PRACTICE 5	2.50	PRACTICE 15	3.74
PRACTICE 6	2.21	PRACTICE 16	0.78
PRACTICE 7	**0.33**	PRACTICE 17	3.14
PRACTICE 8	2.13	PRACTICE 18	2.12
PRACTICE 9	2.42	PRACTICE 19	1.55
PRACTICE 10	1.37	PRACTICE 20	1.94

Fig. 2. Result of Balanced Critical Factor.

Value over 1 in Direction of Development is classed as the practice which are need to be improved and value below 1 means that the implementation performance has been improved. Value 1 in mentioned index indicates that implementation performance has remained on the same level. Respectively, in Gap Index value 1 means there is no gap between expectation and experience. Value over or under 1 shows significant gap between expectation and exprienc.

Only the performance of implementation of five practices degenerated according to Direction of Development Index (Practices 3, 4, 7, 13, and 14). Other practices had improved.

The aim of the research was to figure out the most critical areas that need to improve in order to make the case supply chain more resilient. This goal

have been tried to be reached by Balanced Critical Index. The smaller values of BCFI correspond with the most critical practices. Each practice falls below 1/3 of average level of BCFIs (0.56) have been determined as the most critical practices.

From Balanced Critical Index point of view, four practices (practices 3, 7, 13, and 14) have been identified as the most critical ones among all practices which help case companies to be more resilient against disruption occurrence. Therefore, more attention should be paid to improving velocity of the supply chain through, information sharing, developing collaboration among supply chain member, and developing visibility throughout the supply chain.

Conclusion

Through this case study research, a constructive method for identifying critical practices which lead to a more resilient supply chain was established and tested by weak market test. This identification process is based on internal expert's opinions and systematic analysis of gathered data. The standard deviation, balanced critical index, and weak market test used to verify the validity and reliability of the study.

In this study, it was observed that there are significant gaps between experiences and expectations of implementation performance of resilient practices and that is the reason why we need more analysis. With Direction of development index it was revealed that which practices have developed and what have degenerated.

With Balanced Critical Index the most critical practices were identified. Based on this index, more attention hast to be paid to information sharing and visibility through supply chain. It is also highlighted that velocity in the case is significant to make more resilient supply chain.

References

[1] Stevens Graham C., *Integrating the supply chain*, International Journal of Physical Distribution & Logistics Management, 19 (8), 3–8, 1989.

[2] Fahimnia B., Luong L., Marian R., *Genetic algorithm optimisation of an integrated aggregate production–distribution plan in supply chains*, International Journal of Production Research, 50 (1), 81–96, 2012.

[3] Gunasekaran A., Patel C., Tirtiroglu E., *Performance measures and metrics in a supply chain environment*, International Journal of Operations & Production Management, 21 (1/2), 71–87, 2001.

[4] Christopher M., Towill D., *An integrated model for the design of agile supply chains*, International Journal of Physical Distribution & Logistics Management, 31 (4), 235–246, 2001.

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

[6] Sheffi Y., *The resilient enterprise: overcoming vulnerability for competitive advantage*, MIT Press Books, 1, 2005.

[7] Peck H., *Drivers of supply chain vulnerability: an integrated framework*, International Journal of Physical Distribution & Logistics Management, 35 (4), 210–232, 2005.

[8] Carvalho H., Azevedo S.G., Cruz-Machado V., *Supply chain performance management: lean and green paradigms*, International Journal of Business Performance and Supply Chain Modelling, 2 (3), 304-333, 2010.

[9] Blackhurst J., Kaitlin S. Dunn, Christopher W. Craighead, *An empirically derived framework of global supply resiliency*, Journal of Business Logistics, 32 (4), 374–391, 2011.

[10] Pettit T.J., Fiksel J., Croxton K.L., *Ensuring supply chain resilience: development of a conceptual framework*, Journal of Business Logistics, 31 (1), 1–21, 2010.

[11] Wagner S.M., Neshat N., *Assessing the vulnerability of supply chains using graph theory*, International Journal of Production Economics, 126 (1), 121–129, 2010.

