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**EVALUATION OF SUPPLY CHAINS BASED ON SENSE AND RESPOND  
AND SUSTAINABLE COMPETITIVE ADNATAGE (SCR)**

A case study for

**Iran Automotive Industry**

Master's Thesis in  
Industrial Management

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**Abstract**

Due to globalization of business environment and tendency of companies to be more lean and agile, today supply chains are more vulnerable to disruptions. The most prominent thing affected by disturbances is productivity and consequently financial capabilities of the company. The vital factor of a company that can help tackle disturbances is resiliency capability of its supply chain i.e. the capability of supply chain to absorb disruption and moving back to its original state on more desirable one very soon.

This thesis aims at utilization of sense and responds methodology, as one of the valuable tools to identifying weak points and critical attributes in a business process, to identify critical attributes contributing toward supply chain resiliency. It may help managers to explore supply chain threats from resiliency point of view to achieve more reliable supply chain. A case study was performed in a part of Iranian automotive supply chain consist of one manufacturer and four suppliers was revealed that the main issue in Iran automotive industry regarding resiliency is related to visibility through supply chain. The main concentration of this paper was automotive supply chain. To establish more reliable and meaningful conclusion, the need of more empirical investigation is significant.

**Keywords:** Resilient supply chain, Disruptive event, automotive industry, Sense and Respond, Case study

## **INTRODUCTION**

### **1.1 Aims**

Nowadays, due to globalization, companies are not competing individually but a network of several companies, in which each company plays a prominent role ranging from preparing raw material to delivery end product to ultimate customer, collaborates with other analogous networks to maximize customer satisfaction as well as their own total incomes. This network of different firms, which are in charge of several processes including supplying of raw material, manufacturing of semi-produced components, production, distributing end products and so forth, is called supply chain.

In nowadays supply chains, it is prevalent to see that raw material and components are supplied to a manufacturer, for instance, in United State by supplier from Asia, Europe or even nearby countries such as Canada and then ultimate products must be delivered to a customer living in Africa simultaneously. The point should be considered is that the lowest cost and highest quality as well as shortest delivery time must be guaranteed by the company. Mentzer et al. (2001) describe how a well-coordinated supply chain can secure long-term benefit of companies involved in that supply chain.

We live in the era of globalization characterized by short product life cycle, increasing customer expectation along with escalation of catastrophic events such as terrorist attacks, earthquake, hurricane, and so on. These characteristics of

current era may cause disruption in smooth flow of items in supply chains passing through different countries (Ponomarov et al. 2009). It is a matter of fact that even if catastrophic events may occur in a faraway place, they can cause huge disruption in the supply chain and become amplified because of network characteristic of supply chain (Rosicet et al. 2009). Sheffi (2005) explains that while a disruption occurs in a supply chain, the majority of companies involved are not maintaining their productivity and, consequently, financial losses, because of disruption, will surge.

In comparison to other industry, automotive sector is much more vulnerable to disruptive events. Carvalho et al. (2013) report how automotive industry got deeply and visible shocked after Japan earthquake in 11 March 2011. Therefore it is worth considering automotive industry very close. The 11/9 terrorist attack is named as the peak of disruptive events. Soon after that time US government ordered to establish security plans to improve supply chain reliability. It may come to mind that in the turbulent environment there is no need to develop new security plans. Utilization of insurance plans would be a good idea to secure supply chains. Rice and Caniato (2005) present that just a limited number of companies believe in insurance plans due to two main reasons:

1. Insurance premiums for catastrophic events are unbelievable expensive.
2. Insurance institutions only compensate suffered companies for a part of their financial loss but after disruptions apart from financial loss, the reputation of companies will be harmed.

They continue that companies are trying to progress their resiliency and risk management plans against disruptions instead of just relying on insurance institutions.

Lower cost, higher quality, and decreased lead time are not only key features of a company to sustain its competitiveness and efficiency in the turbulent era, but also the ability of company to triumph over disturbances and maintain current state or even move to more desirable one have a prominent role. This ability in the literature of supply chain management is called resiliency (Carvalho 2012b). To achieve lower cost and more benefits, companies tend to employ lean and agile philosophies but it is apparent that those philosophies are in conflict with resiliency since resiliency recommends companies to make redundancies in resources but what can make companies capable to absorb disturbances is more important than leanness and agility. Moreover, resilience attributes in supply chain improve overall performance of supply chain.

Resilient supply chain has been getting hot topic in last years (Stock et al. 2008). In the past decades, researchers emphasized on cost minimization but this approach has been changed due to significant changes in business environment. Now authors in supply chain context stress on resiliency. A resilient supply chain may not be the optimized one from cost point of view but it definitely is the most capable to tackle inherent issues of turbulent environment.

Much of the conducted works in the area of resilient supply chain address resources of uncertainty in a supply chain. However, it seems that companies are

eager to identify their weak points related to resiliency so that they would be able to improve their capabilities to overcome probable disruptions.

One of the powerful methods has been used to identify changes in advance and react them properly is “sense and respond philosophy”. Nikookar et al. (2012) argue that this method can evaluate managerial concepts to identify weak points. Sense and response can be utilized at any firm regardless of its size and complexity. The main idea behind of “sense and respond” methodology is being prepared against threats and converting them to opportunities by sensing the environment and the organization for ongoing or unexpected changes leading to threats.

## **1.2 Research questions**

While there are lots of works in the literature regarding supply chain resilience but the question “How to identify critical attributes related to resiliency in supply process? ” still has been concealed. Therefore, this thesis aims at applying “sense and respond” methodology to reveal critical attributes related to resiliency in supply chains. To achieve this importance, it is vital to explore the nature of supply chain from disruptive events and resiliency viewpoints.

The following questions are going to be investigated through this thesis:

1. What is supply chain and supply chain management?
2. How supply chain disturbances are defined in supply chain literature?
3. Which attribute must be considered to achieve resiliency in a supply chain?

4. What are the critical attributes in under investigation supply chain?
5. Is the overall strategy of supply chain is sustainable?

## **RESILIENCY IN SUPPLY CHAIN**

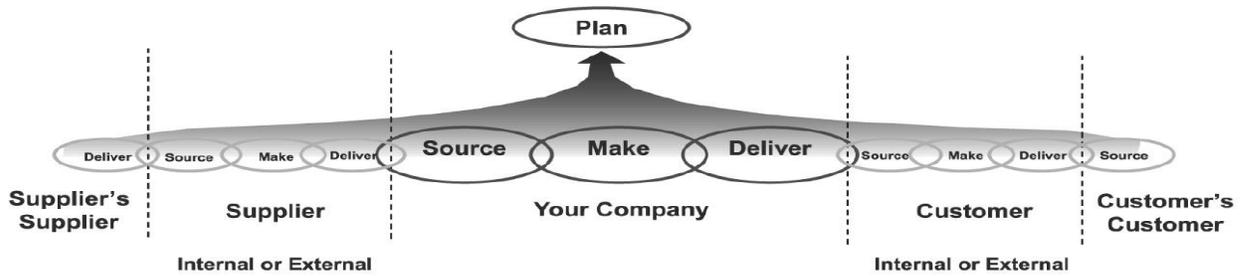
What is going to be addressed in this chapter is reviewing the supply chain literature related to resiliency concept. The discussion starts with embarking on the supply chain management definition and managerial practices in this area then more attention goes to causes which are disturbing supply chains, failures that may happen in any supply chain and finally resiliency in the supply chain will be examined as the final part of the chapter. Along this section of the work, three questions will be answered.

### **1.3 Supply chain management**

#### **1.3.1 Supply chain**

If one goes through the literature, he or she can find numerous definitions of supply chain. Stock et al. (2008) define supply chain as a set of interdependent companies bringing end products or services to the marketplace. Christopher (1992) presents following definition of supply chain “the network of organizations that are involved through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services delivered to the ultimate consumer. According to supply chain council (2002) SCM is defined as the endeavor engaged upon producing and distributing products from point of producing to point of use. The supply chain council also presents a reference model for designing and benchmarking of supply chain processes called

SCOR as illustrated in Figure 1, it classifies all processes involved into four categories, namely source, make, deliver, which are integrated by the plan.



**Figure 1:** SCOR

Mentzer (2001) argues a supply chain is an alignment of some companies or individual straight engaging in the upstream and downstream flow of goods, services, money, and/or information from initial sources to end users. In other words, a supply chain encompasses several firms or individuals, upstream and downstream flow, and consumer. Adopted definition states that each supply chain, on the one hand, consists of individual organizations which have an obligation to produce and deliver the right products, in right time, with right quantity to the end-consumer at downstream side; on the other hand, it is constituted by suppliers which have a duty to provide resources at upstream side.

From the complexity point of view, three kinds of supply chain can be identified: "direct supply chain", "extended supply chain", "ultimate supply chain".

According to Mentzer (2001) direct supply chain is defined as a network of three entities including a firm, a supplier, and a consumer all engaged in upstream and/or downstream flow of products, services (Figure 2a). He also proposed following definition: extended supply chain is a direct supply chain including suppliers of immediate supplier and customers of immediate customer all engaged in the flow of products and services (Figure 2b). Finally, ultimate supply chain presents all organizations and individuals involved in flow of products and/or services through supply chain as illustrated in Figure 2c.

Each supply chain can be considered as a dynamics system that its condition may vary from time to time. It means fundamental variables of supply chain such as level of inventory must be modified as time passes. Banks et al. (2004) propose following definition for state of a system: the set of variable that essential to illustrate the condition of a system at any interval. Carvalho et al. (2012a) define state of a supply chain, in a particular meanwhile, as distinct arrangement of components of supply chain such as producer, retailer, wholesaler, and so forth and their linkage with other supply chains, flow of items and information, policies, and lead times under predefined performance level. They propose six following dimensions that have to be considered to investigate a supply chain:

1. Supply chain elements or all organizations involved in the supply chain.
2. Linkage between supply chains entities.



**Figure 2:** Supply chain classification from complexity viewpoint

3. Flow of items in the supply chain including methods utilized to bring the items to customer points.
4. Flow of information.
5. Policies which are applied to manage the supply chain.
6. Lead times.

Table 1 shows all worth considering variables of any supply chain that should be investigated in research related to supply chain.

**Table 1:** supply chain state variables

Supply chain state variables dimension	Examples
<i>Supply chain entities</i>	Typology (function/role); Geographic localization; Number of available alternatives
<i>Relational links</i>	Type of relation between entities: collaboration, channel leader at dot end, buying-selling relation, bilateral extensive coordination, long-term partnership, preferred suppliers, among others
<i>Material flow</i>	Quantity; Deliver frequency; Transport mode
<i>Information flow</i>	Frequency; Type (manual or electronic)
<i>Management policies</i>	Inventory type and level; Overall process description; number of operations, lot size, capacity for extra orders, % of defects, strategy type (make-to-order or make-to-stock)
<i>Lead times</i>	Production lead time; Transit time; Time to supply for new suppliers (time required for a new supplier to complete a single cycle, beginning with the receipt of an order and ending with the fulfilment of that order)

### 1.3.2 Managing Supply chain

The term of supply chain management, for the first time, was discussed in the area of logistics in 1980 (Hulihan 1980). Whereas logisticians are trying to optimize inventory level, transportation, and flow of information, Supply Chain Management concentrates on long-term profitability of serving immediate customer and next and next tier customers.

Supply chain can be viewed as a network of firms that are working together in order to bring value to customers and increase their satisfaction, therefore, it should be managed effectively. To properly manage a supply chain, it is necessary all organizations involved in a supply chain are rescued from their functional silo and approach to process concept (Stock et al. 2008).

From Mentzer et al. (2001) point of view, supply chain management is strategically coordinating of traditional duties of involved firms in the supply chain which lead to improving long term profitability of individual companies and the chain as a whole. This definition states supply chain management encompassing a set of companies, business functions, and coordinating them across functions and across companies in a supply chain. According to this definition, a supply chain can be illustrated as a pipeline (Figure 3) in which products, services, money, and information always moves in a steady continuous stream.

In order to manage properly this pipeline companies always implement some practices. SCM practices are approaches implementing in a supply chain to effectively manage and coordinate supply and demand in order to improve customer satisfaction and long-term profitability of all members simultaneously

(Wong et al. 2005). Li et al. (2005) categorize dimensions of supply chain management practices into five classes that consider upstream and downstream side of a supply chain. *Strategic supplier partnership* means a long-term relationship among firms and their supplier which results in leveraging capabilities of both side to achieve high level of performance, *Postponement* is defined as the approach of moving forward activities (such as designing, producing, sourcing, and delivering) as late as possible in the supply chain, *Information sharing* is referred to availability and accessibility of information throughout a supply chain, *Information quality* is related to the extent of accuracy and reliability of the information, *Internal lean practices* which are related to eliminating waste in a system, and *customer relationship* encompassing all practices that implementing to manage relations between company and its customers and improve their satisfaction.



