

Occurring disruption in the supply chain and its recovery: Review of literature

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(Communicated by Seyed Hossein Siadati)

Abstract

In this research, the concepts, theories and models on supply chain disruption and its recovery have been investigated. The purpose of this paper is to collect theoretical and applied research for researchers who will tend to research in the future in the field of supply chain disruption and its recovery. After reviewing theoretical studies, the applied research has been studied and the methods and techniques used in these papers have also been examined and its conclusions presented in a separate table comparatively in case.

Keywords: supply chain, supply chain disruption, supply chain recovery
2020 MSC: 90B06

1 Introduction

International trade is one of the vital components of the global economy, which is becoming increasingly important every day. Trade, imports and exports related to national per capita production are developing all over the world and its growth rate is increasing with respect to the role of the Internet, cheap communications and business reengineering in creating global supply chains [42].

Globalization of the economy and the growth of outsourcing make supply chains more complex and dependent and so the supply networks become more vulnerable to disruptions because the defect in one of the chain connections can detriment the whole chain [74]. With the development of globalization, the resilience of supply chains has declined. In many industries, supply chains have been subject to great risks as a result of lack of support capacity, which has so far been unprecedented. Many companies have focused on concepts such as pure activities, on time delivery, single-source and integrated production, with the goal of reducing costs and so on, which leads to a reduction in resources in those industries and, in the event of a disruption, resource shortages lead to escalation of minimum time of primary materials supply and delay in production of final product [54].

In the 1950s, many companies adopted a variety of measures to improve their financial performance. These actions focused on three areas:

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1. Income increase includes: more variety of products, increasing the speed of introducing new products and wider sales markets;
2. Cost reduction includes: supplying requirements with a diminutive approach, timely source finding, including e-markets and auctions, transfer of production facilities to other areas, JIT inventory systems and inventory management by the seller.
3. Reducing assets includes outsourcing of manufacturing activities, information technology and logistics [6].

These actions will result in a stable environment, but the current business environment is constantly changing. Recent changes in supply chains have created a long network with more dispersion and complexity due to the globalization of trade and the increase in the number of partners in the chain. This reduces the direct and uncontrolled control and supervision of companies on ongoing activities of the supply chain [32]. On the other hand, long and complex supply chains usually respond slowly to changes, and have vulnerable points as well as multiple disruptions [42]. According to studies by the Computer Science Society in 2015, 35% of companies reported that their supply chain is vulnerable and is susceptible to disruptions [3]. There are several examples of supply chain disruptions, some of which are: Erickson company lost nearly 400 million Euros due to damage to the production facilities of semiconductor suppliers during the 2004 fire, Land Rover factory caused around 1,400 of its staff members to be service suspended due to bankruptcy of suppliers in 2007, Doll company lost profits with damages to banana farms in South Africa in 2006, and Ford company was forced to shut down 9 factories for several days due to air traffic after the September 11, 2001 accident [73]. According to a large international survey conducted by the Institute for Business Continuity Institute in 2011, 24% of companies around the world face at least one disruption each year, and more than 90% of companies experience between 1 and 9 disruptions per year [19].

Disruptions, in addition to financial effect, also affect on other aspects of production. Based on the analysis of 162 disruptions that occurred over 10 years, Bode and Wagner, have realized that inventory of corporate stocks is reduced over the three years between 40% and 90% that included one year before and two years after the occurrence of disruption [6].

Considering the importance of disruption and its methods of studying, this study examines previous studies on disruption and supply chain recovery. Therefore, firstly, the definitions of supply chain disruptions and the models have been presented and then studies with applied approach have been examined.

2 Disruption in supply chain

Uncertainty refers to the characteristic of a system that results from our lack of our knowledge about the system and the conditions governing it. Uncertainty has many different meanings. Historically, the first terms associated with uncertainty, were incident, chance, and probability which were attributed to Aristotle [15].

Compared to risk, uncertainty is more comprehensive word, and both situations involve a positive deviation (opportunity) and negative (threat) of the expected result [67]. In Figure 1, sources of uncertainty are divided into nine main categories (Figure 1).

Uncertainty factors are usually divided into two groups: probable factors and improbable factors. The first group can be described through probable models. To explain the improbable uncertainty, fuzzy logic with certain membership functions can be used. One of the main dangers of uncertainty is the disruption that affects the planned supply chain path. The disruption of the supply chain is divided into two main categories [15] (Figure 2).

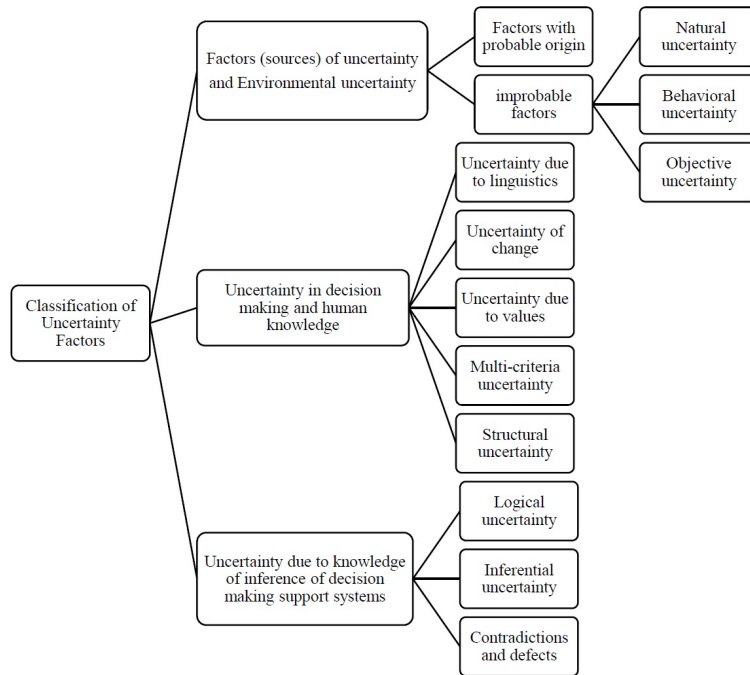


Figure 1: Classification of Uncertainty Factors [15]

