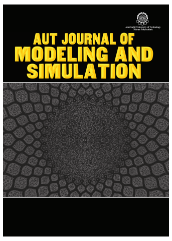


AUT Journal of Modeling and Simulation

AUT J. Model. Simul., 49(2)(2017)181-186
DOI: 10.22060/miscj.2017.11487.4943

# Developing a Model for Measuring Severity of Effects Caused by Interconnected Units in Electronic Supply Chains

A. Kazemi* and L. Ahmadpour

Faculty of Industrial and Mechanical Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran

**ABSTRACT:** For many electronic supply chain networks in the world that can comprise hundreds of companies with several tiers of suppliers and intermediate customers, there are numerous presenting risks to consider. In the electronic supply chain, the situation are even worse, for the characteristics of this supply chain: excessive lean management, global sourcing and the rather more uncertain market demand. Electronic companies are forced to manage their supply chains effectively to increase efficiency and reactivity. This paper proposes a mathematical model for estimating the severity of interactions between supply chain's units and how their affect on the entire supply chain. Based on the model, scholars can model supply chains easily with considering interconnected units. Basic characteristics of supply chains are considered in the model. The units, which are used to simulate the members of supply chains, produce appropriate products by intelligent choices. The relationships on units are connected by their activities ; then, the proposed model is applied to an experimental example. The model yields its numerical parameters and responses by means of Lingo software.

**Review History:**

Received: 19 March 2016
Revised: 27 February 2017
Accepted: 27 February 2017
Available Online: 12 March 2017

**Keywords:**

Supply chain
Interconnected units
Propagated effect

## 1- Introduction

The concept of supply chain management (SCM), which firstly appeared in the early 1990s, has recently attracted much interest as the possibility of providing an integrated SCM can decrease the propagation of unexpected/undesirable events throughout the network and markedly improve the profitability of all the parties involved. A SCM can be described as a network of business entities (i.e., suppliers, manufacturers, distributors, and retailers) who work together with an effort to acquire raw materials, transform these raw materials into intermediate and finished products, and distribute the final products to retailers (Mele, 2007). Supply chain management (SCM) aims to coordinate plants with their suppliers and customers such that they can be managed as a single entity. Besides, it is to coordinate all input/output flows (of materials, information, and funds) such that products are produced and distributed in the right quantities, to the right locations, and at the right time (Simchi et al., 2003).

Traditionally, companies produce products and stock them as an inventory until they are sold. This strategy is so-called MTS (make-to-stock). However, some products cannot be produced with MTS strategy. For many organizations, the products' designs due to different orders is not the same. All organizations must produce different products to satisfy different demands. These organizations have designed their production systems to produce a product only after it is ordered. Thus, many companies have shifted to "pull", holding no inventory at all and producing only after order. This kind of supply chain, that former companies used follow, is referred to as MTO (make-to-order) supply chain. Meanwhile, there can be various types of changes to supply chains that may require adaptations. New trading partners and new products are the main causes of structural changes. Structural changes alter the topology of supply chains (Li et al., 2013). A complex human-machine system is designed as being composed of humans, machines, and the interactions between them, which could properly be defined by a system model. The role of a system model is essential in thinking about how systems can malfunction; in other words, in thinking about accidents. A basic distinction is whether accidents are due to specific malfunctions or "error mechanisms", or whether they are due to unfortunate coincidences. Over the years, the efforts to explain and predict accidents have considered a number of stereotypical ways of accounting for how events may take place (Marhavillas et al., 2011). In view of this, electronic supply chains were emerged as a key factor to enhance the efficiency of classic supply chains to promote their industrial performance and remove their complexity.

Recently, Internet-based technologies such as web services have provided us with additional opportunity to deal with complex supply chains. For instance, information technology provides an infrastructure for integrating the internal and external activities of a company such that it connects the geographically distant supply chain members together to form a network system. In the same vein, electronic markets have eliminated the geographical obstacles and provided opportunities for the meaningful investigation of the buyer-supplier relationships in supply chains. Hence, the traditional linear supply chains are converted into an e-Supply Networks (e-SN) in which collaboration among partners, real-time decision making, and automation of conventional activities are improved (Mohebbi and Li, 2012). Thus, to propose the model, a supply chain network is needed. Before presenting the details of the model, we describe the nature of IT security within the electronic supply chain in more depth.