**Figure 3:** Pipeline illustration of supply chain

If one goes through literature, it will be explicit that it is very difficult to distinguish between supply chain practices and supply chain strategies. For instance some authors count postponement as practice but in contrast other researchers consider it as a strategy. Therefore, different attitudes toward SCM practices can be identified in the literature. Donlon (1996) proposes that working in partnership with supplier, outsourcing, and information sharing as SCM practices. Alvarado and Kotzab (2001) suggest focus on CCs (Core Competencies), implementation of inter-organizational systems like EDI, use of postponement strategies toward supplier in order to eliminate of excess inventory level. Aurty et al. (2008) use SCM practices to evaluate supply chain strategies. Tan et al. (2002) propose six approaches in managing supply chains which have been developed using factor analysis: supply chain integration, implementation a system to share information, customer service management, geographical proximity, and Just In Time system. Later, Pularj (2004) introduce reducing supplier base, establishing long term relationship with supplier, making cross-functional teams, and early supplier involvement in the design process as new SCM practices.

### **1.3.3 Performance measures in the supply chain**

Wong (2009) indicate that in order to manage supply chain preferably companies need to measure their supply chain performance. Suitable performance measures will explicit the effects of supply chain management practices and managers would be able to make decision whether implementing those practices should be stopped or no the company is progressing toward its objectives. There are a lot of

research works in the literature which are concentrated on supply chain performance.

As measures utilized to evaluate and make decisions in different level of companies such as strategic or operational level, it is essential to define various suitable measures (Morgan, 2007). Martin and Patterson (2009) categorize measures of supply chain performance as financial and non-financial scales. They suggest that financial measures are suitable to evaluate supply chain from strategic point of view, Conversely, operational decision should be assessed by non-financial indicators. Chia et al. (2009) argue that to evaluate the performance level of a supply chain, companies have to use a comprehensive measurement system which considers all dimensions of the supply chain. Cia et al. (2009) design a model in which KPIs (Key Performance Indicator) are systematically evaluated and gaps between experience and expectation are identified then the firm can implement appropriate action plans to improve weak points. They categorizer KPIs into four classes: flexibility, sources, outcomes, and innovativeness. Carvalho et al. (2011) grouped key performance indicators in supply chain context into six classes as follow:

1. Financial indicators
2. Environmental indicators
3. Flexibility indicators
4. Innovation indicators
5. Integration indicators
6. Operational indicators

Kainuma and Tawara (2006) argue that a lot of measures can be identified to evaluate and assess a supply chain. All of them can be summarized in service level, quality, cost, and lead time. Christopher and Towill (2000) consider that, in the one hand, cost is essential for a company to be winner in the market on the other hand quality, lead time and service level are precondition to enter to the market. Carvalho, Duarte, and Machado (2011) argue that in the resilient supply chain concept the main concentration is on survive company from disruptive event in its supply chain as soon as possible with acceptable cost. Therefore it can be concluded that cost and time are the most appropriate factors to evaluate resilient practices.

## **1.4 Supply chain disturbances**

### **1.4.1 Risk and uncertainty**

Supply chain as a complex system is always in danger of uncertain situations resulting in various risks. Dynamic and unstable parameters of supply chain such as lead time, customer demand, quality of products, and capacity of resources increase the complexity of the chain and this complexity affect decisions related to the supply chain. In the literature, it is identified that uncertainty in supply and demand has a great impact on every manufacturing systems (Wilding 1998). Davis (1993) believes in managing complex systems the most prominent problem is uncertainty which leads to inefficient decisions. Vorst et al. (2002) indicate uncertainties arise when managers want to make a decision and do not know what

the best decision is since objectives are unclear, accurate information is not available, forecasting processes is not reliable, and the consequence of decisions are not foreseeable.

It would be a true statement that level of performance in the supply chain context associated to ability of system in dealing with uncertainties but in order to manage uncertainty in a supply chain the initial and essential step will be identifying the resource of uncertainty. Childerhouse et al. (2000) categorize resource of uncertainty in a supply chain according to its impact on supply chain main activities. They propose that uncertainty can be classified as:

7. Uncertainty in process of the company affecting on ability of company to meet its production objectives.
8. Uncertainty in supply of requirements. It concerns the ability of suppliers to deliver requirements on time, in right quantity, with agreed specifications.
9. Uncertainty in customer demand. It talks about anticipating customer demand and variation corresponded to it.
10. Uncertainty in control activities. This kind of uncertainty is related to flow of information in the firm.

The terms risk and uncertainty are interchangeably used in the literature. In one hand Risk and uncertainty has intimate relationship but on the other hand someone should distinguish between risk and uncertainty. Based on finding of Knight (1921) explains risk as something that can be measured and also estimated; on the contrary uncertainty cannot be quantified and likelihood of the results is not known.

Handfield (2004), however, explain that insight about risk shows that there must be some uncertainty about results and if likelihood of those results is be clear, there are no risks. Elkinns et al. (2005) argued that uncertainty is a key factor to occur risk but managers can measure and change exposure to risk by using the development of stopping, reduction how serious it and recovery strategies. While these actions do not eliminate uncertainty, they can enable companies to lessen the risk. The term "Risk" has rooted in Italian language and it comes from "risccare" which means to dare (Bernstein, 1996). The royal society of United Kingdom which founded to research on risk and risk assessment was defined risk as "a combination of the probability, or frequency, of occurrence of defined hazard and the magnitude of the consequence of the occurrence (Royal Society 1992)". Lowrance (1980) explains risk as a scale of the likelihood and seriousness of adverse effect. Rowe (1980) argues risk as potential of undesired results to arise from an activity.

Uncertainties in elements such as customer demand, supply, and quality cause risk in operation of supply chain and uncertainties resulting from disruptive events, for instance natural disaster, man-made events, Terrorism and political instability cause another kind of risks called disruption risk (Tang 2006). In last decade, interest in disruption risk has increased due to lengthening in paths each item in supply chain should travel in globalized environment and tendency to reduce lead times there is no chance to make mistake. Taiwan earthquake in September 1999, the terrorist attack of 11/9, and blackout in USA in 2003 are some instances to remind companies that disruptive events have such a great impact on their supply

chains and must be the first priority of attention of top managers (Kleindorfer et al. 2005).

#### **1.4.2 Vulnerability**

By reviewing literature, it will be revealing that the idea of vulnerability is still to some extent vague and unexplored. These days vulnerability is getting prominent because of increasingly intendency to be lean and agile in supply chains causing them to be vulnerable to disruptions , consequently, in danger of losing benefit, share market, and customer loyalty. The presence of disturbances in a supply chain causing deviation in flow of items, which should be supplied, from their scheduled and expected situation that can have negative effects of supply chain normal performance is defined as vulnerability in the supply chain (Svesson 2000). To Juttner (2005), vulnerability in supply chain context is to be in danger of disturbances leading to inability of supply chain to serve consumer through downstream side of supply chain. Azevedo et al (2008) define supply chain vulnerability as inability of supply chain to cope with disturbances arising in supply chain. Christopher and Peck (2004) argue that vulnerability in supply chain concept refer to an exposure sever disturbances coming up from risk in the supply chain or outside of supply chain. In crises management vulnerability is argued as the ability of a person or group of people to anticipate, deal with, and recover from a disaster (Blaikie et al. 1994).

Wagner et al. (2007) state that supply chain vulnerability has a multidimensional construction. Although in the literature there are a lot of factors counted as drivers of vulnerability in a supply chain, to my knowledge, there is no empirically tested publication to confirm the role of mentioned factors in supply chain vulnerability. For instance single sourcing is frequently presented in research papers as a threat that could lead to incapability in facing with disruption. Another prominent source of vulnerability in supply chains highlighted in the literature is globalization.

There are a lot of methods in the literature to reduce the level of vulnerability and eliminate bad effects of disturbances in a supply chain. For instance KAIZEN is defined as a philosophy attempting to achieve continuous improvement and preventive actions. But KAIZEN does not explain how to cope with disturbances. Another example may be Total Productive Maintenance (TPM). Last method suggests that in an organization every employee from production line staffs to top manager should involve the program of improving facilities reliability. It means that each employee in an organization should perform basic maintenance activities on his or her own facility to keep it in a desirable running condition in order to reducing the level of disruption due to equipment breakdown.

### **1.4.3 Disruption and disturbance in supply chain**

Wagner and Bode (2006) define disruption in supply chains as undesirable and unexpected circumstance resulting in risk. Wu et al (2007) argue that any unexpected event in supply chain is disruption. Barroso et al (2008) propose following definition for disturbance. They say unpredictable incident which results

in instability in normal operation of company or supply chain. From the company subjected to disruption viewpoint this situation is totally different from their every-day condition. Disruptions can arise in different area of supply chain management. Consequently their behavior and effects are diversified. For instance disruption in flow of material due to bankruptcy of key supplier and disruption because of earthquake are completely different from each other from their predictability, probability, and severity point of view.

Although some disruptive events in supply chain are predictable but the problem is that the consequence of them are really tough to anticipate accurately. For instance, despite all initial warning in the case of Hurricane in August 2005, most of the companies could not to anticipate the consequences of it therefore did not to be prepared properly.

Disruption in flow of material, irrespective of the fact that where and when it occurs, has serious impact on reputation of affected companies and satisfaction of ultimate consumer (Chopra and Sodhi 2004). For example, fire in production site of Aisin Seiki Co. Ltd, key supplier of Toyota, in February 1997 forced the greatest car manufacturer to shut down its production plants for a while (Nakamoto 1997). Another case in Germany took place at Robert Bosch GmbH in January 2005. The story was that the company failed to identify a small defect on one of its produced parts. That part is used in diesel injection pumps which supplies to huge automotive companies such as Audi, BMW, and Dimler&Chrisler. The small defect caused halt in production line of mentioned automotive OEMs and great financial lose (Wagner 2006).

Those events mentioned are categorized as Low frequency-High impact disruptive events. Greening et al. (2011) classify events occurring in a supply chain base on their impact on structure of the chain. Disruptive events are categorized as events that make irreversible changes in the supply chain. Carvalho et al. (2012) propose a classification for disruptive events in supply chain context. They classify events into four categories: Natural events, operational, Disaster/man-made event, and financial events. The classification and the definition of each class together with some example are illustrated in Table 2.

**Table 2:** *Disruption classification*

<b>Disturbances definition</b>	<b>Categories</b>
Any event, regardless of its nature, that affects negatively the supply chain companies' ability to deliver on-time	<i>Natural events:</i> it includes any type of natural phenomenon like volcano, hurricane, torrential rains and flooding
	<i>Operational:</i> events originated by company operations. Examples include product non conformance, product malfunction, supplier delays and port congestion
	<i>Disasters/intentional man made events:</i> events originated by accidents or intentional acts, including explosion in energy production plant, strike at supplier, strike, strike in French road networks, terrorist attack, "major attack" on a pipeline, fire
	<i>Financial:</i> events originated by financial difficulties like financial crisis or supplier bankruptcy

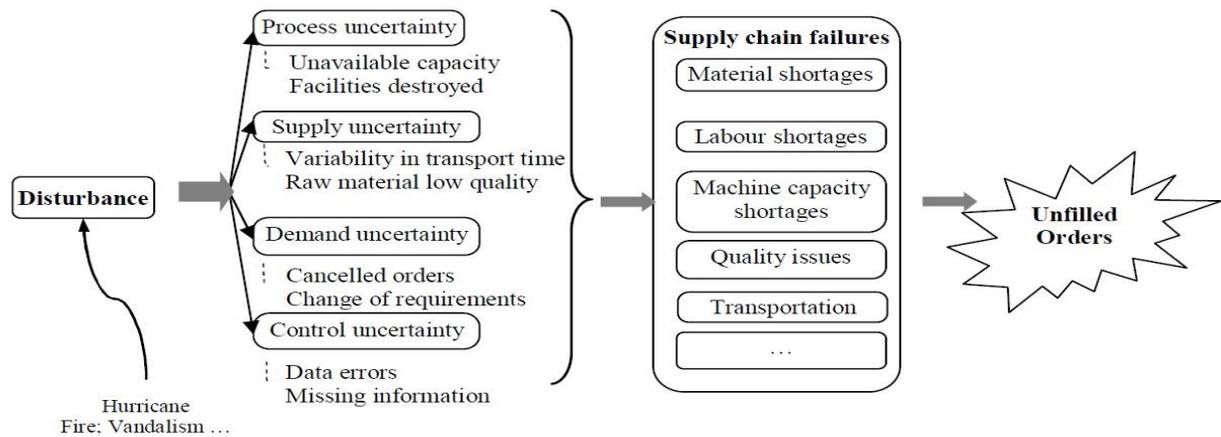
## 1.5 Errors in supply chain

As discussed previously the main duties of every supply chain is to delivery right products, in the right time, at the right quantity, to the right location in order to satisfy ultimate consumer (Simchi 2000). If companies do not confront with disturbances in a determined way, these disturbances committee some serious

errors in normal functions of the supply chain (Carvalho et al. 2012a). All types of disturbances which occur in a supply chain generate errors. The ultimate consequences of these errors are unfulfilled order and destroy customer satisfaction and company reputation.

Due to unforeseeable origin of disruptions in supply chain context the mitigation process of bad-side effects of them is somewhat tough. Therefore, researcher confront with them by using strategies based on consequences instead of disruption origins. Top manager's attitudes toward disruption have been changed. Traditionally, managers are willing to explore the source of disruption in the supply chain but nowadays they are trying to figure out consequences of supply chain disruption and make decision related to eliminate or at least mitigate its bad-side effects (Sheffi et al 2003). Carvalho et al. (2012b) argue that company's capabilities in tackling severity of supply chain disruption play prominent role in its level of competitiveness.