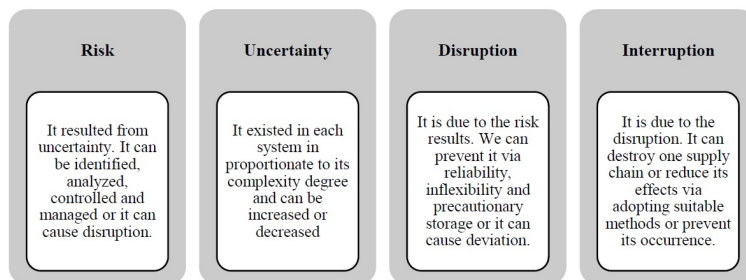


Figure 2: The relationship between uncertainty, risk, disruption and interruption [15]

A. Effect of Targeted Disruption: This type of disruptions can be hostile (disorder in supply chain activities) or non-hostile (upgrading supply chain performance). Examples of targeted Disruption effects include robberies, terrorism, and financial misconduct.

B. Effect of non-targeted Disruption: The second group is natural, economic or technological. An example of the effect of non-targeted economic disruption, is fluctuations in demand and bullwhip effect.

Usually, in analyzing uncertainty, four aspects need to be addressed. The first one is uncertainty and the second is risk. The third aspect is the effect of disturbance (disruption) and the last aspect is the severe effects of disturbance (deviances) [15]. In Figure 2, the relationship between uncertainty, risk, disruption and interruption is shown.

Table 1 presents the uncertainty factors in the supply chain and the actions to be taken into account for managing them [51].

Table 2 also lists examples of disruptions and interruptions in the supply chain.

In general, profits lost by targeted disruptions (for example, terrorism and theft) and non-targeted disruptions (such as demand fluctuations) can be around 30% of annual transactions. The above points indicate the importance of modern supply chain attention to the issue of uncertainty and the need for timely management of them as a very important and vital issue. Because a series of crises are happening, and each one of them alone can endanger the whole supply chain. The supply chain is inherently complex with a network of interconnected activities that includes suppliers, manufacturers, and retailers, and can be linked to several other networks. Dynamic supply chain activities

Table 1: Uncertainty factors and their management methods [51]

Decision making level	Uncertainty factors	Managerial measures
Strategic	Multiple management objectives Terrorism and theft Political and financial crises natural disasters	Multi-criteria analysis techniques Supply Chain Security Management Maintenance of cash assets Strategic material inventory Variation in markets and outsourcing Line Flexibility and Products Modulation
Technical and operational	Poor synchronization Unprocessed processes Precautionary Poor control of shipments Technology failures Human errors	Precautionary storage Allocation of surplus capacity to the supply chain Coordination, refinement and management of supply chain events

Table 2: Example of disruptions and their impact on supply chains [51]

Factors	Example	Effects
Theft and destruction of goods	retail Production	Losing €13.4 million per year Losing €4.6 million per year Loss of more than 15% of the volume of annual equations
Terrorism	eleventh of September	Five manufacturing facilities of Ford's company have been shut down for a long time
Bandit (piracy) natural disasters	Somalia, 2008 1. Earthquake in Thailand, 1999 2. Flood in Saxony Germany in 2002 3. Imposing sanctions on Iranian companies by Trump 2018	Disruption in many supply chains 1. Apple Computer Production in Asia stopped 2. significant decline in Volkswagen company's products 3. Stop the cooperation of transportation companies and other foreign companies with Iranian companies due to the avoidance of heavy crimes and the collapse of the supply chain and transportation balance.
Political crises	Gas crisis, 2009	The interruption of gas supply from Russia to Europe, has caused millions of euros loss to Gazprom company and its customers.
Financial crisis	Great Depression, 2008	Reduce or boost production in most supply chains
Coordination problems	Demand fluctuations Internal imbalance	Loss of customer orders and a decrease of 15 percent of annual transactions

along with uncertainty features scattered throughout this chain (including customer requirements, resource capacity, transport time, production time, costs, quality, priorities and lack of information) have added on its complexity [67]. Events that disrupt supply chain activities in a general division include internal and external events. The internal events of the supply chain have a more damaging effect than external events. The external events of the supply chain are called "environmental incidents" (including technological or economic changes, rival actions, etc.). Internal events may occur on the upstream side of the supply chain (including: slow delivery or receipt, lack of materials or available services, etc.), the middle or central part of the chain (lack of sufficient and adequate capacity, poor performance or poor output of the process, and ...) and the downstream side (including changes in demand composition, change in the timing or volume of requested demand) [51]. Environmental incidents include events that occur outside the supply chain in a wider business environment, and supply chain members have little or no control over them [67]. Environmental incidents can also disable suppliers to meet the needs of the manufacturer, and lead to logistical problems that result in delays, defects or waste deliveries. An example of environmental incidents includes storms, earthquakes, sudden air changes, tsunamis, fires, terrorist attacks, political turmoil, computer viruses, and so on [51]. Internal supply chain incidents may occur when there is a problem with the quality or quantity of manufacturing product that results in a reduction in the company's ability to meet demand. The cause of internal events can be factors such as lack of capacity, incidence of malfunctions in process or equipment, or poor quality performance. Also, the cause of disorder and interruption in internal processes may be accidents such as employee strikes, contagious disease, or the simultaneous abandonment of a number of employees [57]. Table 3 summarizes the source of events that disrupt supply chain activities [67].