The corresponding author; Email: abkaazemi@qiau.ac.ir

The rest of the paper is organized as follows. Firstly, the definition of Supply chain IT security will be explained. In section 2, literature review is presented. In section 3, the proposed conceptual model of the supply chain is addressed. The proposed mathematical model and results are presented in section 4. The conclusion part and directions for the future studies appear in section 5.

### 1- 1- Supply chain IT security

IT security incidents occur when a threat directed against an asset causes a compromise in one (or more) of three areas, namely Confidentiality, Integrity, or Availability. Examples of threats/incidents involve malicious code infection, denial-of-service attacks, unauthorized system access or modification, network outage, insider abuse of access, data compromise, insider misuse of resources, lost or stolen physical resources, errors and omissions, and social engineering. These examples includes systems and applications, networks, end-user systems, and offline media and devices. Incidents may be proven very costly within a supply chain, such as malcode bringing down an ERP system and disrupting production, hacking into an EDI or payment system causing missed payments or payment delays, or social engineering (deceit) allowing an outsider to represent as a partner in order to access sensitive customer data.

A simple example (see Fig. 1) shows how the threats attack assets to generate a risk. The expected threat rates and associated costs of a successful attack for each of the firms in our simple supply chain are the same. We acknowledge that this is an unlikely scenario since these factors are likely to vary substantially from firm to firm; however, the consistency makes the example easier to follow. The expected rate of each threat against each organization is assumed to be 400 a year. Further, threat 1 attacks asset 1, threat 2 attacks asset 2, and threat 3 threatens assets 1 and 3. If the cost of each attack on each asset for either firm is $2K, then the attacks on asset 1 generate a risk to the upstream organization of $1.6M. For a total risk of $3.2M, asset 2 generates a risk of $800K, and asset 3 a risk of $800K. Now because the upstream and downstream firms are sharing data, we postulate an infection path leading to a disruption. We assume that the unmitigated threat 1 from the upstream company joins threat 3 of the downstream company. Thus, while the upstream firm was faced with 400 threat 3s per year, the downstream's total risks add up to 800 per year. While the downstream organization still faces 400 attacks against asset 2 per year, it will now face 1200 attacks against asset 1 per year and 800 against asset 3 per year. This will bring the risk to the downstream firm to $4.8M. We should also address that while this simplified example focuses on the direct dollar impacts of the threats, there can additionally be significant indirect effects as this disruption propagates shutting down processes, which could ultimately cascade through the entire chain.

Countermeasures or controls help mitigate threats and asset loss. The National Institute of Standards and Technology classifies information security controls (NIST 800-53) into three categories, including Technical, Operational, and Management Controls (Stoneburner et al., 2002). Information security in a SCM requires more than just technical solutions such as firewalls and secure facilities. Management and operational policies can become critical as well, particularly when the risk must be reduced across organizational boundaries. Some common controls and countermeasures in the latter two categories include employee hiring/termination practices, periodic employee training and awareness initiatives, help desk/IT support training, periodic testing and review procedures, accessible documentation, monitoring and logging procedures, network auditing, business continuity/incident response procedures, backup and recovery procedures, and protection for all sensitive informational assets. In their survey of the state of the art of security management, Baker and Wallace (2007) found that high implementation and maintenance costs of security controls are increasing pressure on managers to distinguish between critical controls and those that are less critical. They determined the optimal level at which to implement individual controls is a delicate balance of risk reduction and cost efficiency. This problem is described within a supply chain, where a single organization can cause disruption of the whole chain. As pointed out by Craighead et al. (2007), "Because complexity is a reflection of the nodes and flows within a given supply chain and, therefore, interdependencies on these nodes, a supply chain management disruption at any node can potentially propagate, with the effects of the initial disruption being passed from one node to another connected node and so on." Because of the potential of propagating disruptive incidents from one partner to another, it is important to determine who will pay for the countermeasures, and who will pay for the cost of incidents. More generally, it is essential to ascertain how partners can work together to reduce individual and global risk as well as the associated costs (Jason et al., 2009).