We have already presented disturbances as unpredictable situations preparing the ground for appearance of uncertainty in a supply chain as illustrated in Figure 4. As you can see uncertainties can have multiple drivers. Carvalho et al (2012) argue that if company does not cope with these uncertainties by using suitable responsive solutions they may cause errors in normal function of supply chain. These errors may cause failure to fulfill commitments.



**Figure 4:** Supply chain uncertainty and errors.

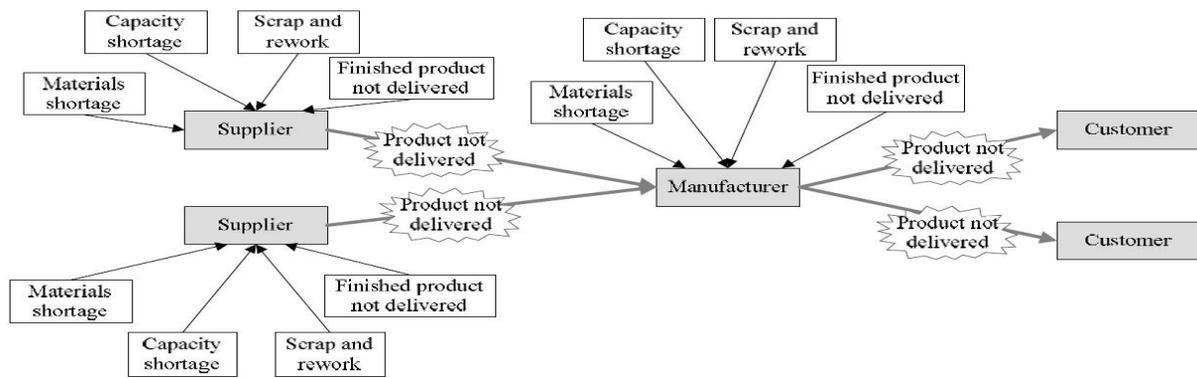
Error in supply chain context is defined as a circumstance in which the supply chain disables to perform its normal tasks to delivery right product to at right quantity, in right time, to right location (Berle et al. 2011). Rice et al (2003) argue that the number of errors which may occur in supply chain is finite and it is contrary to the number of disturbance drivers. They classify errors in supply chains into: Transportation system errors, Production errors, human errors, information errors, and supply errors. Sheffi, Rice, Fleck, and Caniato (2003) propose following categorization for supply chain errors: disruption in demand, disruption in transportation system, disruption at facilities, break in freight, and disruption in supply. Carvalho et al. (2012a) count supply chain errors as primary causes that result in failure to deliver items on time through a supply chain. They classify errors according to its impacts on supply chain normal activities to seven classes as shown in Table 3:

**Table 3:** Classification of errors in supply chain

Failure mode definition	Categories
Negative consequences of supply chain disturbances lead to a supply chain failure, i.e. unfilled orders. It is the main reason why the company fail in on-time delivery	<i>Material shortages</i> - when there is not enough material to satisfy product demand because materials were destroyed or the suppliers do not deliver on-time, among others reasons
	<i>Labour shortages</i> - when the workforce is not enough to satisfy the production needs
	<i>Capacity shortage</i> - when the existing production capacity is not sufficient to satisfy the demand level because the facilities were destroyed, there is an energy shortage or even if demand shrinks
	<i>Quality issues</i> - when the components/products are deliver on-time but do not fulfil all the quality requirements, for example conformance problems or product recall
	<i>Transportation delays</i> - when it is not possible to deliver the products on-time because the transportation is not available, routes (e.g. roads or airlines) are closed
	<i>Demand variation</i> - when the customers reduces or increases demand and orders can not be adjusted
	<i>Supply rupture</i> - when suppliers are unable to deliver materials because they are bankrupt or insolvent

Hendricks et al. (2009) argue that disruption in a supply chain can derive from diversified resources such as internal sources, consumer, supplier or combination of them and if one or some of them take place in a supply chain then it may culminate in errors, namely, lack of parts, production problem or undelivered orders. An empirical investigation of supply chain failure modes by Koh and Saad (2002) make it explored that lack of material, lack of human resources, lack of capacity in equipment of production, rework, and undelivered end products are attributed to unfulfilled orders in the supply chain.

Since a supply chain can be defined as a network of companies that work together in order to deliver products and services to final consumer, the severity level of disruption is a function of its density, and complexity (Craighead et al. 2007). Rice et al. (2003) argue that arising error in one facility of supply chain network may lead to entire network collapse as illustrated in Figure 5.



**Figure 5:** Errors diagram in supply chain.

## 1.6 Resiliency of Supply chain

Nowadays, if one go through literature there are so many scientific works can be identified in which researchers have turned more attention in vulnerability and suggested to firms to look after and assessing regularly their level of resiliency. Due to tendency of companies to increase the level of efficiency in today's supply chain leading to no extra source in supply chain to face and cope with disruptions and also because of globalization as well as the escalating interdependent relationship between companies involved in a supply chain the likelihood of

disruption occurrence is getting higher than before (Christopher and Peck 2004). In comparison to all efficacious news on supply chain management, news regarding disruption in flow of material has tremendous effect on the value of company's shares (Hendricks and Singhal 2001). Disturbances are likely to have negative effects on performance, profitability, operation incomes and sales (Hendricks and Singhal 2009). Ji and Zhu (2008) argue that the effect of disruption on performance of the entire supply chain from financial point of view is significant.

### **1.6.1 Definition**

Researchers have addressed to the concept of resiliency in supply chain from various point of view, for instance Zsidisin and Wagner (2010) count resilient supply chain management as a subset of supply chain risk management. Supply chain risk management is a field that recently has been paid great attention by academics and researchers (Ghadge et al. 2012). Due to inversing uncertainty in supply and demand, globalization and global sourcing, and decreasing life cycle of new products, risk management is becoming challenging matter in modern environment (Christopher & Lee 2004). Risk is defined as the probability of loss (Chiles & McMackin 1996). Knemeyer et al. (2009) propose following quantitative definition of supply chain risk:

$$\text{Probability of occurrence} \times \text{Impact on business (severity)}$$

They argue that all risks related to business drive from five factors:

1. Environmental factors

2. Industrial factors
3. Organizational factors
4. Problem-specific factors
5. Decision-makers related factors

Jüttner, Peck & Christopher (2003) propose a four steps process to manage risks. They argue that in order to manage risk throughout a supply chain managers should follow below steps:

1. Risk identification: identifying potential threats
2. Risk assessment: assessing the probability and severity of identified risks
3. Risk mitigation: reducing the probability of a particular risk or reducing its severity or combination of them.
4. Responsiveness to risks: implementing proper responding solution after math

Disruption is inherent in supply chains, hence the importance of concentration on designing and managing a supply chain that is able to react and survive from any kind of disturbances is clear (Glickman et al. 2007). Since the level of interdependency in today's supply chain is increasing, the need to be agile enough to respond and escape from disruption trap is sensed, particularly for any individual company (Hanna et al 2010).

The concept of resilient is widely used in variety of different fields of science. Fiksel (2003) defines resilient system as a system that has tendency to return to its equilibrium state. This system is able to survive from tremendous disturbances. In material science resiliency is defined as a quality of subject to store energy and

release it when unloaded without any long-term deformation. A resilient ecosystem is argued as a system that is able to sustain its identity after internal or external disturbances (Bhamr, Dani & Burnard 2011).

In production and manufacturing domain the concept of resiliency is defined as the capability of a production line to put resistance against disturbances (Asbjornslett 1999). Rice et al (2003) argue that a supply chain can be called resilient supply chain in which all entities are able to react properly to unavoidable disruptions. In another research resiliency is defined as company's capability to survive from facing uncertainty and keep on growth in turbulent environment (Knemeyer, Zinn & Eroglu 2009). Sheffi and Rice (2005) ability to jump back from disturbance call resiliency, in contrary Peck (2005) prefers the definition presented in dictionaries. She says the capability of supply chain to return to its initial state or even more desirable one after any internal or external disruption. Berle et al. (2011) define the capability of a supply chain in facing disruption and recovering immediately without any major effect on customer satisfaction.

If one review all definitions proposed in the literature, it is revealed that main concentration of authors is moving from just focus on individual company to whole entities of supply chain as well as preventing action to coping with and recovery in the aftermath. For instance Berle et al. (2011) concentrate on proactive planning to handle any disruptive events. Since disruptive events seem inevitable in today's turbulent supply chain environment, the ultimate goal of resilient strategies and practices in supply chain context should focus on elimination or reduction of errors in the supply chain after disruption occurrence. Consequently the final target of supply chain design for resiliency should concentrate on

stopping supply chain to shift to the state in which errors may occur. Due to networked nature of supply chains it is critical that all member of the supply chain utilize resilient practices to reduce errors occurrences and immediately respond to disruption events. The worst effect of supply chain disruption is on performance. Therefore, the main concentration in analyzing supply chain from resilience point of view must be:

1. Defining the best state of system which should be sustain
2. Identification of state variable those are affected by disruptions
3. Proactively planning to avoid sifting main state variable from original state to undesirable ones

### **1.6.2 Managerial practices and important attributes in the way to resiliency**

Resiliency can be count as one of the core competences in a company and great strength of that can be utilized to compete against competitors since a resilient company can react effectively to demand fluctuation a head of other players in the market (Hong and Hwang 2011). Carvalho et al. (2012b) argue that resilient strategies and practices should have two main objectives: firstly to switch state of the system from disturbed situation to its original one or even more desirable state secondly, mitigating the effect of potential disturbance in advance. The grade of severity of a disruptive event in a particular supply chain is directly related to capability of that supply chain in absorbing the consequences of disruption and these capabilities are determined based on the level of utilization of mitigation and

contingency practices (Carvahlo et al 2012c). Tomolin (2006) argue that contingency practices are those that deploy in advance to reduce severe consequences of disruption. In this case, company must pay the cost of not occurred event to secure itself in advance. It should be noticed that this cost is much lesser than the total cost of damages after disruption. Contingency practices are referred to practices in which main purpose is to return to original state of the system. The level of efficiency of a contingency practice is determined based on the time which is take the system works properly after the disruption (Tomolin 2006).

Sheffi et al (2005) presents flexibility and redundancy as two main strategies that should be utilized to eliminate or suppress horrible effects of disruption. Juttner et al. (2011) argue that practices related to resiliency of supply chain can be implemented in any level of supply chain including individual company level, upstream level and downstream level.

*Utilization of strategies in sourcing* in which firms can change suppliers easily, *establishment of a production line* which is able to produce multiple products, *employing multi-skilled worker, using of reserved capacity, alternative transportation system* are introduced by Rice and Caniato (2003) as resilient practices. Christopher and Peck (2004) investigated on resilient supply chain in British companies. They found out that increasing the level of visibility through supply chain, using postponement strategies, strategic buffer, identifying “pinch points” and allocating additional inventory or even production capacity, increasing the level of visibility in the manufacturing line, reduction of lead time as much as possible in the focal company, developing organization culture especially the dimension concerning risk management, collaboration with other member of

company in order to mitigate risks support companies to be resilient. Since in sense and respond methodology related attributes to under investigation process should be considered, therefore after reviewing literature and discussing with managers and experts in case companies attributes related to resiliency in supply chains were extracted and presented in Table 4, Table 5, and Table 6.

**Table 4:** attributes related to resiliency in supply chain at upstream side

Supply chain level	Resilient practices	References			
		(a)	(b)	(c)	(d)
<i>Resilient practices developed upstream</i>	Sourcing strategies to allow switching of suppliers	√			
	Committing to contracts for material supply (buying capacity, whether it is used or not)	√			
	Flexible supply base/flexible sourcing			√	
	Developing visibility to a clear view of upstream inventories and supply conditions		√		

**Table 5:** attributes related to resiliency in supply chain at focal company

Supply chain level	Resilient practices	References			
		(a)	(b)	(c)	(d)
<i>Practices deployed by companies in their daily internal operations</i>	Designing production systems that can accommodate multiple products and real-time changes	√			
	Multi-skilled workforce	√			
	Exceed capacity requirements	√			
	Postponement			√	
	Minimal batch sizes		√		
	Strategic stock		√	√	√
	Make-and-buy trade-off			√	
	Strategic disposition of additional capacity and/or inventory at potential “pinch points”		√		
	Developing visibility to a clear view production and purchasing schedules		√		
	Creating total supply chain visibility				√
	Lead time reduction		√	√	
	Process and knowledge backup				√
	Supply chain risk management culture		√		
	Developing collaborative working across supply chains to help mitigate risk		√		
<i>References:</i> (a) - Rice and Caniato (2003); (b) - Christopher and Peck (2004); (c) - Tang (2006a); (d) - Iakovou, Vlachos, and Xanthopoulos (2007)					

**Table 6:** attributes related to resiliency in the supply chain at downstream side.

Supply chain level	Resilient practices	References			
		(a)	(b)	(c)	(d)
<i>Resilient practices deployed downstream</i>	Maintaining a dedicated transit fleet	√			
	Flexible transportation			√	
	Silent product rollover			√	
	Developing visibility to a clear view of downstream inventories and demand conditions		√		
	Demand-based management				√
<i>References:</i> (a) - Rice and Caniato (2003); (b) - Christopher and Peck (2004); (c) - Tang (2006a); (d) - Iakovou, Vlachos, and Xanthopoulos (2007)					

Companies would like to be more resilient in facing to disturbances and disruptive events should strengthen resilient attributes along with other practices to manage their supply chain.