Disruptions in the supply chain create uncertainty that may indicate itself in the shape of uncertainty in control, process, supply and demand. Figure 3 shows the effect of disruptions in the supply chain process. Suppose that you have 1000 interested audiences and 50% of these audiences will become your customers. These customers buy an average of 200 Tomans from your business and you have spent a total of 4 thousand Tomans on marketing these

Table 3: Summary of the source of incidents in the supply chain

Case	Source
Environmental events	[10, 23, 35, 47]
Upstream events	[1, 20]
Internal events	[4, 22, 37]
downstream events	[12, 17, 40]

interested audiences. If you put these costs into the ROI formula, you get this equation:

$$ROI = \frac{(1000 \times 0.50 \times 200) - 4000}{4000} = \frac{100000 - 4000}{4000} = \frac{96000}{4000} = 24$$

The objective of the main problem is defined as follows and the cut constraint is added to it. In the cut limit, rep determines the number of repetitions. Also, a lower limit is set to reduce the calculation time.

$$\min \sum_{i=1}^n c_i x_i + \alpha$$

$$\sum_{j=1}^m d_j y_j^{(k)} + \sum_{i=1}^n \lambda_j^{(k)} (x_i - x_i^{(k)}) \leq \alpha \quad k = 1, \dots, (rep - 1), \quad 0 \leq x_i \leq x_i^{up} \quad i = 1, \dots, n, \quad \alpha^{down} \leq \alpha$$

$$b = \frac{n \sum xy - (\sum x)(\sum y)}{n(\sum x^2) - (\sum x)^2}, \quad a = \frac{\sum y - b \sum x}{n}$$

$$\sum xy = 32792; \quad \sum x = 222; \quad \sum y = 1461; \quad \sum x^2 = 5026; \quad (\sum x)^2 = 49284$$

$$b = \frac{10 \times 32792 - 222 \times 1461}{10 \times 5026 - 49284} = 3.666, \quad a = \frac{1461 - 3.666 \times 222}{10} = 64.715, \quad y = 64.715 + 3.666x$$

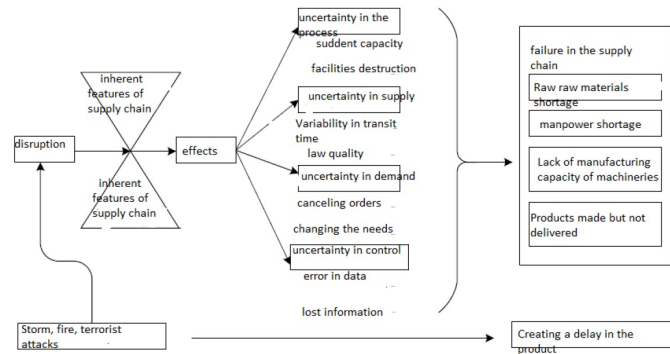


Figure 3: Supply chain model based on the main processes [51].

Ivanov et al. [29] identified following cases as the main factors in reducing the stability of the supply chain at the strategic level through analyzing the events that occurred in various supply chains:

- Specialization and a tendency to a market (or a customer)
- Plans for unlimited profit growth
- High credit requirements
- Lack of alternative suppliers
- High dependence on inventory exchange

- The geographical focus of the supply chain facilities in a particular area, as well as the factors affecting technical and operational levels, are:
 - Weak matching of plans and information on supply and demand
 - No inventory processes
 - Poor control of security of shipments
 - Specialized separation (machines, transportation and information systems)
 - Human mistakes and misinformation management [29]

Various control methods can be used to deal with these disorders, including: supply chain security management, precautionary storage, inventory of strategic materials, diversification in the market and outsourcing, product line flexibility and modulation, refinement coordination, and events management. The basis of all preventive measures is focused on the precautionary storage of chain supply. These measures vary in terms of the importance of factors such as the use of precautionary storage or the diversification of the market in each supply chain. Recent changes in supply chains have led to longer and more complex networks due to globalization and outsourcing of services and activities (such as production, logistics, information technology services, warehousing, etc.) [67]. As chain members' interdependencies and interconnections increase to meet requirements, this increases the number and variety of potential incidents for companies. These changes and increased risks require new management processes. At the same time as the changes, the supply chains experience new techniques such as pure systems and timely production, which these methods are based on close supplier-manufacturer relationships and strict inventory policies that emphasizes to eliminate precautionary storage and inventory among processes [37]. The above processes have caused an increase in the fragility and vulnerability of supply chains. Efforts to create supply chains with higher efficiency and lower costs may lead to unanticipated outcomes that increase the risk of disruption and interruption in the supply chain or increase the severity of the effects of events [51].

Table 4: Types of Supply Chain Risks [51].