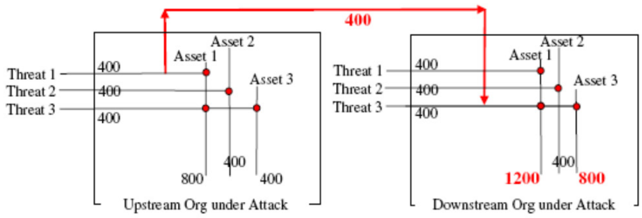


**Fig. 1. Showing how three threats generate upstream and downstream risk (Jason et al., 2009)**

## 2- Literature review

A lot of attempts have been made to model and optimize the SC behavior, developing a big number of deterministic (Timpe and Kallrath, 2000) and stochastic derived approaches. Since the nature of most SCs is characterized by numerous sources of technical and commercial uncertainties, consideration of all model parameters, such as cost coefficients, production rates, demand, and so forth, as being known is not realistic. Several works deal with uncertainty in SCM at different levels. One part of the effort has been oriented with control theory in which the uncertainty is modeled as disturbances arriving at a dynamic model of the system.

The work by Bose and Pekny (2000) looks for the inventory set points that ensure a desired customer service level with a planning tool, and then track them with a model predictive control (MPC) approach. Similarly, Perea-L´opez et al. (2003) determine the optimal variables that maximize the profit of the system, by optimizing a multi-period mixed-integer linear programming (MILP) problem, and using a rolling horizon MPC approach so as to include the disturbance influence. All these approaches work at an operational level. Other approaches are able to cope with the uncertainty through fuzzy programming (Sakawa et al., 2001) at the strategic level. Their limitations are related to the simplicity of the production/distribution models usually used. A third group and the biggest one includes the statistical analysis-based methods in which it is assumed that the uncertain variable follows a particular probability distribution. On the other hand, the most popular model applied is the two-stage decision approach . Approaches differ primarily in the selection of the decision variables and the way in which the expected value term, which involves a multidimensional integral accounting for the probability distribution of the uncertain parameters, is computed. The difficulty of continuous distributions is eliminated by introducing discrete scenarios, or combinations of discrete samples of all uncertain parameters. (Cohen and Lee, 1989) have expressed alternative strategies to evaluate the integral term, by changing from cubature methods to sampling methods. Maranas and collaborators (Gupta and Maranas, 2000, 2003) convert stochastic features of the problem into a chance-constrained programming problem. Finally, a different approach at the strategic level is the work of Applequist et al. (2000), who present a method for evaluating SC projects with the capability to assess the integral values based upon polytope volumes.

Nagurney et al. (2005) developed a supply chain network model in which both physical and electronic transactions are allowed and in which supply-side risk, as well as demand side risk, are included in the formulation. The model consists of three tiers of decision-makers: the manufacturers, the distributors, and the retailers, with the demands associated with the retail outlets being random. They investigated the optimizing behavior of the various decision-makers, with the manufacturers and the distributors being multi-criteria decision-makers and concerned with both profit maximization and risk minimization. Georgiadis and Besiou (2008) examined the impact of ecological motivation and technological innovations on the long-term behavior of a closed-loop supply chain with recycling activities. They adopted System Dynamics methodology applied to many environmental systems seeking long-term gains.

Assavapokee and Wongthatsanekorn (2012) proposed a solution methodology to design the infrastructure of the reverse production system by utilizing the mixed-integer linear programming (MILP) model. A case study for designing the reverse production system in the state of Texas is also presented. Li et al. (2015) developed a set of mathematical models to examine and compare different pricing and launch strategies of electronic books (e-books) under two types of copyright arrangements, namely the royalty and buyout arrangements. They conducted a sensitivity analysis to assess how various market structure parameters influence the publisher's pricing options in different copyright policies, launch modes, and channels of distribution. Wang et al. (2017) considered a contract design problem for a manufacturer by entrusting the collection of waste electrical and electronic equipment (WEEE) to a retailer. They developed an information screening contract for the manufacturer to obtain the information of collection effort level, and the optimal decision with several properties of contract parameters is derived.

The literature reveals that the most extensively studied source of uncertainty has been demanded. The emphasis on the incorporating and the integrating of demand uncertainty into the planning decisions obeys the fact that this is one of the most important factors that could affect the capacity of a company to meet the customer demand. However, there are many other factors that could seriously affect this capacity. Hence, in the present work, not only demand delays is considered but also processing information along the frame of web transactions in a supply chain is important.

## 3- Proposed conceptual model of supply chain

To acquire a competitive advantage in the expanding market, manufacturing enterprises should be able to manage their supply chains as efficient as possible. It is now becoming popular to model supply chains as network systems and use discrete event simulation to learn more about their behaviors or investigate the implications of alternative configurations. In this regard, interactions and interconnected relations under web networks have gained major attractions which are based on web transactions (Stoneburner et al., 2002).