## RESEARCH METHODOLOGY

### 1.7 Manufacturing Strategy Index

Manufacturing strategy index (MSI) is calculated based on the data gathered by OP questionnaire adopted from Ranta and Takala (2007). The attributes in the OP questionnaire is assigned to categories of RAL including: Quality (Q), Cost (C), Time (T), and last but not least Flexibility (F). While all attributes were assigned then, the normalized total share of them will be available by using below equations (Figure 6 ) (Takala 2007).

$$Q\% = \frac{Q}{Q + C + T}$$

$$C\% = \frac{C}{Q + C + T}$$

$$T\% = \frac{T}{Q + C + T}$$

$$F\% = \frac{F}{Q + C + T + F}$$

**Figure 6:** Total share of RAL factors.

After calculating the values, the next step is calculating MSI in each group according to formulations illustrated in Figure 7.

$$\phi \sim 1 - \left(1 - Q\%^{\frac{1}{3}}\right) (1 - 0.9 * T\%) (1 - 0.9 * C\%) * F\%^{1/3}$$

- The MSI model for analyzer group:

$$\lambda \sim 1 - (1 - F\%) [ABS[(0.95 * Q\% - 0.285) * (0.95 * T\% - 0.285) * (0.95 * C\% - 0.285)]]^{1/3}$$

- The MSI model for defender group:

$$\varphi \sim 1 - \left(1 - C\%^{\frac{1}{3}}\right) (1 - 0.9 * T\%) (1 - 0.9 * Q\%) * F\%^{1/3}$$

**Figure 7:** MSI formulas.

## 1.8 Sustainable competitive advantage

These days, Due to turbulent environment of business, the need for adjusting to rapid changes in technology and shortening in product life cycle is becoming increased. As a consequence static competitive advantages do not satisfy the current need and it should be replaced by sustainable competitive advantages. Besanko (1999) argue that if a company would like to survive in current situation, it must achieve sustained competitive advantages instead of temporary ones.

It was defined that if a company could achieve more value and benefit in comparison to its opponents then that company has competitive advantage but this advantage may be temporary or permanent (Takala et al. 2013b). SCA is defined as a method to evaluate the risk (percentage of likelihood) for that the strategy improvement should be conducted. The main idea lies behind sustainable

competitive advantage is to figure out the critical factor in resource allocation and make improvements in operational level of a company in order to support dynamic adjustments which helps the company to improve corporation strategies (Takala et al. 2013). Sustainable competitive advantage methodology does not concentrate only on current competitors but also it concerns on potential opponents which will enter to the market.

Takala et al. (2013b) state that SCA methodology is used to estimate the risk of implementing operation strategies. It would be possible with the help of SCA chose the operation strategies of a firm with the lowest risk. It was concluded that operation evaluation of SCA may provide better sensitivity, sustainability and flexibility for the company in general as well as strengthen the performance and competitiveness in the market place. Sustainable competitive method provides the opportunity of taking suite decision regarding operation strategies. Mentioned risk level is calculated according to different methodologies. Right operation strategies support companies to sustain their performances.

In order to estimate SCR, there are three methods proposed in the literature including: MAPE, RMSE, and MAD. Below formulas are deployed for calculating (Figure 5).

$$\text{MAPE (absolute percentage error): } SCA = 1 - \sum_{\alpha,\beta,\gamma} \left| \frac{BS-BR}{BS} \right|$$

$$\text{RMSE (root means squared error): } SCA = 1 - \sqrt{\sum_{\alpha,\beta,\gamma} \left( \frac{BS-BR}{BS} \right)^2}$$

$$\text{MAD (maximum deviation): } SCA = 1 - \max_{\alpha,\beta,\gamma} \left| \frac{BS-BR}{BS} \right|$$

**Figure 8:** SCA formulas.

In this case B corresponds to angle (in radians), which are referred to analysis in prospector, analyzer and defender categories. In addition, S refers to operational strategy (MSI) and R – to resource allocation evaluated by S&R (CFI) methodology.

### 1.9 Sense and respond methodology

Sense and respond methodology emerged in management context for the first time in 1992. This method can evaluate managerial concepts to identify weak points. Sense and response can be utilized at any firm regardless of its size and complexity (Nikookar et al. 2012). The main idea behind of “sense and respond” methodology is being prepared against threats and converting them to opportunities by sensing the environment and organization for ongoing or unexpected changes leading to threats.

Basically, sensing changes which, in the most cases, have not been happened and also due to dependency of right strategic decision on comprehensive understanding about current situation in the business makes it clear that we need a completely new methodology, therefore, the critical index factor (CFI) have been developed (Nadler, Takala, 2008).

### **1.10 Critical Index Factor (CFI) and Balanced Critical Index Factor (BCFI)**

Nadler and Takala (2010) argue that CFI is a tool to determine which attribute of a process in a business needs to be cared. *Required input is collected based on experience and expectation of stakeholders of the company depending on the case.* The utilization of this method in more than 50 research studies conducted in different business fields and environments prove that CFI can be used in all business process (Nadle and Takala 2010).

At the beginning of analysis mean value and standard deviation all answers are calculated for each line of questionnaire, then all indices illustrated in Figure 6 will be calculated according to mean value and standard deviations:

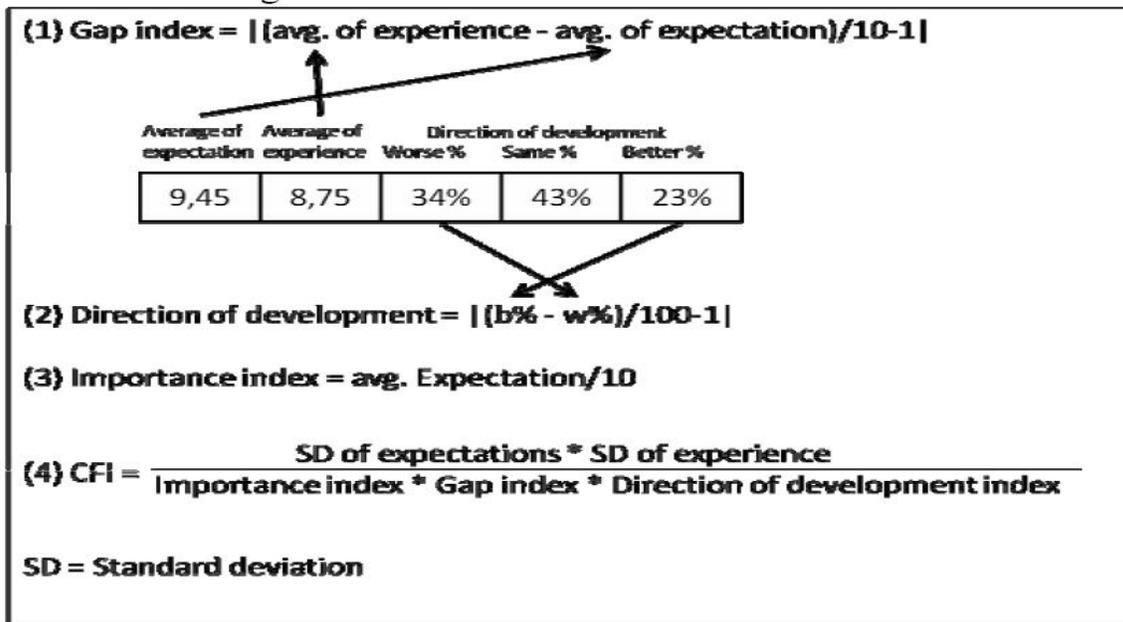


Figure 9: CFI formulas.

Nadler and Takal (2010) claim that the most frequent reported weakness of CFI is high impact of standard deviation on the index. In order to eliminate this weak point they proposed Balanced Critical Index Factor (BCFI). In the new formula the high impact of standard deviation has been reduced as well as the problem which arise when the  $SD = 0$  (Nikookar et al 2012). The new formulas illustrated in Figure 7.

$\text{BCFI} = \frac{\text{SD expectation index} - \text{SD experience index} - \text{Performance index}}{\text{Important index} - \text{Gap index} - \text{Direction of development index}}$
$\text{SD expectation index} = \left( \left( \frac{\text{SD of expectation}}{10} \right) + 1 \right)$
$\text{SD experience index} = \left( \left( \frac{\text{SD of experience}}{10} \right) + 1 \right)$
$\text{Performance index} = \text{Average of experience} / 10$

**Figure 10:** BCFI Formula.

Moreover, Nadler and Takala (2010) modified four other indices proposed in previous researchers. They modified GAP index and Development Index as well as Importance index and Performance Index which could help to predict undesirable changes in the business (Table 7).

**Table 7:** Calculating formulas of Sense and respond.

$\text{Importance index} = \frac{\text{Average of expectation}}{10}$
$\text{Performance index} = \frac{\text{Average of experience}}{10}$
$\text{Gap index} = \left  \frac{(\text{avg. of experience} - \text{avg. of expectation})}{10} - 1 \right $
$\text{Development index} =  (\text{better} - \text{worse}) * 0.9 - 1 $

### 1.11 Building the questionnaires

The most reliable and convenient tool to gather data in qualitative research is using questionnaire and due to this fact questionnaire as the most important tool used in this research. We used two questionnaires in the work one base on general

questionnaire for operation strategy proposed by Ranta and Takala (2007) and the second one developed by researcher based on resilient supply chain attributes. Proposed questionnaire consists of relevant and vital attributes to resiliency which can be found in the supply chain resiliency literature.

Nadler and Takala (2010) state due to the fact that *each process in a business has its own especial attributes, therefore, it is not possible to propose a standard questionnaire for all kind of process; instead required questionnaire must be established based on target individually*. Since this study aims to evaluate resilient practices and attributes in supply chain process to identify critical factors therefore a questionnaire by using it, companies belong to a certain supply chain will be able to evaluate and monitor their resiliency and capability in absorbing disruptive events based on sense and respond is developed. Right understanding about current situation of the companies in this regard has a great role and possibly the most prominent role in getting resilient. Due to the dependency of the long-term benefits of company on continuity of materials and information through supply chain, it is essential to maximize resilience capabilities as well as optimizing the efficiency of supply chain. This can ensure the ability of supply chain in absorbing side effects of disruptions (Colicchia and Strozzi 2012).

Ranta and Takala (2007) argue that there is a significant relationship between right and reliable answers of a questionnaire and the simplicity of questionnaire and also it would be pretty easy to collect more answer. In this case study we adopted questionnaire format proposed by Nadler and Takala (2010). They used simple and workable scales as illustrated in Table 7 to estimate expectation, experience, Direction of developments and comparison with competitors.

**Table 8:** Model of questionair.

Supply chain practices	Scale: 1=low, 10=high		Direction of development, expectations (future)			Direction of development, experiences (past)			Compared with competitors		
	Expectations (1-10)	Experience (1-10)	Decreasing	Same	Increasing	Worse	Same	Better	Worse	Same	Better
Practice 1											
Practice 2											
practice 3											

Development process of the questionnaire for evaluating resiliency in supply chains have been adopted from a similar case study conducted by Ranta and Takala (2007) based on “sense and respond” methodology with some modification for current research. The process consists of three stages:

- **First stage:** Analyzing current situation of the supply chain
  - **Utilized tools and methods:** Direct observation along with interview
- **Second stage:** Identification of practices affecting supply chain resiliency
  - **Utilized tools:** Literature review, information from previous stage, and consulting with managers who are in charge of supply chain in focal companies.
- **Third stage:** Analysis of results
  - **Utilized tools:** BCFI, Gap Index, and Direction of development index.

Manager's perception of current situation in supply chain may vary from company to company and from manager to manager. In first stage in order to get informed about the perception of companies about situation of business, related managers in all under investigation companies were interviewed. Purchasing manager of manufacturer, sale manager of supplier of wire harness, marketing and sale manger of exhaust supplier, operation manager of CNG conversion kit supplier, and the procurement manager of piston supplier have been introduced by companies as the person who is in charge of the topic of the research.

#### **1.11.1 Elements of proposed questionnaire:**

Practices implemented by companies in all around the globe to make their supply chains more resilient against disruption can be categorize into 3 classes including: practices used in upstream level, practices used in downstream level, and practices used by companies in daily activities. The lack of efficient implementation of each may result in low level of resilience in the supply chain. These several practices were proposed by researcher make companies resilient against disturbances give a good insight to the most important attributes related to resiliency in automotive supply chain. After discussion with companies they also confirm that all the practices support resiliency in the supply network they are engaged. Due to support of literature as well as experts, useful attributes related to resiliency supply chain extracted from mentioned practices. These attributes are presented in Table 4 to 6. The questionnaire was constructed in the way that proposed in Ranta and Takala (2007) research. The extracted attributes classified into three as

suggested groups in the literature: attributes affecting upstream level, attributes affecting daily activity of companies and the last but not least attributes affecting downstream level of supply chain. The final versions of questionnaires are presented in Appendix.