Type of risk	Risk Drivers and Related Example
Disruptions	Natural disasters, terrorism, dependence on one supplier, capacity and ability of responding to alternative suppliers Example: Natural disasters can have an impact on commerce or take down the wide distribution network (September 11 terrorist attacks, Japan earthquakes, and Katrina storms)
Delays	Widespread displacement of materials leads to a change in the transportation network. Example: Katrina Hurricane blocked the New Orleans communication road and undoubtedly delayed the delivery of products.
System	Disability of infrastructure in the field of information technology, transportation of financial network
Prediction	Wrong predictions will result in long response times and bullwhip effect, or distortion of information will reduce transparency and exaggeration in demand in times of shortage of production.
Purchase	Applying and using the vast volume of industry
Inventory	Product value and uncertainty of supply / demand Example: When demand for items such as generators reaches its peak with the onset of a storm, since these events are sudden and unpredictable, they cause fluctuations and changes in inventory planning.

Supply chain disruptions have become a critical issue for many companies. The loss of performance due to disruption has turned this issue into one of the prominent issue of today's business environment. Environmental changes, more complex and vulnerable supply chains, have made companies susceptible to disruption. According to research conducted at Cranfield University in 2017, the factors that increase the potential disruption of supply chains are: globalization of supply chains, specialized production processes, increased outsourcing, reduced supplier numbers, demand high variability and technological innovations. Recent cases refers to lack of parts in Ericsson company due to a fire in the supplier facilities, lack of parts in Motorola company, which reduced the ability of the company to meet the demand for camera phones, the suspension of several Japanese car factories due to the failure of facilities of the only supplier of piston rings due to the earthquake [9].

By reviewing the literature, there are several definitions of disruption. According to Fernandez et al., supply chain distortion, is an unplanned occurrence that affects the flow of materials, information, and other components. Therefore, organizations must continuously identify, measure, and evaluate their operating environment and continuously identify the risks associated with a potential disruption. In this case, there could be a significant reduction in the negative effects of disruption in the supply chain [17].

Huntington argues that disruption begins with an unpredictable incident and interrupts the supply chain material flow. This accidental incident could include natural disasters, employees' strikes, dependence to a supplier, supplier bankruptcy, war or political instability [27].

In the other definitions, supply chain disruptions are unplanned and unpredictable events that interfere with the regular flow of goods and materials of supply chain. As a result, members of the supply chain are prone to financial and operational risks [9]. According to Kumar et al., supply chain disruption is a stop in a continuous and regular flow of the chain that has many negative effects [37]. And finally, Abidin and Ingirige defined the disruption as "anything that causes undesirable effects on the flow and supply of raw materials, parts, components, and manufacturing goods from the source to the final demand point" [1]. Any significant interruption will affect the performance of the company in ways that are predictable. Interruptions have a particular look, depending on the extent and severity of their impact on company performance. The company's performance can be measured in terms of sale, production level, profit level, customer service, or any other appropriate measure. The nature of the disruption or interruption and the responsiveness of the company can be expressed in eight steps [67].

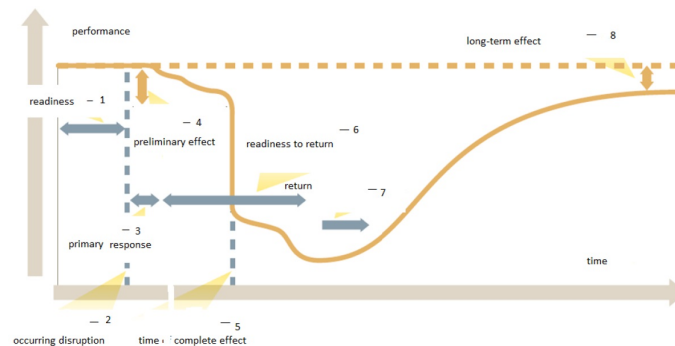


Figure 4: A Disruption View [67]

1. Readiness: In some cases, the company can anticipate before and ready itself for disruption. In this way, the effects of the disruption will be minimized. The range of warning of events for companies varies. For example, the range of warnings rang for General Motors Company 30 minutes before the storm. Failure to negotiate with West Coast harbor workers over the past several months has been indicative of the likelihood of a disruption for many companies. In some cases, such as the September 11th terrorist incident, there are few warnings or no warnings [1].
2. Occurrence of an incident involving disruption: a terrible storm, a bomb explosion, or strike of workers can take away a supplier from a business cycle.
3. Preliminary response: whether companies face physical impairments or interruptions in information technology, companies will have the primary response to control the situation, maintain life, shut down affected systems, and prevent further breakdowns.
4. Primary Effect: The full effect of some disruptions is immediately felt. The Union Carbide chemical plant in Bhopal and India after the gas leak in December 1984 was forced to immediate closure of its production line. Other disruptions to influence the company may take time depending on factors such as the severity of the disruption, the available surplus member and the inherent elasticity of the organization and the relevant supply chain. When inventory of vital parts were fully consumed during the time the West Coast Harbor was shut down in 2014, the New United Motor factory experienced such a case. During the time between the occurrence of the incident and the full effect, the negative growth trend of performance usually begins.
5. Full Impact: Whether the impact of an impairment is immediately detected or delayed, in any case, despite the impact of a full impact, companies will face a severe drop in efficiency.
6. Readiness to return: readiness to return typically starts in parallel with the first response, and sometimes even before the disruption, if the disruption is predicted. The readiness to return is largely linked to the competence of other suppliers and the re-direction of the supplier's resources (as the Nokia did the necessary measures after the fire at the Royal Philips factory in 2000 and the disruption of the supply chain). Also, finding alternative transportation methods (as NUMMI used the aviation method when the west coast harbor came was shut down in 2002) and determining what parts are available and selling products made from these components (as Dell did after the 1999 earthquake in Taiwan).

