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Reliability of the Supply Chain: Method of Self-Assessment as a First Step to Building Resilient Systems

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Abstract. Measure the reliability of a supply chain is an important step to promote the construction of more resilient chains. The resilience is necessary to guaranty the efficient and secure global movement of goods. This paper proposes an instrument to analysis and evaluates the reliability of a system. Also compare scenarios of reliability between a basic supply chains versus complex systems. Finally present useful conclusion to the construction of resilient and robust supply chain.

Keywords: Resilient supply chain, reliability evaluation, risk analysis.

1. Introduction

Currently, the most important economies in the world are looking for promoting the timely, efficient flow of legitimate commerce while protecting and securing the supply chain from exploitation, and reducing its vulnerability to disruption [1, 2, 3].

In this regard, The White House recently released The National Strategy for Global Supply Chain Security (NSGSCS). This document recognizes that, the development of nations depend upon the efficient and secure transit of goods through the global system of supply chains. In addition, it exposes the need to assess and understand the effects of disruptions mainly generated for three factors: i) natural disasters; ii) criminal acts, and iii) terrorist acts [4]. However, despite the clear current interest in understanding the effects of the disruptions, some authors have identified that there is actually no clear consensus regarding the elements that should be analyzed to contribute to an effective management of the risk of disruptions in supply chains [2, 3, 5, 6]. In fact references as ([1, 3, 5, 6, 8]), demonstrate that the research area in the field of risk propagation in supply chains remains relatively unexplored. Under the challenge of linking security and efficiency as a single goal, the aim of this article is to present a methodology to measure the reliability of a supply chain system to a step to develop more resilient systems. Resilience refers to the ability of an organization to quickly go back to a functioning initial state after disturbance. [6]

The rest of the document is organized as follows. Section 2 presents a review of risk factors that currently threaten the supply chain, making a brief analysis of the different proposed methodologies to assess risks propagation in supply chains. Section 3 describes the model developed. In section 4, the results obtained through the evaluation of different decision scenarios will be discussed. Finally, section 5 presents the conclusions obtained and analyses regarding the proposed method.

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2. Background to Supply Chain Risk Management

As a result of unfortunate events occurred over the last decade in which global supply chains have been the target of disruptions, such as terrorist attacks, natural disasters, changes in behavior of the client and economic crisis among others; the interest to understand risk and how to deal with the effects of the disruptions in supply chains has arisen. In this way, important works have been oriented to the development of techniques for the identification of areas of vulnerability in the chain [8, 9, 5].

As supply chains develop operations in a greater number of international markets, these have become more complex, which is hindering the early detection of the disruptions, thereby delaying its prompt recovery and affecting its resilience ([10, 11, 12, 13, 5). However, even when decision-makers recognize that the impact of the disruptions can have devastating consequences throughout the supply chain, at global level, in most organizations, strategies to mitigate them are generally not properly developed or are not even initiated [14].

In fact, reference [13] presented a worrying statistic in which they estimated that only between 5 and 25 percent of the 500 world richest companies could handle a crisis by disruptions in the supply chain. This means that in the best of cases 75 % of the best companies are not prepared to handle security crisis and in the worst-case scenario 95% of them could not face a disruption in an appropriate way. This information is confirmed by the results of recent studies that claim that only 25 percent of the companies have a proactive approach to risk management [15].

Reference [16], have argued that the problem in risk management is that decision-makers are not clear on how to face and deal with disruptions. Reference [11] argues that the effects of the risk can be localized on a specific point or that they can propagate through a network, causing damage with global impacts in the supply chain. According to [5, 11], the basic problem for risk management lies in that this can manifest itself in many different ways, virtually affecting any link in the chain from the initial provider to the final customer. This feature is also identified by [12], who assure that the understanding of propagation in the supply chain is the prerequisite for an effective integration of supply chains.

In this sense, [8, 17, 18, 19] among others acknowledged researchers, argue that risk management should not focus on the specific nature of the disruption. They claim that those responsible for the chain cannot foresee every potential threat and much less determine how likely that threat could materialize. Therefore, they suggest that it is better to focus efforts to manage risk in assessing the impact generated by the disruptions in supply chain operations. They conclude that a wide variety of disruptive events including natural disasters and terrorist attacks, tend to have similar effects on the supply chain. On the other hand, according to [6, 12, 20] suggest analyzing if the effects of the disruptions have local influence or if they may propagate to other members of the chain. Reference [1], studied the effect of propagation and the influence of the cross of international borders. However, they identify the necessity of measure the reliability index as an important step to construct more resilient supply chains.

In this context, a method to measure the reliability of a supply chain system will be presented in the next chapter. It contributes to logistical knowledge within the framework of the NSGSCS' goals: i) promoting the safe goods movement and ii) building resilient supply chains.

3. Model description.

3.1. Model structure

As a result of the goal raised for our research and due to the variables of interest identified during the literature review, as well as during in the case study, the multiple relationships between the different steps were identified. Therefore, we took the decision to define two structures of supply chain, a basic structure and a complex structure. Consequently, the supply chain model was made of the following basic components: (a) component supplier; (b) manufacturer; (c) international border; (d) warehouse and (e) retail. (see figure 1). The customer demand flows from the lowest stage manufacturer) of the supply chain, to the upper stage of the chain (supplier of raw materials).