## CASE STUDY

### 1.12 Supply chain in automotive industry

The most important feature of supply chain in automotive industry is that there are numerous sorts of raw materials for instance, wire, plastic parts, steel parts, electronic devices and so forth. 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 (2011) argue that in automotive industry, the majority of product aspects are determined, designed, and developed by OEMs. 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 et al (2009) 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 those in charge of distributing vehicles and deliver them to end customer. 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 system used in automotive industry is just in time or just in sequence system. 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 base for applying these systems in the supply chain. Disney et al (2005) state that although in automotive industry just in time system and just in sequence system are used but lead time of initial components is about 40 day 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 completion. Another change in situation argued by Meyr (2004) is that OEMs recently implement cost reduction policies as well as delivering customized vehicles as soon as customer orders. Implementation of these policies also increases pressure on supplier to be more rapid and responsive then before.

As mentioned in methodology chapter a sample of five companies involved in Iranian automotive supply chain were determined to be investigated during this work. The target supply chain in this study is constituted by one manufacturer 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.

### **1.12.1 Manufacturer**

Manufacturer is a subsidiary of a greatest OEM in Iran named IKCO. It was established in August 1962 in Tehran, Iran. Similar to other OEMs, the parent

company is in charge of designing and developing of all products and subsidiaries located in different parts of the country only produce vehicle according to dictated production plans. In this case the responsibility of sourcing belongs to especial subsidiary of OEM called SAPCO 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 vehicles from which 4 models are produced by focal plant which is called in this work manufacturer. The OEM is the best exporter company of Iran and it was marked as first company from sale viewpoint, pioneer in the field of job creation, second rank company in profitability. Production of 755,555 vehicles in 2010 can be count as a record of OEM in the Middle East (IKCO annual reports 2013).

The recent strategy of company is concentrated on producing customized vehicle based upon end user preferences, simultaneously, reducing cost to achieve price reduction since price reduction leads to increase customer satisfaction in current economic situation in Iran. The options offered by OEM to its customer range from body color, internal trim, audio and video panel to engine characteristics.

### **1.12.2 Firs tier suppliers**

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 related to safety and environmental issue. Therefore, OEMs in automotive industry not only control first tier suppliers but also they do control second tier supplier i.e. suppliers of suppliers. In our case first tier supplier and also suppliers of them i.e. second tier suppliers are audited according to particular predefined instructions regularly by a specific department called Q.A which is the abbreviation for Quality Assurance.

Manufacturer in this case has established long-term relationship with approximately 465 suppliers and in some cases they intend to develop partnership relations. The main goal of company to develop long-term relationship with its supplier is to ensure that all components and raw materials, which they need to deliver final product to end users, correspond exactly to orders.

In order to increase 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 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.

### **1.13 Results**

From 40 questionnaire distributed to four selected companies in under investigation supply chain researcher succeed in gathering 25 completed questionnaires. The return rate is about 62.5% which is good enough to rely on the results. Collected data was analyzed by using three different tools more frequent

suggested in the literature including: balanced critical factor index (BCFI), "Direction of development", "Gap index". The initial results are illustrated in Table 9.

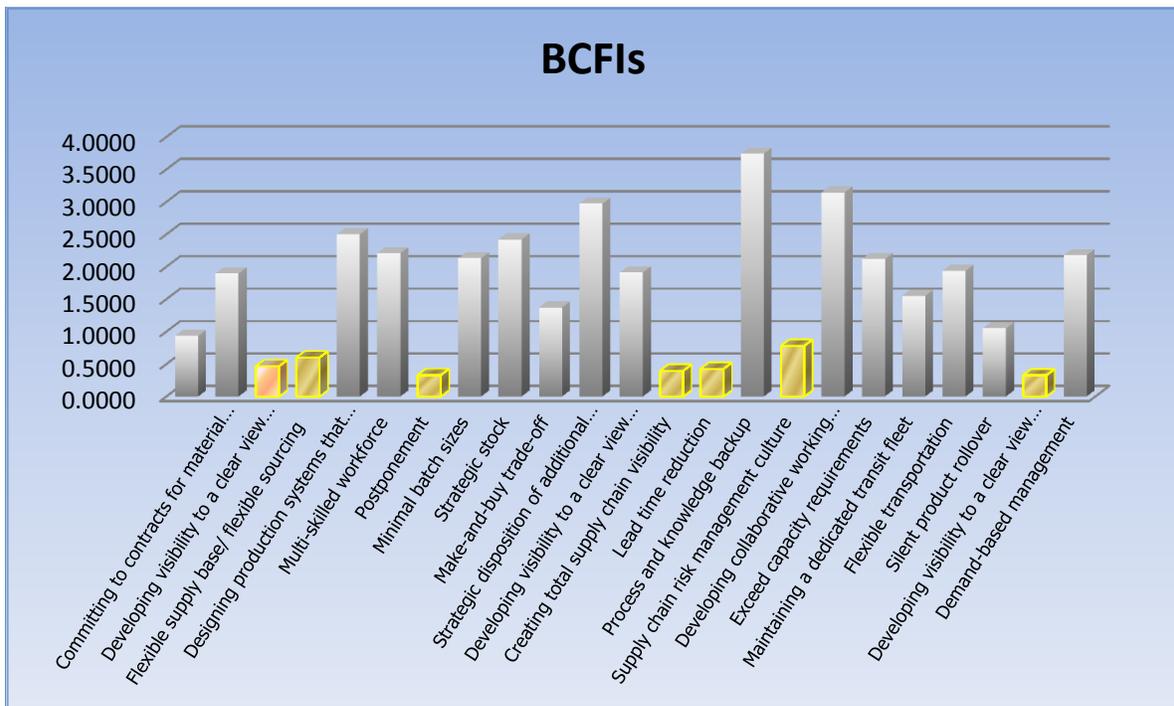
### 1.13.1 Balanced Critical factor index

The most valuable tools in sense and respond philosophy as it identify critical factors influencing overall performance of process. Critical attribute is defined as those attributes have great influence on productivity of focal process. As a result company would be able to allocate more resources or attention in a way to optimize process performance. Nadler and Takala (2010) argue that in sense and respond methodology by using BCFI all attributes that their corresponding BCFI value is under one are critical and attributes with BCFI value equal to one can count as optimal attribute and those are above one can be considered to be "high performers".

**Table 9: Calculated Indices.**

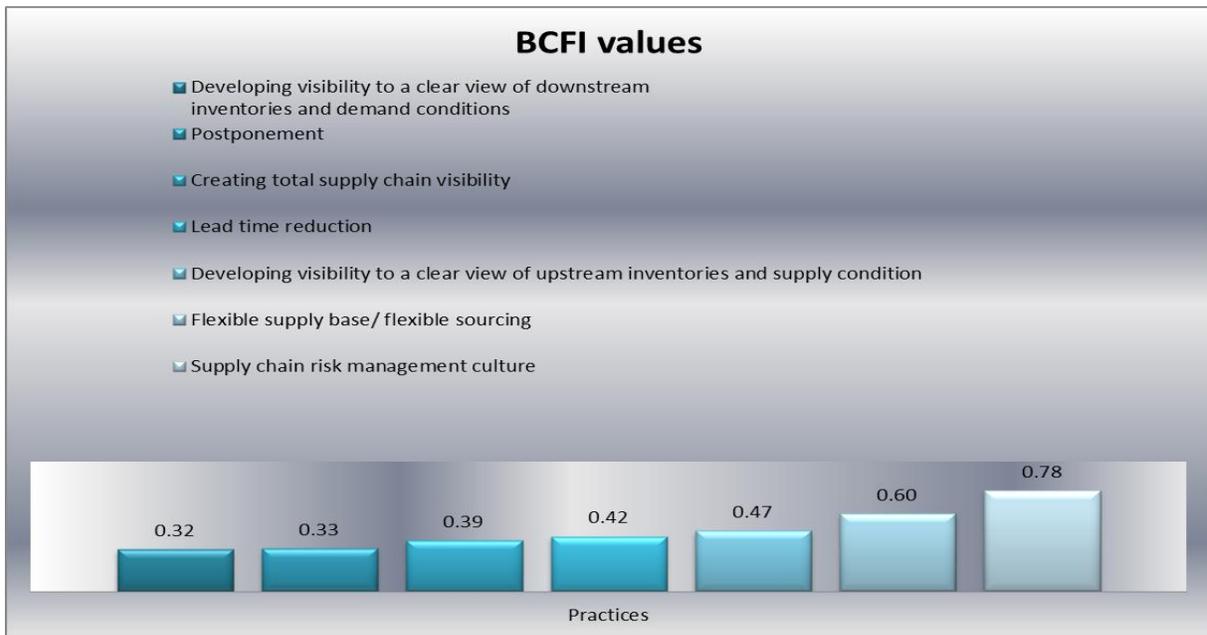
Attributes	Average of expectations	Average of experiences	Importance index	Direction of development	Gap index	BCFI
<b>Practices developd upstreams</b>						
Sourcing strategies to allow swithcing of supplier	8.20	7.08	0.82	0.98	1.15	0.93
Committing to contracts for material supply	8.84	8.20	0.88	0.99	1.08	1.89
Developing visibility to a clear view of upstream inventories and supply condition	9.16	5.56	0.92	1.03	1.47	0.47
Flexible supply base/ flexible sourcing	8.80	6.16	0.88	1.02	1.34	0.60
<b>Deployed by companies in their daily internal operations</b>						
Designing production systems that can accommodate multiple products and real-time changes	7.48	6.92	0.75	0.40	1.07	2.50
Multi-skilled workforce	9.44	9.12	0.94	0.48	1.04	2.21
Postponement	7.36	4.36	0.74	1.48	1.39	0.33
Minimal batch sizes	8.36	8.24	0.84	0.52	1.02	2.13
Strategic stock	9.44	8.76	0.94	0.40	1.09	2.42
Make-and-buy trade-off	7.12	7.16	0.71	0.84	0.99	1.37
Strategic disposition of additional capacity and/or inventory at potential “pinch points”	7.04	7.12	0.70	0.40	0.99	2.97
Developing visibility to a clear view production and purchasing schedules	9.28	9.28	0.93	0.60	1.00	1.91
Creating total supply chain visibility	9.72	6.80	0.97	1.44	1.38	0.39
Lead time reduction	8.56	5.40	0.86	1.24	1.41	0.42
Process and knowledge backup	7.12	7.96	0.71	0.40	0.89	3.74
Supply chain risk management culture	9.64	6.64	0.96	0.72	1.39	0.78
Developing collaborative working across supply chains to help mitigate risk	7.84	9.48	0.78	0.56	0.79	3.14
Exceed capacity requirements	6.88	7.32	0.69	0.60	0.94	2.12
<b>Practices developd downstreams</b>						
Maintaining a dedicated transit fleet	6.60	6.28	0.66	0.68	1.04	1.55
Flexible transportation	9.16	9.24	0.92	0.60	0.99	1.94
Silent product rollover	6.76	7.64	0.68	0.65	0.89	1.05
Developing visibility to a clear view of downstream inventories and demand conditions	9.12	6.12	0.91	1.68	1.39	0.32
Demand-based management	6.76	7.00	0.68	0.56	0.97	2.18

If company intends to increase the level of efficiency, more resources have to be allocated to the process. Based on calculated BCFIs shown in Table 9 and Figure 8 seven practices through the supply chain are critical.



**Figure 11:** BCFI values.

Two of them belong to category which should be applied to upstream level i.e. suppliers of the manufacturer and four out of seven critical practices refer to manufacturer and finally only one is related to downstream level of supply chain. As more the number of BCFI is approaching to zero as more critical attributes are (Nadler and Takala 2010). According to this statement it is easy to rank practices in order of criticality. The most critical practice is concerning visibility in downstream level of the supply chain. This critical practice is mainly argued by suppliers whereas the demand is reflected to them by manufacturer very late. Then immediate critical factor is discussing postponement. In Figure 10 the ranking of critical practices is illustrated based on the value of BCFI.



**Figure 12:** *BCFI Values.*

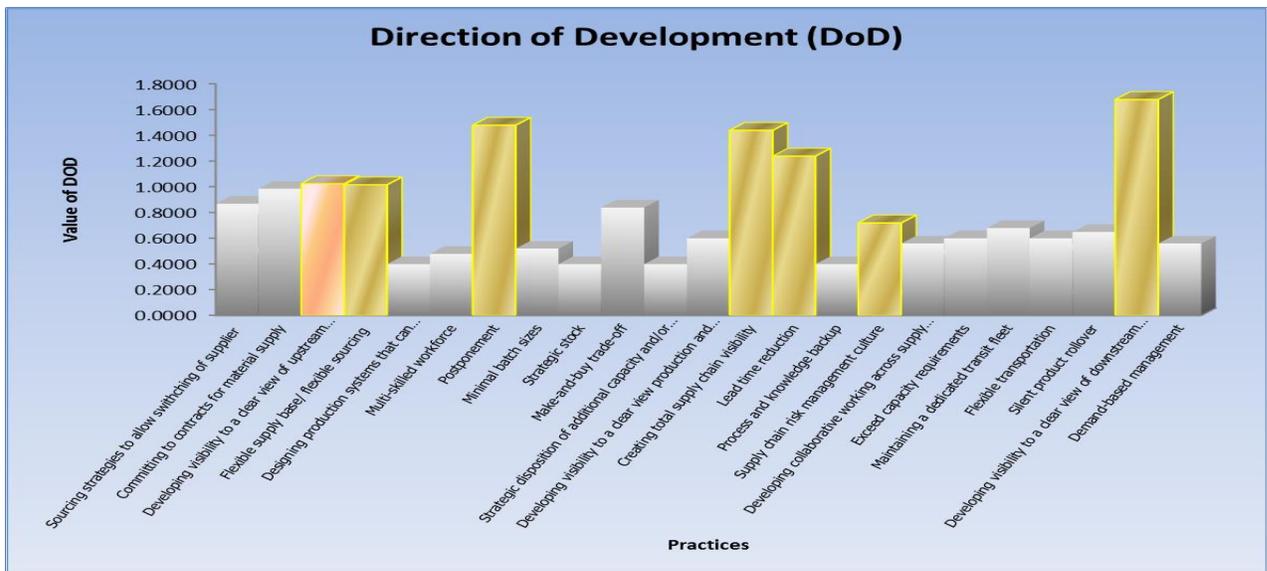
### 1.13.2 Direction of development

This indicator demonstrates direction of change in attribute performance. The indicator provides managers with a clear view on how implementations of practices were in the past and it also lets manager to make guess about future.