7. **Return:** To return to the primary and normal operating level, many companies reimburse their lost production by utilizing more than normal capacity, doing overtime even for suppliers. For example, after the shutdown of the West Coast Harbor in 2002, NUMMI made its delayed orders within a week and sent the customers all the orders, regardless of the last year's holiday.
8. **Long-term effect:** Usually, return from disruption is time-consuming, but if the relationships with customers are damaged, return from the interruption is more difficult and will have long-term effects. For example, shoe factories network in Kobe, Japan, produced and sold 34 million pairs of shoes annually. But with the earthquake in 1995, the company lost 90% of its markets because customers tended to the other Asian products, and most of them never returned. Disputation in companies depend on the size, scope and structure of the firms. Because companies are associated with their environment, they are vulnerable to the effects of various events. If we take into account the smallest piece of equipment used in a company, making this piece has a long process in which many suppliers are involved in different parts of the world. A disruption can be detrimental to any of the supply chain members. In Kumar et al. [37], supply chain disruption is divided into three main groups:

- A. Supply disruption (supply):** It is related to the construction, delivery and availability of inventory at the required time and place
- B. Production disturbances:** The process of manufacturing products or services by the central company
- C. Demand disruptions:** Include distribution and sales of products to customers [37].

In another division, Melnyk et al. [45] categorized disruption resources into seven categories:

1. **Natural:** disruptions that are created by nature and can include storms, hail, fire, dust, lightning and wind.
2. **Changes in Demand:** Disruption due to changes in demand occur when the demand created by customers is available more than capacity. Because adding time takes a long time. Changes in demand (due to factors such as market forces or increase in demand due to standardization of the product) create situations where the available capacity to respond to demand is inadequate. Kondo [35] argues that disruption in demand include unexpected decreases or increase in producer demand. He said these disruptions could happen due to technological changes, new rivals, or the sudden loss of a major customer's trust. For example, if one of the manufacturing compounds of a company that produces chemical materials face an error and using it have health risks for consumes, in addition to losing customer confidence, a significant share of the company's market may be reduced. The Johnson and Johnson (J&J) Company faced such a problem in 1982. The company, which accounted for nearly 40 percent of the market share, suffered significant losses with the suspicious death of seven customers who had used the company's products and lost a large percentage of its market share. Naturally, imbalance in demand could include unexpected demand for company products, which would result in loss of sales or inappropriate services or even loss of customers [57].
3. **Supplier problem:** The supplier is unable to provide and supply the goods and services required for any reason. This disability can be due to factors such as problems that arise in the production of goods, and can not meet the minimum requirements of the customer, or problems that arise in confidence of delivering goods. For example, General Motors suffered a disruption occurred for the second-rank supplier (supplier of one of the suppliers) in the semiconductor industry. Without the chip components manufactured by the company, the next plant would not have been able to prepare and send parts required by General Motors company, and General Motors could not produce a car for sale without this part. But supply disruptions do not just come from accidents. For example, the Nissan Automobile Company, Japan's second-largest automaker, was forced to shut down three of its four products in Japan in late 2014 due to a shortage of steel. The shortage was due to the high demand created in China's growing economy. This disruption struck Nissan with a dramatic impact that demand for Nissan cars which were newly presented to the market, were increased [1].
4. **Organizational / Human Behavior:** Any disruption that directly occurs is the result of organizational or human actions (whether accidental or intentional). Such actions could include terrorism, fire, human errors, strikes, and shut downs.
5. **Technology / Information:** Any disruptions that result in the deployment of information and technology systems. The cause may be due to factors such as system disruption, incorrect data, or computer viruses. Increasing the use of information technology will increase the vulnerability of companies against computer viruses, software issues and other technical issues. For example, SQL Slammer was a computer worm that quickly hurt computers

that were connected to the Internet in January 2010. Without human intervention, the virus hurt 50% of users in 10 minutes. The hardest hit was done to an Internet server in Asia. The virus disturbed 911 phone centers and famous companies such as American Express and computer centers of several airlines. It also hurt 13,000 ATMs of US bank. Eventually, the virus had a loss more than \$750 million to \$1.2 billion [28].

6. Financial: These disruptions arise due to inconsistent changes in the financial status of each sector involved in the supply chain, such as a supplier's bankruptcy or shutdown.
7. Legal / Judicial: These disruptions arise from legal / judicial issues. The impact of events that cause disruptions in the supply chain appears in many ways. The first and perhaps most obvious form of this is the disruption in access to materials and goods. In this case, the company may face a shortage or inventory surplus, which is in both cases undesirable. For example, in the case of inventory shortage, it can lead to a shift in the timetable of delivering customer orders. Accelerating the delivery and transportation, or the need to purchase materials from other suppliers, and in most cases at a higher price, is the consequence of this state. Also, inventory surplus can increase shipping costs, capital opportunity expense, and outsourcing, which can result in financial flow and investment volume of company [57].

The second effect of disruption in the supply chain is related to the flow of information. The lack of material or lack of transparency of inventory information, especially in global supply chains, is the result of this. Also, the deviation from demand information will increase as it flows into the supply chain. Information on constantly changing markets (such as competitors' activity, changes in the content of provisions, etc.) is essential for effective management of the supply chain, and can provide the necessary warnings for potential incidents [67].