The transaction is a sequence of URLs combined into one complete process. Typical web transactions are when a customer logs in a member website, makes a purchase on a shopping site, fills in and submits a web form and performs other interactions with a website and web application. In other words, as we explore online supply chains, online transactions are our major preference. Online transaction processing (OLTP) is a mode of processing characterized by short transactions recording business events which normally requires high availability and consistent, short response times. This category of applications requires that a request for a service be answered within a predictable period that approaches "real time." Unlike traditional mainframe data processing, in which data is processed only at specific times, transaction processing puts terminals online, where they can update the database instantly to reflect changes as they occur. In other words, the data processing models the actual business in a real time, and a transaction transforms this model from one business state to another. Tasks such as making reservations, scheduling, and inventory control are especially complex; all the information must be real-time. Supply chain and IT leaders can transform their supply chain planning by using OLTP to understand the maturity and viability of various supply chain planning technologies, as well as some of the underlying technologies that will transform the way by which planning can be accomplished (Fernando et al., 2007).

Based on the aforementioned conceptual model of electronic supply chains, a specific electronic supply chain framework is designed. It is simplified to display the information transfer processes inside the selling service under web transaction and on the boundaries of the customer, manufacturer. As a customer requests a driven supply chain system , the information flow starts from the customer incoming orders. Fig. 2, provides the architecture of electronic supply chain framework. Our approach extends the ideas of several previous works in order to apply a mathematical model which is introduced later.

The proposed electronic supply chain framework is a customer centric supply chain that comprises three categories of units: (1) order unit responsible for dealing with customer information management, (2) demand analyzer unit that is responsible for analyzing the order, (3) financial unit responsible for dealing with financial affairs such as pricing and lead time. To utilize the customer information in a

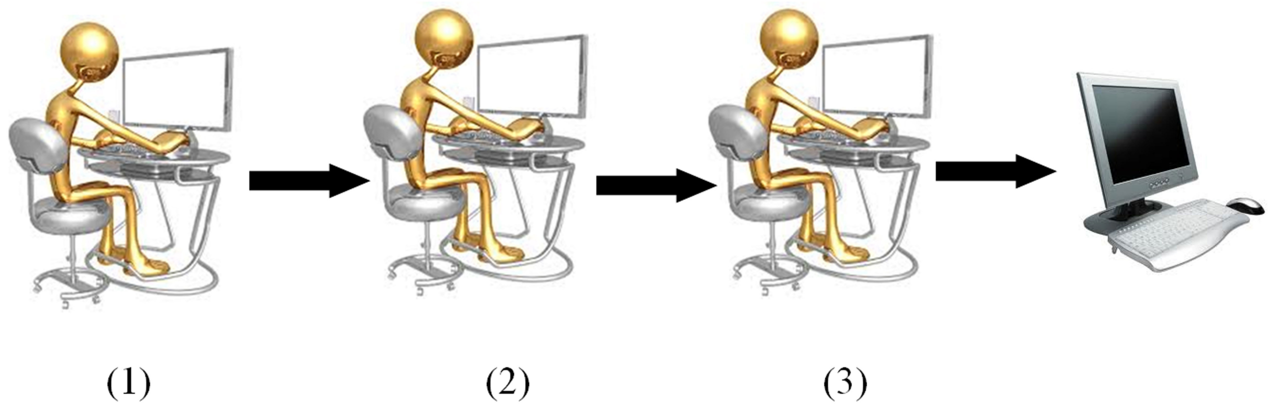


**Fig. 2. The architecture of electronic supply chain framework**

meaningful way to produce what the customer needs at the right time all interactions are under the web transactions which will be considered in a mathematical model.