The index is calculated by using below formula:

$$\text{Direction of Development Index} = \left| \frac{(\text{better \%} - \text{worse \%}) * 0,9}{100} \right| - 1$$

According to the calculated values (Table 9) the most critical factor from direction of development point of view is again refer to visibility through the supply chain. Here the problem is more sever in visibility in downstream level of supply chain. After discussing with managers and experts about results of this indicator all confirmed that this situation emerges from the policy of manufacturer regarding keeping secret its sales plan.



**Figure 13:** *Direction of development index*

### 1.13.3 Gap index

Ranta ana Takala (2007) argue that Gap index states the differences between expectation and experience of respondents for corresponding attribute. They continue that utilization of this fundamental index helps researcher explore

attributes or in our case practices in which real situation is lower than expectation. Nadler and Takala (2010) propose below formula for calculating GAP index:

$$\text{Gap index} = |(\text{avg. of experience} - \text{avg. of expectation}) * 1,3 / 10 - 1|$$

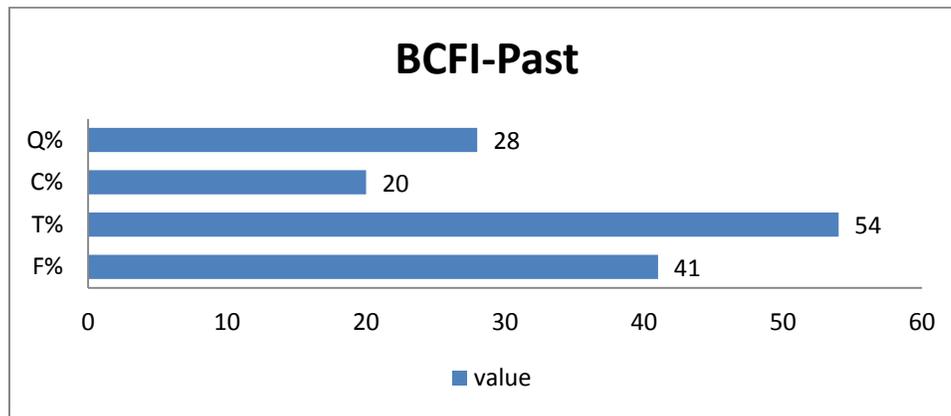
They argue that attributes with GAP value ranges between 0.1 and 1.9 where 0.1 is considered as low i.e. non critical and 1.9 means critical.

In order to determine critical value of GAP index we suppose GPA = 1 as base line and compare results with this baseline. Values under baseline are acceptable. After taking a look to the results especially GAP index it is revealed that this index also confirm the previous findings, the same critical practices and attributes. The results are shown in Figure 10.

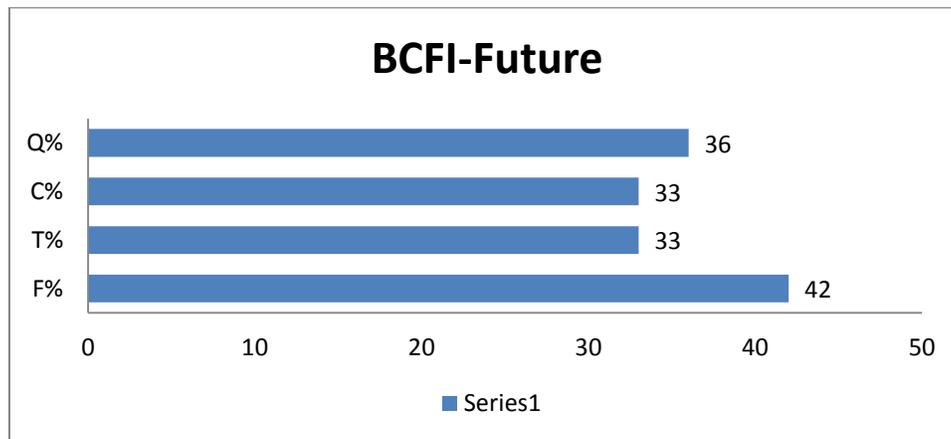
## **1.14 Sustainable competitive advantage (SCA)**

### **1.14.1 Manufacturer**

In order to calculate SCA we need first calculate competitive priorities in the past and future of the manufacturer. As illustrated in Figure 14-15



**Figure 14:** Competitive priorities in past-Manufacturer

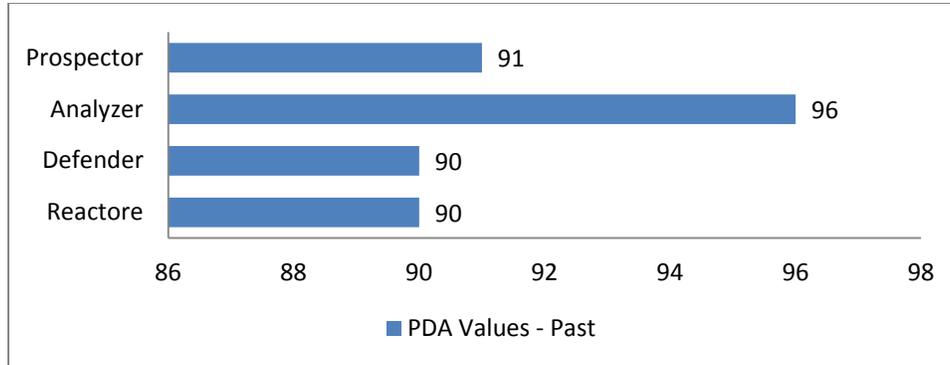


**Figure 15:** Competitive priorities in future-Manufacturer

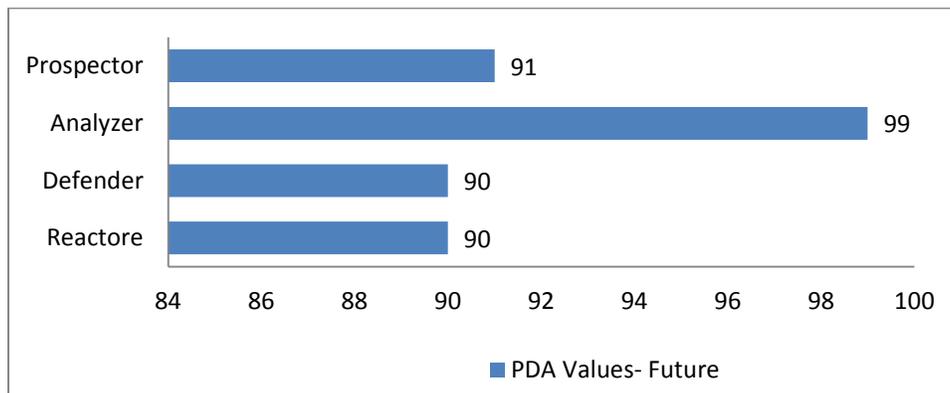
Similarities between two figures show that quality is the most important priorities for the manufacturer. Share of the Q for past and future company strategy is %53 and %64 respectively which illustrate, in future company has more concentration on quality.

The next step is to calculate PDA values in the past and future. According to the Figure 16 – 17 the position of analyzer for manufacturer is proved. This position

shows the balance between quality and flexibility. This statement is approved based on results of figure 14 -15.



**Figure 16:** PDA Values – Past



**Figure 17:** PDA Values – Future

Comparing two above figures reveals that the strategies of manufacturer are sustained in past and future.

In tables 10 and 11 SCA risk level for past and future of manufacturer strategies are illustrated:

**Table 10:** SCA risk level (past)-Manufacturer

	<b>CFI</b>	<b>BCFI</b>
<b>MAPE</b>	96%	89%
<b>RMSE</b>	97%	93%
<b>MAD</b>	98%	94%

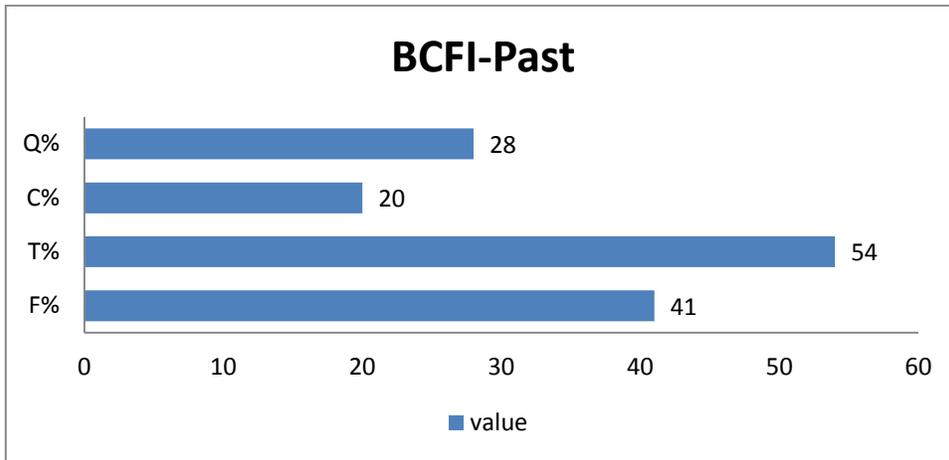
**Table 11:** SCA risk level (Future)-Manufacturer

	<b>CFI</b>	<b>BCFI</b>
<b>MAPE</b>	89%	98%
<b>RMSE</b>	94%	99%
<b>MAD</b>	95%	99%

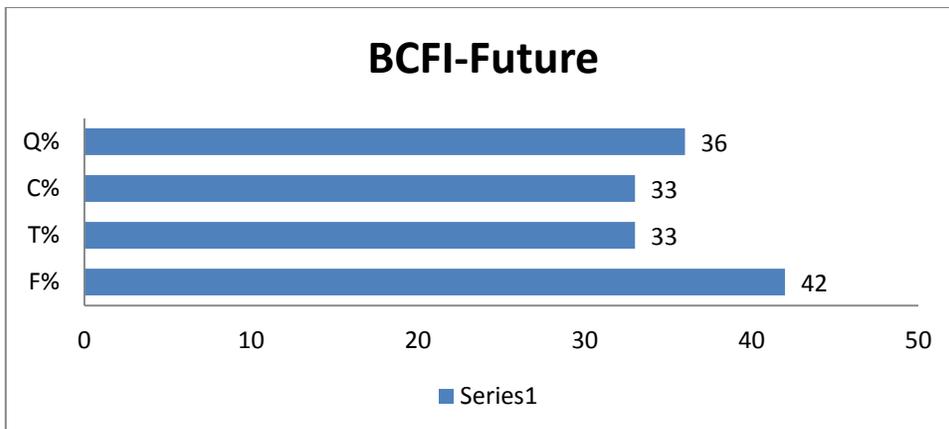
Comparison among tables 10 and 11 proves that the resources allocation for different attributes follows company strategy better in future than in past and also as the risk level is almost less than 10% according to all the calculation so it is concluded that in general resources allocation follows company strategy well.

#### 1.14.2 Supplier of wire harness

Figure 18 and 19 show that competitive priority of wire harness supplier in the past was time but it has changed to cost.