The third one is related to financial effects, because cash flow is in parallel with the flow of resources between the members of the chain. In many cases, making decision is based on special tax deductions, but if these tax deductions change, the supply chain cost structure will be affected. Supply chain members can be sensitive to material price changes and their fluctuations, the credit value of members of the chain, timely payments, and the financial stability of suppliers and customers [32].

The fourth effect of disruption on supply chain is related to communications and relationships between the supplier and the customer. In general, there is a kind of interdependence between the members of the chain, which is based on maximizing the profits and benefits of each individual company and help them in delivering service to customers. Therefore, selection of partners should be done in terms of their ability to achieve intended goals and also the ability to support in the disruption [57].

The fifth effect involves damages to physical assets such as major damage or destruction of facilities due to flood, fire or severe climate change. The result of such an effect can be a stop in the production and delivering services to customers, which can lead to a loss of profit and a reduction in market share [9]. Although disruptions can occur in several companies, interdependencies between companies cause to spread disruption to other members. So, when an incident occurs in other parts of the supply chain, other members may be susceptible to disrupting their goods and services. Therefore, companies must create a supply chain that is firstly safe (reducing the likelihood or reducing the impact of accidents) and, secondly, flexible (adaptability, accountability, and recovery during incident) to minimize the total effect of events that cause disruption in the supply chain. But recent studies show that only 5 to 25 percent of the top 500 companies in the Fortune magazine formally prepare themselves for serious crises and disruptions, and less than 20 percent of companies review their own supply network annually. This weakness in planning is while industrial statistics indicate an increase in disruptions for various natural and human causes [31]. The first major challenge in disruption management is understanding the disruption. Some of the disruptions that occur in supply chain activities may be the result of accidental events. This makes it difficult to recognize that we are faced with a systematic issue. The second challenge is to identify the cause of the disruption. Disruption in supply chain activities occur due to various reasons. Most of them are related to external factors. In addition, many products are made up of a number of different parts that many suppliers are involved in. Understanding the root of a disruption requires the identification of active companies in the supply chain. In many cases, finding the cause is the only way to make it clear that there is a problem. These challenges delay the detection of the problem and cause more quandary in the event of disruption, resulting in increased damage and costs [3]. Many organizations use statistical process control to determine the upper and lower limit of the process and the mean for alerting before the disruption occurs. Viewing the process control chart in identifying unusual trends can help organizations recognize the conditions that the process is out of control [57].

It provides a model for management after occurring disruption that includes exploration and recovery process. After the recovery phase, an overall performance evaluation is carried out and eventually, lessons are learned to avoid

repeating similar events in the future [9].

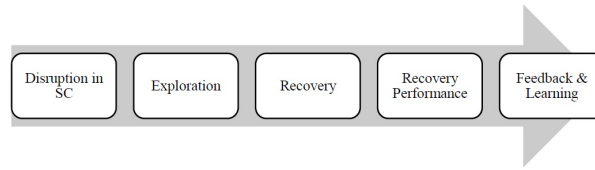


Figure 5: Disruption Management Processes [9]

1. In the first stage, a severe disruption in the supply chain has been referred to. At this stage, attention is needed to some cases. First, determining places where disruption occurs and are affected. Second, the cause and root of the disruption must be determined. Third, time period that affects the supply chain performance disruption must be paid attention. Finally, estimating the severity of the disruption is essential [57].
2. Exploration, the next step in Figure 5. Understanding the disruption and speed of its discovery is very important.
3. The third stage is recovery and improvement. In fact, according to the type of disruption, the company should decide on its design and strategy to deal with the situation. Should I use precautionary storage? Or use the alternatives for transportation?
4. In the fourth stage, attention should be paid to the company's performance in dealing with the disruption. Is the company's recovery speed of disruption appropriate? What is the cost of the disruption?
5. The last step is to learn the company from the incident. What lessons can be learned from disruptions and how can companies take advantage of them to prevent similar incidents in the future?

Models, parameters and decision variables of the model Here, first the proposed mathematical model and then an explanation about its characteristics are presented. This model has five indices of suppliers (i), wholesalers (j), retailers (k), periods (t) and goods (p). Model variables include the following: $ypijt$: the amount of product p that is shipped from supplier i to wholesaler j at the beginning of period t . $upkjt$: the amount of product p that is shipped from wholesaler j to retailer k at the beginning of period t . $vpikt$: quantity of product p shipped from supplier i to retailer k at the beginning of period t . $Bpkt$: Retailer k 's shortage amount of product p in period t . $Inpkt$: additional quantity delivered of product p to retailer k in period t . $v'pkt$: variable of zero and one indicating the presence of shortage or surplus in the amount delivered from product p to retailer k in period t . The model parameters also include the following: $aipj$: delivery time of product p from supplier i to wholesaler j . $fikp$: delivery time of product p from supplier i to retailer k . $Spit$: production capacity of product p by supplier i in period t . $dpkt$: the amount of demand for product p in retail k at the beginning of period t . cp : the cost of transporting a unit of goods p per unit of distance. $cupi$: purchase price of each unit of product p from supplier i . $blpkt$: the maximum allowed shortage of product p in the warehouse of retailer k in period t . mij : distance between supplier i and wholesaler j . nik : distance between supplier i and retailer k . ojk : distance between wholesaler j and retailer k . hpj : the cost of keeping each unit of product p in the warehouse of wholesaler j in each period. $h'pk$: the cost of keeping each unit of product p in the warehouse of retailer k in each period. Qpj : Storage capacity of wholesaler j for product p in period t . $Q'pkt$: storage capacity of retailer k for product p in period t . $Cajt$: the capacity to receive goods in the warehouse of the wholesaler j in the period t . $Ca'kt$: the capacity to receive goods in the warehouse of retailer k in period t . 2-3- Proposed mathematical model Based on the above parameters, the following two-objective model is presented for the problem:

3 Applied research

Ghesmati et al. in their research presented a fuzzy-probable planning model for the design of a sustainable supply chain network. This research presents a new fuzzy-probable planning model for designing a multi-stage supply chain network that simultaneously addresses these two important issues. First, a robust pessimistic approach was used to sustainable designing of a model with two types of vulnerable and invulnerable facility against occurring probable disruptions, and then a sustainable fuzzy model was developed to deal with the business's uncertainties. Flexibility in customer constraints (s) and determining the optimal level of this limitation (s) is also studied in the mentioned

	Type 1	Type 2	Type 3	Type 4
Q	[800,1300]	[400,800]	[600,1600]	[500,700]
Q'	[100,200]	[150,400]	[100,200]	[100,200]
h	[500,1500]	[500,1500]	[500,1500]	[100,300]
h'	[500,1500]	[500,1500]	[500,1500]	[100,250]
cu	[1000,5000]	[1000,5000]	[1000,5000]	[100,600]
c	[50,100]	[50,100]	[50,100]	[50,100]
m	[50,500]	[200,1000]	[50,550]	[200,450]
n	[500,1500]	[500,1500]	[50,550]	[500,700]
o	[200,1000]	[50,500]	[50,550]	[200,450]
a	[1,3]	[1,3]	[1,3]	[1,3]
f	[1,3]	[1,3]	[1,3]	[1,3]
d	[50,100]	[50,100]	[20,50]	[50,100]
S	$[800,800+240*K/I]$	$[2000,2000+240*K/I]$	$[1000,1000+240*K/I]$	$[400,400+160*K/I]$
ca	$[700,700+160*P*K/J]$	$[500,500+240*P*K/J]$	$[500,500+160*P*K/J]$	$[70,70+160*P*K/J]$
ca'	$[500,500+160*P]$	$[300,300+240*P]$	$[300,300+160*P]$	$[200,200+160*P]$
bl	[500,700]	[100,500]	[150,500]	[150,500]

model. In addition, in order to develop the concept of reliability in this issue and cover the important features of real-world issues, partial non-deterministic disruption and the limitation of expected time of the customer are considered in modeling the problem. Finally, in order to demonstrate the effectiveness and applicability of the developed model, a case study of an active company in the health system of Iran has been used [18].

Zagerdi and Davarzani in their research determined the factors influencing the severity and diversity of disruptions risks in the supply chain: Case study of automobile industry. For them, an important group of risks to supply chains is the group of disruption risks in the supply chain that results in the disconnection of the flow of materials in the chain and may result in the inability to deliver the final product of the chain. In this paper, the concept of disruption, which has not passed through much of its introduction in the supply chain literature, has been attempted to be studied in the automotive industry of Iran. Based on the nature and essence of the research question, the experimental path is chosen for this research. In the experimental way, the research is exploratory and its nature is making theory and the chosen approach to theorizing the development of the theory and method of research is case study in the automotive industry. Therefore, with a thorough study of automotive industry, the risks in this area are identified and at the end, a model for factors influencing the severity and frequency of supply chain disruptions and their relationship is presented. The present study is qualitative and lacks a mathematical model [79].

Rabbani et al. (2015) in a research designed a multi-objective supply chain considering the risk of disruption of facilities, supply and demand in the uncertainty condition of economic parameters. In this paper, the design of supply chain network is modeled in terms of multi-objective fuzzy integer math programming, which aims to maximize the present net value of revenue, minimize delays in receiving product by customer, and maximize the reliability of suppliers, considering the risk of demand, supply and disruption, that an interactive opportunity planning approach has been used to solve the multi-objective mathematical model. In order to ensure a high level of supply chain performance in the event of a disruption, a stability index is used using a scenario-based modeling approach. Also, due to lack of information, some economic parameters such as tax rate and inflation rate are considered as fuzzy in the presented model. Due to the complexity of the proposed model, a genetic algorithm is used to solve large-scale problems. In the end, the performance and efficiency of the proposed model and method are examined in numerical examples [61].

John Nessari et al. in a study investigated the identification and prioritization of supply chain disruptions using the combined PROMETHEEIII and fuzzy ANP (case study: Isfahan Steel Alloy Plant). In this study, a hybrid method of fuzzy promethee and fuzzy ANP has been used to prioritize disorders. Also new and suitable criteria for assessing disruptions are also considered for the first time in this research. The results of this study indicate that disruption in raw material shortages, disruption in packaging materials in terms of safety and health, problems in designing the website of the inquiry, increasing labor costs and supply planning disruptions are among the most important supply chain disruptions in the steel alloy plant of Isfahan [30].

Studies of Ivanov et al. [28] show that poor management of disruption can have an adverse effect on the company's reputation, and the market mentality changes to the company's brand and detriment the customer relationship. Instead, the proper administration of such events will lead to good opportunities for companies.