## 4- Proposed mathematical model and results

The linear model is studied in this section by means of different occurrence scenarios to calculate severity and is presented in mathematical formulation afterward. The proposed model corresponds to the supply chain in Figure 2. Furthermore, different uncertainties have been taken into consideration, thus, the calculated severity of interactions is converted to an interval variable. The modeling process includes four steps:
Step 1. Identify the concept of the process of the supply chain.
Step 2. Illustrate failure scenarios in supply chain management. Mapping all failure scenarios are not an easy task, as failures are not homogeneous and different consequences are the results of different activities. Furthermore, different scenarios occur in different periods which cannot be recognized. By considering different failure events in a scenario, the tree of failures can be traced. Fig. 3 shows a failure mode in a supply chain.
$S_1$ is the first scenario showing that there is a failure mode

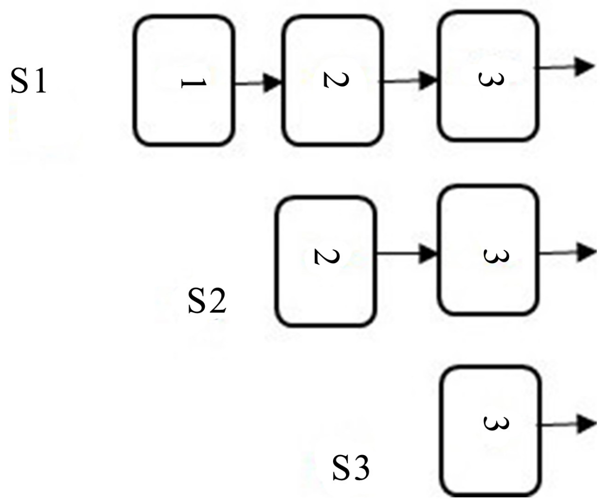


**Fig. 3. Tree of failure process in a supply chain**

starting from unit 1, then unit 2 and 3 may/may not work properly.
$S_2$ is the second scenario showing that there is a failure mode starting from unit 2, then unit 3 may/may not work properly.
$S_3$ is the third scenario showing that there is a failure mode in unit 3, then units 1 and 2 are working properly, but we never consider $S_3$ in modeling activities, since more than one unit is needed for estimating propagated effects.
Step 3. Calculate occurrence probability of a scenario by means of probability rules in relation (1):
Step 4. All parameters, decision variables, and scenarios are

$$a_z = P(failure\ in\ scenario\ S_1) = P(failure\ in\ 1 \cup failure\ in\ 2 \cup failure\ in\ 3) \quad (1)$$

$$a_z = 1 - P(\overline{failure\ in\ 1} \cap \overline{failure\ in\ 2} \cap \overline{failure\ in\ 3})$$

introduced here, as follows:
i index of subagents
j index of propagated effects
a set of failure probability of agents (ai denotes failure probability of unit i).
x set of subagents ($x \in \{0,1\}$, if x=0 then the subagent is out of order and will not be taken into account in the scenario).
z set of target agents ($z \in \{0,1\}$, if z=0 then the agent is out of order and will not be takeen into account in the scenario).
c set of effects ($c_{ij}$ denotes j-th propagated effect caused by i-th unit).
n active units in a scenario.
t set of transaction variables ($t_{ij}$ denotes the relative amount of transactions from unit i to unit j).
Thus, propagated effect (interaction severity) estimation modeling depends on how scenario occurs and is constructed as follows in relation (2):
Then, we apply the model to $S_1$ for instance and describe the

$$\max = \prod c_{ij} . x_i$$

$$\sum_i a_i x_i + \sum_{i,j} c_{ij} t_{ij} x_i \le a_z t_{ij} z \quad (2)$$

$$\sum_i x_i + z = n + 1$$

$$c_i \ge 0$$

solution methodology.
In $S_1$, there is a failure mode that starts in unit 1, then units 2

and 3 are affected by the failure. This scenario contains four failure modes as in the following:

1) Unit 1 has a failure but units 2 and 3 are working properly, then the failure of unit 1 propagates as an effect. It is calculated by means of the relation (2) and results in relation (3):

where failure in $x_1$ propagates to $x_2$ and $x_3$ and the effect

$$\begin{aligned} &\max = c_{11}x_2 \times c_{12}x_3, \\ &a_1x_1 + c_{11}t_{12}x_2 + c_{12}t_{23}x_3 \le a_z t_{3.} z, \\ &x_1 + x_2 + x_3 + z = 4, \\ &c_{11}, c_{12} \ge 0, \end{aligned} \tag{3}$$

is limited by $a_z$ (probability of the scenario), calculated by relation (1).