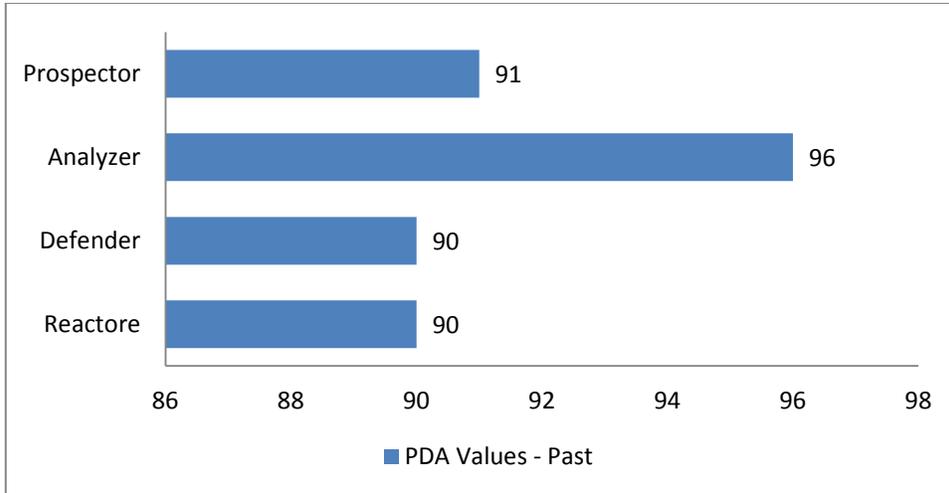
**Figure 18:** Competitive priorities in past-supplier of wire harness



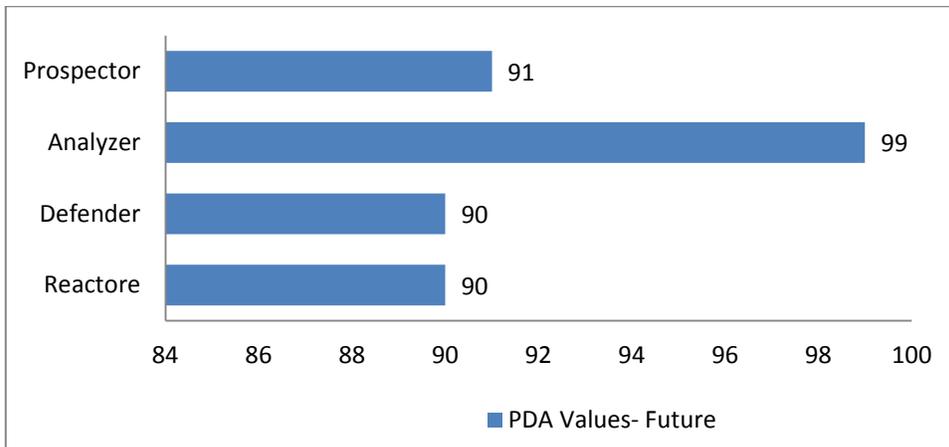
**Figure 19:** Competitive priorities in future-supplier of wire harness

Two following charts illustrate the PDA value of wire harness supplier in the past and future. After considering carefully on the values of PDA, it is revealed that the wire harness supplier primarily acts as analyzer in the past but it seems that its strategy would be defender in the future. As the PDA values for wire harness

supplier change significant in future in comparison to the past, so the company strategy could not be sustainable.



**Figure 20:** PDA Values – Past (Wire harness supplier)



**Figure 21:** PDA Values – Future ( Wire harness supplier)

Based on the literature, SCA risk level argues about the support of company strategies from resource allocation. If these values approach to 100% then it means that strategies strongly are supported by resource allocation. According to the

illustrated results in table 12 and 13 in the case of wire harness supplier, strategies highly supported by resource allocation.

**Table 12:** SCA risk level (past)-Wire harness supplier

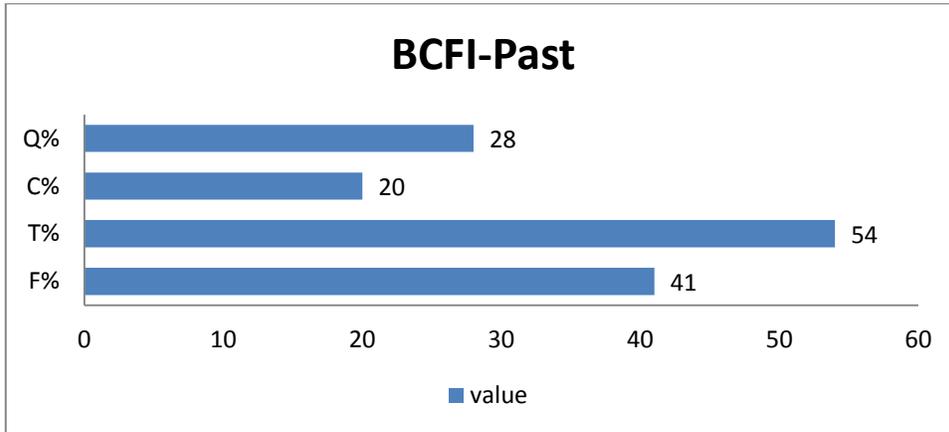
	<b>CFI</b>	<b>BCFI</b>
<b>MAPE</b>	96%	88%
<b>RMSE</b>	97%	93%
<b>MAD</b>	98%	95%

**Table 13:** SCA risk level (past) - Wire harness supplier

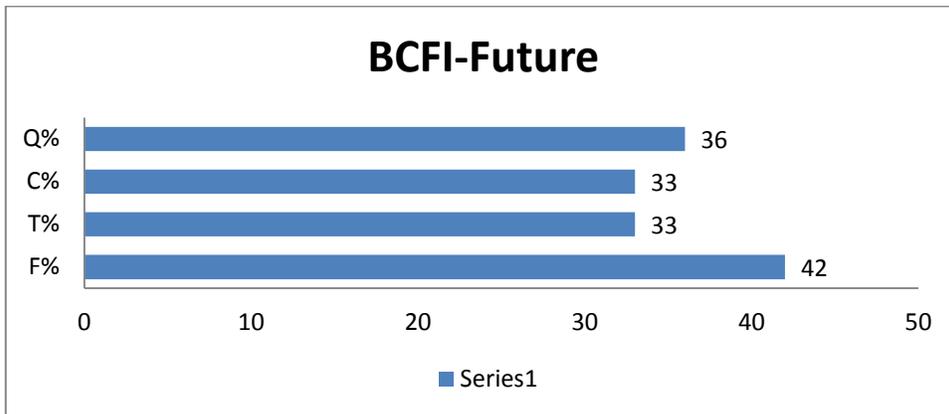
	<b>CFI</b>	<b>BCFI</b>
<b>MAPE</b>	89%	99%
<b>RMSE</b>	94%	98%
<b>MAD</b>	95%	99%

### 1.14.3 Exhaust supplier

Competitive prioritization values of exhaust supplier in our supply chain are illustrated in figure 22-23. As you can see the main concentration of company in the past and future is on time, however, they also intend to focus on cost in future.

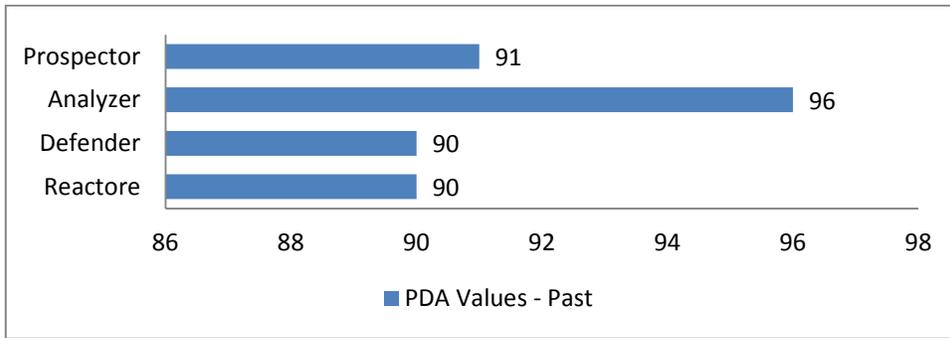


**Figure 22:** Competitive priorities in past- Exhaust supplier

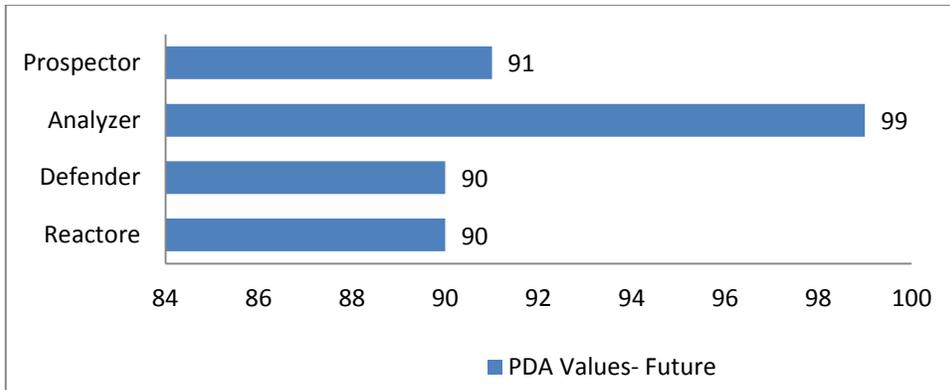


**Figure 23:** Competitive priorities in future- Exhaust supplier

As illustrated in figure 24- 25, there is no difference between dominant value in the past and future. It means that exhaust supplier has sustainable strategy both in past and future. In other words, company was analyzer in the past and it is still analyzer.



**Figure 24:** PDA Values – Past (Exhaust supplier)



**Figure 25:** PDA Values – Future (Exhaust supplier)

Generally speaking, due to the fact risk levels are less than 10%, company strategy is highly supported by resource allocation (Tables 14&15).

**Table 14:** SCA risk level (past)- Exhaust supplier

	CFI	BCFI
<b>MAPE</b>	93%	95%

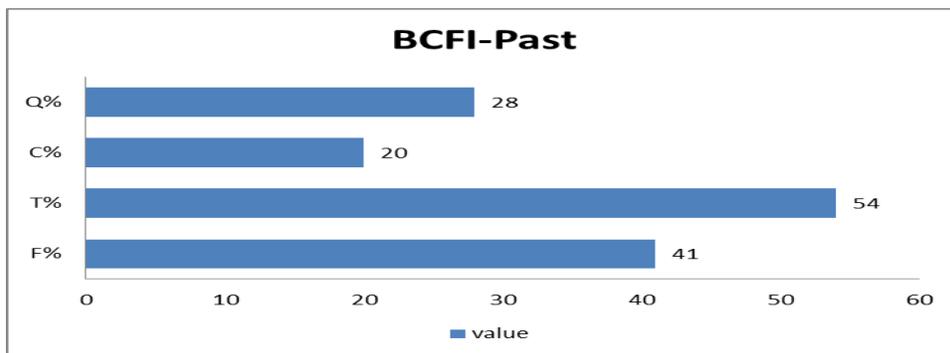
<b>RMSE</b>	98%	96%
<b>MAD</b>	97%	99%

**Table 15:** SCA risk level (future) - Exhaust supplier

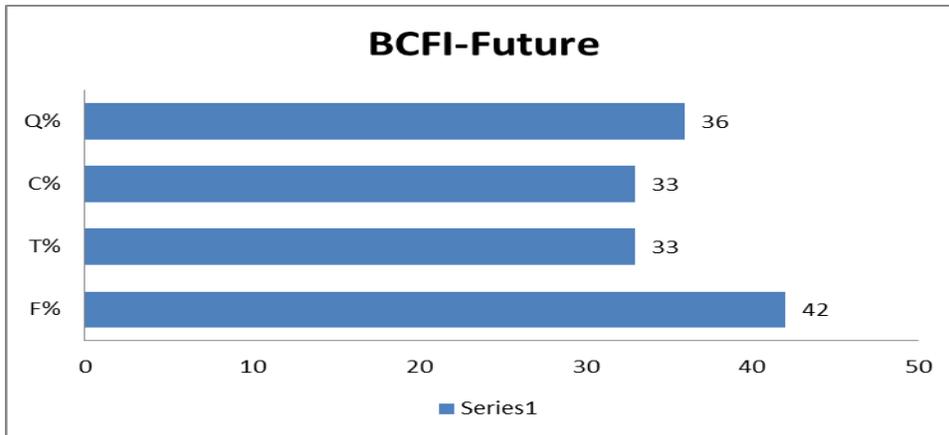
	<b>CFI</b>	<b>BCFI</b>
<b>MAPE</b>	95%	94%
<b>RMSE</b>	97%	95%
<b>MAD</b>	96%	98%

#### 1.14.4 CNG conversion kit supplier

The values of figure 26 and 27 reveal that the main concentration of 4.3.4 CNG conversion kit supplier was time and then it changed its focus toward flexibility and quality respectively.

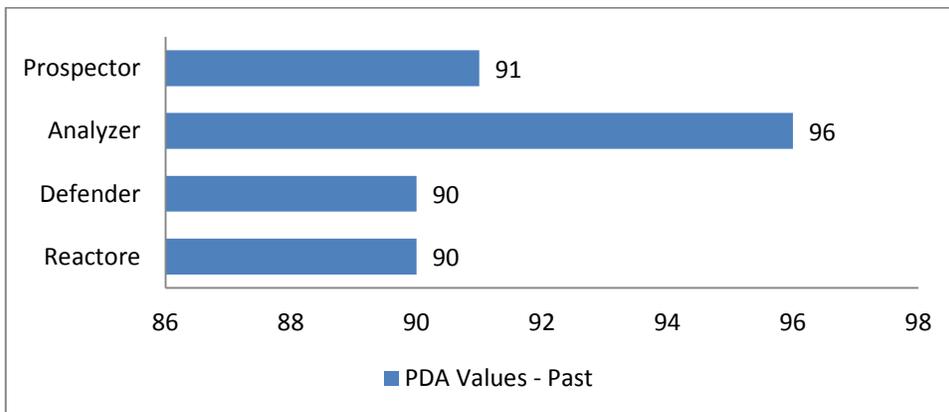


**Figure 26:** Competitive priorities in past- CNG kits supplier

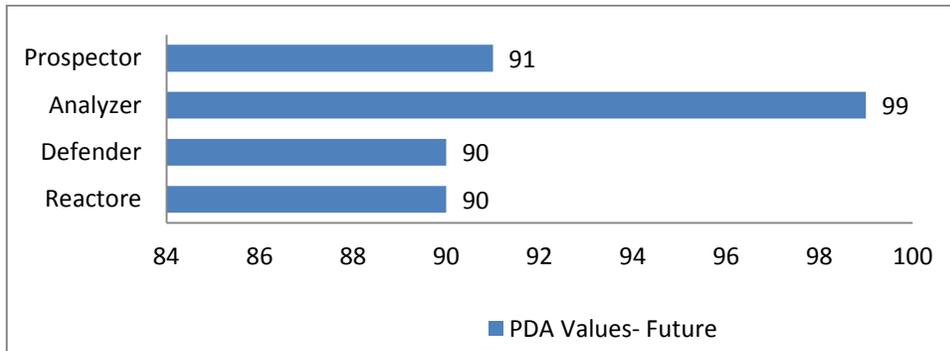


**Figure 27:** Competitive priorities in future- CNG kits supplier

Figure 28 and 29 illustrate PDAs of CNG kits supplier in the past and future. As the figures show the position of company was analyzer in the past and it will maintain it stable in the future. So it means that CNG kits supplier is located between Prospector and Defender and strives to stay in market.