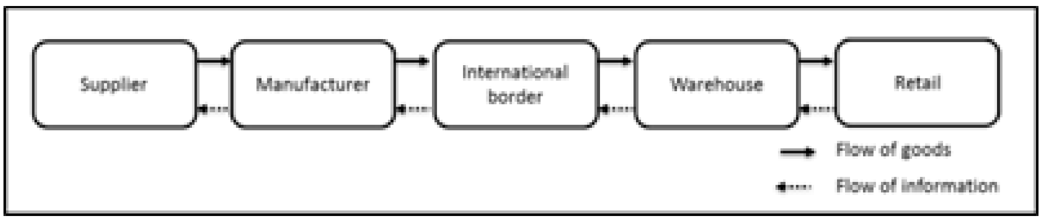

Figure 1. Basic structure of a supply chain.

The complexity of this traditional supply chain, increase because each member can participate in more than one supply chains at the same time. For that case we propose the use of the next configuration of a supply chain. (see Fig. 2).

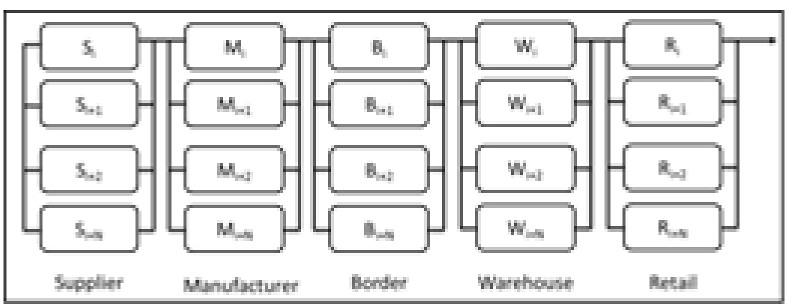

Figure 2. Complex structure of a supply chain.

In order to measure the reliability, reference [11], argue that basically exist two types of supply chain systems, i) parallel and ii) serial arrangement. (See fig. 3 and fig. 4).

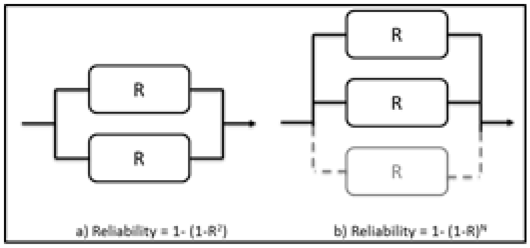

Figure 3 Reliability in parallel systems (adapted form [11])

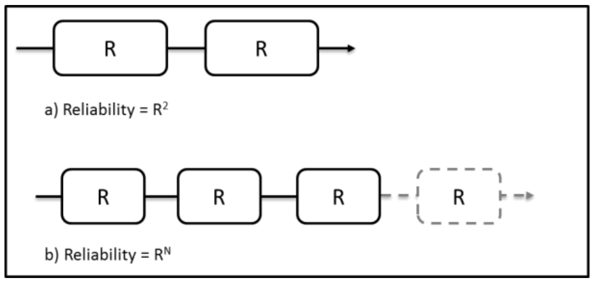

Figure 4 Reliability in series systems (adapted form [11])

For parallel systems, the proposed way of measure the reliability is:

$$R = 1- (1-R)^N \quad (1)$$

On the other case, when the systems is configured in serial way, the reliability is measure as

$$R= R^N \quad (2)$$

For the formulation propose the different elements that constitute the supply chain are named (E), total system reliability will be represented by (R), and the individual stage reliability are represented as: E_1= Supplier (Rs), E_2=Manufacturer (Rm), E_3=International border (Rb), E_4=Warehouse (Rw), E_5=Retailer (Rr). Also, $0 \leq R \leq 1$, if R=1 indicate a strong reliability and R=0 means a no reliability element.

Complex Supply chains, represent a parallel integration, and require the generalization of (1) and (2). That's because, even when stages are arranged in parallel, the link between the elements are presented in a serial way.

$$R = \prod_{i=1}^{E} [1 - \prod_{j=1}^{N} (1 - R_{ij})] \quad (3)$$

On the other hand, basics supply chains systems, suppose a serial integration of five elements, and only require the generalization of (2).

$$R = \prod_{i=1}^{N} R_i \quad (4)$$

The next section demonstrates the use of (3) and (4). For that, two different scenarios were evaluated.

4. Discussion of Results

Reference [11], expose, that a complex supply chain has a higher chance of disruption than a simple one. More complex chains have more members and more links and in this context more things to go wrong. In addition, the vulnerability of a supply chain does not depend just on the number of members but also on the way that they are arranged.

Some supply chains are integrated at different levels; some stages works in serial and in other cases stages are configured in parallel. In this paper show tow different generalizations of the supply chain that can help to the decision makers to measure the reliability of theirs systems.