2) There is a failure mode in units 1 and 2, then unit 3 is working properly. Therefore, modeling process will consider propagated effect from units 1 and 2 in relation (4):

where failure in $x_1$ and $x_2$ propagates to $x_3$.

$$\begin{aligned} &\max = c_{11}x_2 \times c_{(1,2)2}x_3 \\ &a_1x_1 + a_2t_{12}c_{11}x_2 + c_{(1,2)2}t_{23}x_3 \le a_z t_{3.} z \\ &x_1 + x_2 + x_3 + z = 4 \\ &c_{11}, c_{(1,2)2} \ge 0 \end{aligned} \tag{4}$$

3) There are failure modes in units 1 and 3, then unit 2 is working properly. Propagated effects come from units 1 and 3 in relation (5):

4) There are failure modes in units 1, 2 and 3, then all units

$$\begin{aligned} &\max = c_{11}x_2 \times c_{(1,2)2}x_3 \\ &a_1x_1 + c_{11}t_{12}x_2 + a_3c_{(1,2)2}t_{23}x_3 \le a_z t_{3.} z \\ &x_1 + x_2 + x_3 + z = 4 \\ &c_{11}, c_{12} \ge 0 \end{aligned} \tag{5}$$

are responsible for the effects in relation (6):

In order to evaluate the possibility of modeling, a series of

$$\begin{aligned} &\max = c_{11}x_2 \times c_{(1,2)2}x_3 \\ &a_1x_1 + a_2c_{11}t_{12}x_2 + a_3c_{(1,2)2}t_{23}x_3 \le a_z t_{3.} z \\ &x_1 + x_2 + x_3 + z = 4 \\ &c_{11}, c_{(1,2)2} \ge 0 \end{aligned} \tag{6}$$

computational tests is run in this section. The required data have been obtained from expert teams that have designed the electronic supply chain network since specialists in this field are appropriate options to evaluate the reliability of supply chain. Table 1 demonstrates failure probability of all units and transaction variables:

The structure of model in the supply chain is as follows:

**Table 1. Failure probability of units and transaction rate obtained from expert teams**

| units | Failure probability | $a_z$ | $t_{ij}$ | Normalized tij |
|---|---|---|---|---|
| 1 | 0.12 | 0.3 | $t_{12}$=2KB | $t_{12}$=0.28 |
| 2 | 0.14 | 0.3 | $t_{23}$=1KB | $t_{23}$=0.14 |
| 3 | 0.07 | 0.3 | $t_{3.}$=4 KB | $t_{3.}$=0.57 |

scenario $S_1$ is assumed and data are assigned in relation (3) as follows and a solution is provided by Lingo software:

And all information provided in Table 1 are assigned in

$$\begin{aligned} &\max = c_{11}x_2 \times c_{12}x_3 \\ &0.07x_1 + c_{11}(0.28)x_2 + c_{12}(0.14)x_3 \le 0.3(0.57)z \\ &x_1 + x_2 + x_3 + z = 4 \\ &c_{11}, c_{12} \ge 0 \end{aligned}$$

relations (3) - (6). Results gained from Lingo software are demonstrated in Table 2:

Since in some models two separate interactions are addressed,

**Table 2. Propagated effects gained from Lingo**

| Supply chain | Scenario | Propagated effect |
|---|---|---|
| A | $S_1$ | (0.36,1.28) |
| | $S_2$ | (0.71,5.9) |

it is preferred to consider the propagated effect as an interval scale. In other words, the deterministic model will lead to better responses, without loss of modality, if all answers are adapted to interval data.

## 5- Conclusion and discussion

The industrial world as we know it today has become a global network of demand and supply nodes, interlinked through interacting logistics systems. The Internet and related 'e-services' have opened up the demand and supply markets of the world so that the 'next-door' marketplace could as well be the 'next-continent' marketplace. These systems are complex entities with multiple physical and virtual relationships and multiple internal and external interfaces which are the major preference in research arias. Judging based on the growing number of papers in research journals and various stories in professional magazines, supply chain risk management is a field of growing importance. Thus, estimating and managing the risk is critical for today's supply chains. In this paper, we focused on the quantitative method of risk measurement, in particular estimating interactions or effects of interconnected units and the severity of failures in supply chain with considering the transactions.

In addition, a linear model was presented to estimate the effect which is understandable with mathematical relation and solvable with Lingo software. As supply chains shifted to e-services, some other variables such as timeline and speed of product line can be applied in this model which can be considered as further studies.

## References

[1] G. Applequist, J. Pekny, G. Reklaitis, Risk and uncertainty in managing chemical manufacturing supply chains, Computers & Chemical Engineering, 24(9-10) (2000) 2211-2222.