**Figure 28:** PDA Values – Past (CNG Kits supplier)



**Figure 29:** PDA Values – future(CNG Kits supplier)

SCA risk analysis of CNG Kits supplier is demonstrated in tables 16 and 17. According to those tables, it is revealed that generally risk of company strategy is less than 10%. It means that strategy of company is supported well by resource allocation in past and future. Also it is showed the company risk strategy is less in past in comparison with in future but the differences is not significant.

**Table 16:** SCA risk level (Future)CNG kits supplier

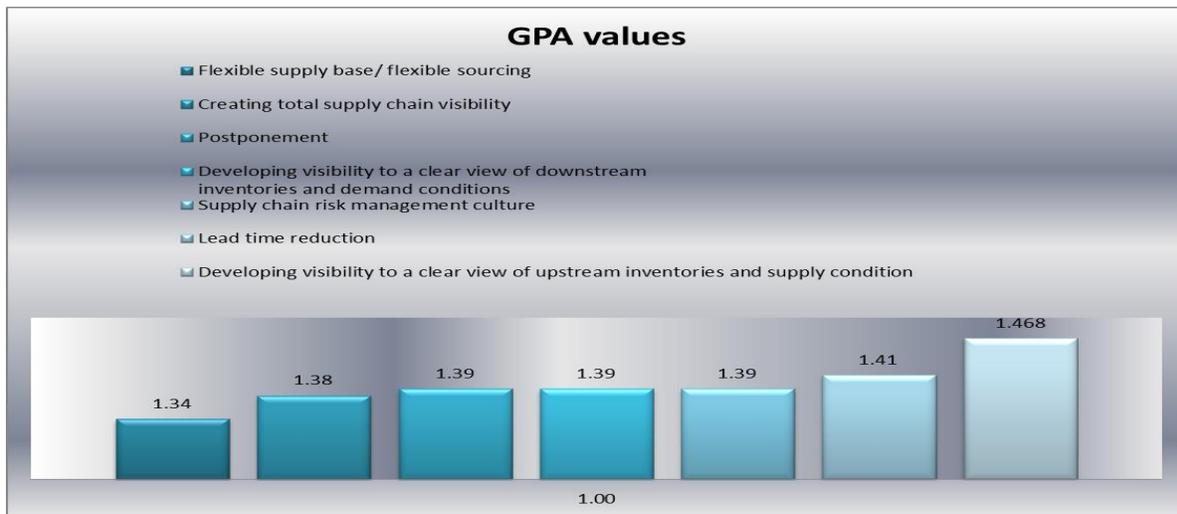
	<b>CFI</b>	<b>BCFI</b>
<b>MAPE</b>	100%	95%
<b>RMSE</b>	100%	98%
<b>MAD</b>	100%	97%

**Table 17:** *SCA risk level (Future)CNG kits supplier*

	<b>CFI</b>	<b>BCFI</b>
<b>MAPE</b>	96%	92%
<b>RMSE</b>	98%	96%
<b>MAD</b>	97%	96%

### 1.15 Discussion

In this research a constructive model was developed and utilized in order to identify weaknesses causing companies fail to establish a resilient supply chain. The method aims to explore major obstacles and factors which cause companies to be unsuccessful in absorbing disruptive events. This process is based on manager's opinions of under investigation companies in the area of supply chain and systematic analysis by tools proposed and approved in many cases. The validity and reliability of these methods have been verified based on SDs and balanced critical index factor utilization in many conducted case studies in almost every filed especially automotive industry (Ranta and Takala, 2007; Nadler and Takala, 2010; Nikookar et al. 2012; Liu and Takala, 2012).



**Figure 30:** *GPA values*

After reviewing literature by researcher and analysis of current situation of the supply chain through conducting interview with managers, all practices contributing to resiliency issue in a supply chain gathered and formed as a questionnaire (Appendix 1) then 40 copies of questionnaires were distributed among managers and staff-members of companies whose responsibility is in the area of supply chain management and completed ones collected after one week. 25 questionnaires out of 40 were usable in the research and the rest due to missing information were excluded.

Critical practices based of BCFI can be classified into three groups:

1. Practices concerning developing visibility
2. Practices concerning production methods and product design

### 3. Concerning organizational behavior and cultural issues

Researcher figured out from the results that the most critical issue in the supply chain is visibility throughout supply chain. Christopher and Peck (2004) argue that poor visibility through upstream and downstream of supply chains is frequently reported by researcher as significant issue in supply chain management. In other words sharing information among entities of a supply chain is not efficient. Since the results is not verified without reflecting to companies and approving by them. Therefore in order to check validity of findings and receive confirmation from them top managers of companies were interviewed again and investigated their viewpoints regarding the findings. They almost approved the poor information sharing in supply chain. First tier suppliers state that they have ambiguous view of manufacturer demand due to lack of information regarding the rate of annual sale. Christopher and Lee (2004) state that “end to end” visibility must be considered in any supply chain design strategy.

A serious issue in the majority of supply chains is poor connection between companies belonging to those supply chains which lead to significant reduction in level of visibility. One of the great technological advances of the 20<sup>th</sup> century undoubtedly is Internet. With the help of the new emerged technology companies are enabled to make decision upon same data i.e. actual demand instead of approximated one. (Christopher 2000).

Ponomarov and Holcomb (2009) propose that the best strategy which may be taken by companies to confront supply chain errors could be increasing the level of

trust through supply chain. They argue that trust has close relationship with visibility in supply chain.

The results of SCA show that the main concentration in area of competitive priorities is on time and flexibility. For more detail, the table is prepared. Regarding to strategy position of case company, the results of PDA test show that focal supply chain mainly is analyzer

**Table 18:** Competitive prioritise

<b>Company</b>	<i>Competitive priority in past</i>	<i>Competitive priority in future</i>
<b>Manufacturer</b>	quality	quality
<b>Wire harness supplier</b>	time	cost
<b>Exhaust supplier</b>	time	time
<b>CNG kit supplier</b>	time	flexibility
<b>Piston supplier</b>	cost	cost

In detail, Manufacturer, exhaust supplier, CNG kit supplier, and piston supplier take the position of Analyzer in past and future. But wire harness supplier is

Analyzer in past and Defender in future. Finally, there are not any prospector or defender companies among these five cases.

## CONCLUSION

### 1.16 Overview

The ultimate target of supply chain management is to increase customer satisfaction as much as possible as well as benefits of all entities in the supply chain. But the clearest feature of today's business environment is inherent uncertainty and in this turbulent situation supply chain as a complex system is always in danger of various risks and disturbances resulting in vulnerability and appearing errors in supply chains. These days vulnerability is getting prominent because of increasingly intendency to be lean and agile in supply chains causing them to be vulnerable to disruptions , consequently, in danger of losing benefit, share market, and customer loyalty. The presence of disturbances in a supply chain causing deviation in flow of items which should be supply from their scheduled and expected situation that can have negative effects of supply chain normal performance is defined as vulnerability in a supply chain In order to maintain productivity and avoid loss in s disruptive situation, supply chains and following they example member companies must be resilient enough to overcome these events. Therefore, the main core of the thesis is resilient supply chain.

In the first step, researcher performed an all-embracing literature review to explore different dimensions of supply chain along with identifying various aspects of probable disruptive events as well as corresponding errors may occur. Identifying supply chain practices utilized by companies to improve their resilience was

conducted as second step. From literature related attributes to resiliency were extracted and put in the sense and respond methodology. Empirical part of work performed as a case study in the most famous Iranian automotive company and data gathered throughout distribution of a questionnaire among managers and staff of automaker and four its upstream suppliers.

Presenting practical finding and theoretical knowledge to top managers of companies gave this opportunity to researcher to compare his finding with reality. Almost all results were confirmed by top managers and let them to identify current weaknesses as well as potential traps that they may fall into in the near future. The developed questionnaire was accepted as a tool to evaluate situation of resiliency of supply chain in the future.

### **1.17 Main finding**

From literature review, it was revealed that disruptions in supply chains as undesirable and unexpected circumstance resulting errors derived from these disturbances in a supply chain but in contrast with disturbances, they are finite. This thesis showed that disruptions can arise in different area of supply chain management. Consequently their behaviors and effects are diversified. For instance disruption in flow of material due to bankruptcy of key supplier and disruption because of earthquake are completely different from each other. Although disruptive events in supply chain are predictable but the problem is that the consequence of them are really tough to anticipate accurately but there are some attributes by optimizing those companies can prevent supply chain

errors due to disruptive events. Sense and respond was found to be workable approach for identification of critical attributes related to resiliency.

Literature review and case study results help answer to research questions:

1. What is supply chain and supply chain management?

Literature review and discussion with managers and experts of case companies shows that the best definition for supply chain is what proposed by Mentzer (2001): a supply chain is an alignment of some companies or individual straight engaging in the upstream and downstream flow of goods, services, money, and/or information from initial sources to end users and supply chain management is strategically coordinating of traditional duties of firms with in the supply chain they are involved which lead to improving long term profitability of individual companies and the chain as a whole.

2. How supply chain disturbances are defined in supply chain literature?

According to supply chain literature any event that occurrence of it may cause disruption in smooth flow of items in a supply chain in defined as disturbance in supply chain context. Disturbance occurrence results in reduction in performance of companies. This reduction is due to incapability of companies in sustaining their productivity in case of disturbances.

3. Which attribute must be considered to achieve resiliency in a supply chain?

Literature review shows that there are 23 attributes related to supply chain resiliency as listed in the questionnaire (Appendix 1).

4. What are the critical attributes in Iranian automotive supply chain?

Case study finding also reveal that automotive supply chain in Iran currently suffers from invisibility of information. This phenomenon causes companies to get inefficient due to high level of inventory cost and also vulnerable to disruptive events.

5. Is the overall strategy of supply chain is sustainable?

IF we go through strategy position of member companies in our supply chain, it is reveal that there is no difference among company position in past and future for majority of cases. This means that the strategies of companies are sustainable except wire harness supplier.

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APENDIX

Appendix 1: Questionnaire used in the research

SENSE & RESPOND QUESTIONNAIRE,				Company:									
This questionnaire measures organization's opinions level of utilization of resilient practices in the company. All boxes must be filled in order to form a useable answer.													
RESILIENT PRACTICES	Scale: 1=low, 10 =high				Direction of development,			Direction of development,			Compared with competitors		
	Expectations	(1-10)	Experience	(1-10)	Worse	Same	Better	Worse	Same	Better	Worse	Same	Better
Practices developd upstreams													
Sourcing strategies to allow swithching of supplier													
Committing to contracts for material supply													
Developing visibility to a clear view of upstream inventories and supply condition													
Flexible supply base/ flexible sourcing deployed by companies in their daily internal operations													
Designing production systems that can accommodate multiple products and real-time changes													
Multi-skilled workforce													
Postponement													
Minimal batch sizes													
Strategic stock													
Make-and-buy trade-off													
Strategic disposition of additional capacity and/or inventory at potential "pinch points"													
Developing visibility to a clear view production and purchasing schedules													
Creating total supply chain visibility													
Lead time reduction													
Process and knowledge backup													
Supply chain risk management culture													
Developing collaborative working across supply chains to help mitigate risk													
Exceed capacity requirements													
Deployed downstream													
Maintaining a dedicated transit fleet													
Flexible transportation													
Silent product rollover													
Developing visibility to a clear view of downstream inventories and demand conditions													
Demand-based management													
<p>Expectations = What is the level of expectations for an attribute in a scale of 1-10                  Experiences = What is the level of experiences for an attribute in a scale of 1-10                  Direction of development (future) = Direction of development compared to the situation expected 1 year after this questionnaire                  Direction of development (past) = Direction of development compared to the situation 2 years before this questionnaire                  Compared with competitors = Level of experiences compared to the competitors</p> <p>Knowledge/technology requirement = evaluate how the required technology is divided between basic-, core- and spearhead technologies. The row total should be 100 %.</p> <p>The effects on perfumance measures=Please indicate your perception of the relationship that you believe exists between management practices and performance measures, indicating whether the implementation of management practices increases or decreases the level of performance measures, or if the relationship is not applicable (N / A).</p>													