For evaluate formulas (3) and (4), two different scenarios were developed, the first one, use a basic supply chain described by [1] and including a supplier, one manufacturer, one international border, one warehouse, and a retailer. (see fig. 5).

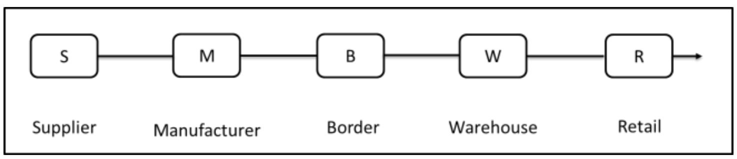

Figure 5 first scenario a serial supply chain system

In this case, the following reliability values were assigned to each element: Rs= 0.86, Rm=0.98, Rb= 0.98, Rw=0.91, Rr=0.98. Using (equation 4), we obtain:

$$R = \prod_{i=1}^{5} R_i = R_s \ x \ R_m \ x \ R_b \ xR_w \ x \ R_r = 0.86 \ x \ 0.98 \ x \ 0.98 \ x \ 0.91 \ x \ 0.98 = .74$$

For the second scenario, In order to evaluate if the reliability of the system rise if the number of elements increase, the scenario propose a supply chain with multiple elements of each stage to construct a parallel system. (see fig. 6).

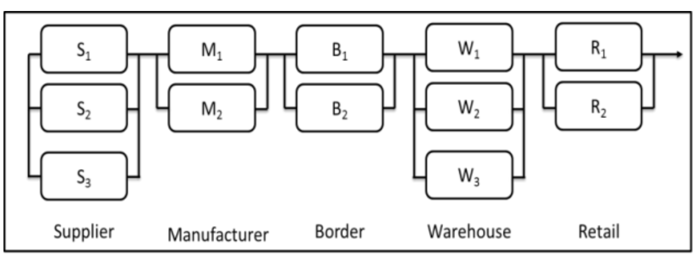

Figure 6 second scenario a parallel supply chain system

In this case, the following reliability values were assigned to each element: Rs_{1to3}= 0.95, $Rm_{1 \ to \ 2}$=0.99, $Rb_{1 \ to \ 2}$= 0.99, Rw=$0.97_{1 \ to \ 3}$, $Rr_{1 \ to \ 2}$=0.99

Using the formula (3) and simplifying the calculus to each stage the following results was obtain:

For E1 to E5

$$R_{E1} = 1 - \prod_{j=1}^{3}(1 - R_{sj}) = (1 - 0.95)x(1 - 0.95)x(1 - 0.95) = 1 - (1 - 0.95)^3 = 0.86$$

$$R_{E2} = 1 - \prod_{j=1}^{2}(1 - R_{mj}) = (1 - 0.99)x(1 - 0.99) = 1 - (1 - 0.98)^2 = 0.98$$

$$R_{E3} = 1 - \prod_{j=1}^{2}(1 - R_{bj}) = (1 - 0.99)x(1 - 0.99) = 1 - (1 - 0.98)^2 = 0.98$$

$$R_{E4} = 1 - \prod_{j=1}^{3}(1 - R_{wj}) = (1 - 0.97)x(1 - 0.97)x(1 - 0.97) = 1 - (1 - 0.97)^3 = 0.91$$

$$R_{E5} = 1 - \prod_{j=1}^{2}(1 - R_{bj}) = (1 - 0.99)x(1 - 0.99) = 1 - (1 - 0.98)^2 = 0.98$$

Total system Reliability = R= 0.86 x 0.98 x 0.98 x 0.91 x 0.98 = 0.74

From this scenarios evaluation, can be inferred, that even when the resilient strategies in the design of a supply chain promote integrate a complex chains, the cases evaluated in this paper, shows that in supply chains, parallel configurations are more robust but no necessary more reliable that serial integrations. According whit Klibi et al, (2009), robust is the capacity of an organization to respond positively to the constants or suddenly changes of the internal or external environment. It means that, the organization can work in a reduced capacity.

In this sense, complex systems that has several member, also has a wide window of vulnerability. When a disruption is materialized in an element, the advantage of complex systems is that their structure allows to the supply network keep working because, if an element its down there are other elements to support the operations, but on the other hand even when the chain still work, the supply capacity is reduced and is high probable that the desired level of service will decrease and the client satisfaction is negative affected.

5. CONCLUSIONS

Promote the construction of resilient supply chains is one of the goals of the decision makers and researchers in the area. However it is not clear what direction would be the best path to promptly reach an efficient and secure supply chain. This paper exposes a useful manner to measure and evaluate the reliability of a supply chain system in a quantitate way. Also the analysis, demonstrate that a parallel chain is more robust and can be functional when an element suffer a disruption. However, the operative capacity of the chain decrease, and then as consequence the level of service is affected too, according whit [1] this changes on the supplier capacity originate the reverse bullwhip effect phenomena. Finally this research contribute to an unexplored area presented this tool as an effective and quick way to approximate the index of reliability of a supply chain system. Know the index allows developing robustness environments and efficient supply chains.

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