Loh and Van Thai in a study investigated the comprehensive assessment of disruption fuzzy and threats in the supply chain with an approach of inspecting the transportation network. In this study, they examined the components of the supply chain network and the probability of occurring incident in each part of this chain. The data used in the

research were gathered from the activists in the supply chain. Using interviews with each of these activists, the risks and threats that caused disruption in the supply chain were identified. Then the required data was collected using a set of words that indicate ambiguity and fuzzy. Finally, a fuzzy math model was designed to reduce the impact of these disruptions. The results showed that incidents created for transportation terminals, lack of equipment and facilities and disruption in information networks have the greatest impact on increasing supply chain disruption [41].

Rajagopal et al. [62] also examined the impact of risk reduction strategies (such as changing strategy from one supplier to several suppliers) on supply chain performance at the time of the disruption.

Kamalahmadi and Mellatparast in a study evaluated strategies of reducing the effects of disruption in the supply chain. In this paper, they designed three scenarios to reduce the impact of disruption in the supply chain including unpredicted inventories (inventory of confidence storage surplus on system requirements), spare suppliers (suppliers that the system currently does not provide materials from them but are identified in the system to refer to them as needed) and the third scenario is also the supported suppliers that, under any circumstances, the system continues to interact with them and has a special relationship with them. The results of the research show that all three scenarios reduce risks and costs compared to the general model of supply chain, but the selection of support suppliers in the supply chain can be more effective than other scenarios [32].

Behzadi et al. in a study investigated the sustainability and resilience of the supply chain at the time of disruption in the agricultural business models. They believe that the supply chain of businesses related to agricultural industry due to natural and seasonal incidents and, on the other hand, the corruption of materials and products, are likely to be disturbed than other industries, and planning to reduce the impact of this disruption and increase the stability and resilience of supply chain is essential. Therefore, they have provided a probable two-stage model in this research that in one stage the model of material and product corruptions were studied that the time of this event should be optimized and, on the other hand, the supply chain risk in the event of a disruption should be decreased. Designed model for supply chain was the Kiwi fruit. The results showed that the combination of resilient and sustainable strategies in the supply chain is effective in reducing the risk of occurring disruption in the supply chain [3].

Paul et al. were among the researchers who studied the origin of disruptions in the supply chain. They attribute the events to two general sources outside the supply chain and inside it [57].

Sawik states that one of the ways to prevent excessive reduction of inventory storage and achievement of an optimum inventory level is that the expected cost of inventory reduction is included in the total cost equation and is summed with other costs. But predicting future states and estimating different costs requires considerable resources to collect relevant data that make it difficult to implement [67].

The following tables provide a summary of the research carried out on the subject under study. These studies have been carried out over the past years in areas related to uncertainty, risk, disruption and management practices.

In Table 5, the classification of past research has been presented based on the types of disruptions that are considered in most studies, and in Table 6, the overall analysis of the studied articles and the status of the present research is presented in order to expand and complete the previous research.

Table 5: List of studied disruptions in previous research

	Disruption	References	
Company level	Breakdown of production facilities	[43, 56, 57]	
	Qualitative problems in the final product	[13, 28, 31, 43, 60]	
	Information system failures	[16, 33, 51]	
	Human resource problems (such as strike)	[46, 71]	
Network level	Demand side	Distribution network failure [8, 24, 58, 71] Demand fluctuations [7, 26, 56, 67]	
	Supplier side	Quality problems of raw materials [7, 28, 55] Supplier delay [7, 24, 52, 55] supplier Liquidation [8, 53, 70]	
		Transportation	Liquidation of the transportation company [39, 71] Delay in transportation [66, 78] Disruption of the port [71]
			Environment

Table 6: Analysis of subject literature

Researcher/ year	Type of disruption study					Research method				
	Risk management	Exploring disruption	System recovery after disruption	Learning from disruption	Conceptual study	Qualitative			Quantitative	
						Survey and interview	Case study	Experimental study	simulation	modeling
[5]	*	*					*			
[8]	*					*	*			
[36]	*					*	*			*
[39]	*					*	*			
[43]	*					*				
[63]	*									*
[65]	*				*		*			
[68]	*					*				
[73]	*				*					*
[77]	*									*
[14]	*				*					
[26]	*									*
[34]	*				*					
[44]	*					*	*			
[49]	*				*		*			
[50]	*					*	*			
[71]	*				*			*		
[13]	*		*					*		
[38]	*					*				*
[55]	*									*
[60]	*	*	*	*	*		*			
[64]	*						*			*
[66]	*					*				
[78]	*					*				
			*							*
[24]			*							*
[24]			*							*
[56]			*							*
[56]			*							*
[56]			*							*
[56]			*							*
[24]			*							*
[11]			*							*
[56]			*							*
[57]			*							*
[54]	*								*	
[28]			*	*						*
[51]	*		*							*
[33]	*	*								*
[32]			*							*
[57]	*		*							*
[9]			*							*
[52]			*	*						*
[31]			*				*			*
[67]			*							*
[58]	*		*							*
[67]				*						
[2]			*		*		*			
[59]		*		*						
[21]	*			*						
[75]		*					*			
							*			*
[48]							*		*	*
[76]			*		*			*		
[25]		*		*						*

4 Conclusion

In this research, the concepts, theories and models about disruption in supply chain and its recovery were investigated. We tried to survey related sources. Then, the applied researches were investigated and the methods and techniques used in these papers were also examined and presented in a table comparatively. Finally we achieve to a collection of performed researches from theoretical and applied viewpoint for researchers who will tend to research in the future in the field of supply chain disruption and its recovery.

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