[2] T. Assavapokee, W. Wongthatsanekorn, Reverse production system infrastructure design for electronic products in the state of Texas, Computers & Industrial Engineering, 62(1) (2012) 129-140.

[3] W.H. Baker, L. Wallace, Is information security under control?: Investigating quality in information security management, IEEE Security & Privacy, 5(1) (2007).

[4] S. Bose, J. Pekny, A model predictive framework for planning and scheduling problems: a case study of consumer goods supply chain, Computers & Chemical Engineering, 24(2-7) (2000) 329-335.

[5] M.A. Cohen, H.L. Lee, Resource deployment analysis of global manufacturing and distribution networks, Journal of manufacturing and operations management, 2(2) (1989) 81-104.

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

[7] F.D. Mele, G. Guillén, A. Espuna, L. Puigjaner, An agent-based approach for supply chain retrofitting under uncertainty, Computers & chemical engineering, 31(5-6) (2007) 722-735.

[8] P. Georgiadis, M. Besiou, Sustainability in electrical and electronic equipment closed-loop supply chains: a system dynamics approach, Journal of Cleaner Production, 16(15) (2008) 1665-1678.

[9] A. Gupta, C.D. Maranas, A two-stage modeling and solution framework for multisite midterm planning under demand uncertainty, Industrial & Engineering Chemistry Research, 39(10) (2000) 3799-3813.

[10] A. Gupta, C.D. Maranas, Managing demand uncertainty in supply chain planning, Computers & chemical engineering, 27(8-9) (2003) 1219-1227.

[11] J.K. Deane, C.T. Ragsdale, T.R. Rakes, L.P. Rees, Managing supply chain risk and disruption from IT security incidents, Operations Management Research, 2(1-4) (2009) 4.

[12] J. Li, F.T. Chan, An agent-based model of supply chains with dynamic structures, Applied Mathematical Modelling, 37(7) (2013) 5403-5413.

[13] Y. Li, Z. Lin, L. Xu, A. Swain, "Do the electronic books reinforce the dynamics of book supply chain market?"–A theoretical analysis, European Journal of Operational Research, 245(2) (2015) 591-601.

[14] [14] P.-K. Marhavilas, D. Koulouriotis, V. Gemeni, Risk analysis and assessment methodologies in the work sites: on a review, classification and comparative study of the scientific literature of the period 2000–2009, Journal of Loss Prevention in the Process Industries, 24(5) (2011) 477-523.

[15] A. Mele, Asymmetric stock market volatility and the cyclical behavior of expected returns, Journal of financial economics, 86(2) (2007) 446-478.

[16] S. Mohebbi, X. Li, Designing intelligent agents to support long-term partnership in two echelon e-Supply Networks, Expert Systems with Applications, 39(18) (2012) 13501-13508.

[17] A. Nagurney, J. Cruz, J. Dong, D. Zhang, Supply chain networks, electronic commerce, and supply side and demand side risk, European journal of operational research, 164(1) (2005) 120-142.

[18] E. Perea-Lopez, B.E. Ydstie, I.E. Grossmann, A model predictive control strategy for supply chain optimization, Computers & Chemical Engineering, 27(8-9) (2003) 1201-1218.

[19] M. Sakawa, I. Nishizaki, Y. Uemura, Fuzzy programming and profit and cost allocation for a production and transportation problem, European Journal of Operational Research, 131(1) (2001) 1-15.

[20] D. Simchi-Levi, E. Simchi-Levi, P. Kaminsky, Designing and managing the supply chain: Concepts, strategies, and cases, McGraw-Hill New York, 1999.

[21] G. Stoneburner, A.Y. Goguen, A. Feringa, Sp 800-30. risk management guide for information technology systems, (2002).

[22] C.H. Timpe, J. Kallrath, Optimal planning in large multi-site production networks, European Journal of Operational Research, 126(2) (2000) 422-435.

[23] W. Wang, Y. Zhang, Y. Li, X. Zhao, M. Cheng, Closed-loop supply chains under reward-penalty mechanism: Retailer collection and asymmetric information, Journal of cleaner production, 142 (2017) 3938-3955.

Please cite this article using:

A. Kazemi and L. Ahmadpour, Developing a Model for Measuring Severity of Effects Caused by Interconnected Units in Electronic Supply Chains, *AUT J. Model. Simul., 49(2)(2017)181-186*.

DOI: 10.22060/miscj.2017.11487.4943