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

[13] Bhamra R., Dani S., Burnard K., *Resilience: the concept, a literature review and future directions*, International Journal of Production Research, 49 (18), 5375–5393, 2011.

[14] Soni U., Jain V., Kumar S., *Measuring Supply Chain Resilience Using a Deterministic Modeling Approach*, Computers & Industrial Engineering, 2014.

[15] Hanna Joe B., Skipper J.B., Hall D., *Mitigating supply chain disruption: the importance of top manage-*

ment support to collaboration and flexibility, International Journal of Logistics Systems and Management, 6 (4), 397–414, 2010.

[16] Ji G., Zhu C., *Study on supply chain disruption risk management strategies and model*, In Service Systems and Service Management, International Conference on (pp. 1–6), IEEE, 2008.

[17] Hendricks K.B., Singhal V.R., *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, 2005.

[18] Fiksel J., *Designing resilient, sustainable systems*, Environmental Science & Technology, 37 (23), 5330–5339, 2003.

[19] Brady G.S., Clauser H.R., Vaccari J.A., *Materials handbook*, McGraw-Hill, 15, 1956.

[20] Cumming G.S., Barnes G., Perz S., Schmink M., Sieving K.E., Southworth J., Van Holt T., *An exploratory framework for the empirical measurement of resilience*, Ecosystems, 8 (8), 975–987, 2005.

[21] Ganor M., Ben-Lavy Y.U.L.I., *Community resilience: Lessons derived from Gilo under fire*, Journal of Jewish Communal Service, 79 (2/3), 105–108, 2003.

[22] Rice J.B., Caniato F., *Building a secure and resilient supply network*, Supply Chain Management Review, 7, 5, 22–30, 2003.

[23] Christopher M., Peck H., *Building the resilient supply chain*, International Journal of Logistics Management, 15 (2), 1–14, 2004.

[24] Azevedo S.G., Machado V.H., Barroso A.P., Cruz-Machado V., *Supply chain vulnerability: environment changes and dependencies*, International Journal of Logistics and Transport, 2 (1), 41–55, 2008.

[25] Hong P., Hwang W., *Operational capabilities and performance toward global supply chain: an overview of Korean manufacturing and service firms*, International Journal of Logistics Systems and Management, 8 (2), 183–197, 2011.

[26] Carvalho H., Maleki M., Cruz-Machado V., *The links between supply chain disturbances and resilience strategies*, International Journal of Agile Systems and Management, 5 (3), 203–234, 2012.

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

[28] Sodhi M.S., Tang C.S., *Managing supply chain risk*, Springer, 172, 2012.

[29] Thun J.H., Hoenig D., *An empirical analysis of supply chain risk management in the German automotive industry*, International Journal of Production Economics, 131 (1), 242–249, 2011.

[30] Sturgeon T.J., Memedovic O., Van Biesebroeck J., Gereffi G., *Globalisation of the automotive industry: main features and trends*, International Journal of Technological Learning, Innovation and Development, 2 (1), 7–24, 2009.

[31] Holweg M., Disney S.M., Hines P., Naim M.M., *Towards responsive vehicle supply: a simulation-based investigation into automotive scheduling systems*, Journal of Operations Management, 23 (5), 507–530, 2005.

[32] Rautiainen M., Takala J., *Measuring customer satisfaction and increasing it by choosing the right development subjects*, In 2nd International Conference on Logistics & Transport, LOADO, 2003.

[33] Ranta J.M., Takala J., *A holistic method for finding out critical features of industry maintenance services*, International Journal of Services and Standards, 3 (3), 312–325, 2007.

[34] Sillanpää I., Malek A., Takala J., *Critical attributes on supply chain strategy implementation: case study in Europe and Asia*, Management and Production Engineering Review, 4 (4), 66–75, 2013.

[35] Nikookar H., Sahebi D., *Comparing sense and respond based critical factor index methods for optimizing operations strategies*, In MIC 2012: Managing Transformation with Creativity; Proceedings of the 13th International Conference, Budapest, 22–24 November 2012 [Selected Papers] (pp. 1067–1077). University of Primorska, Faculty of Management Koper, 2012.