Assessment of the relationship between sustainability and resilience in supply chain management using α-D MCDM

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Abstract

Several research on the topic of supply chain resilience and sustainability have been done in recent years. However, they make clear that there are various points of view when it comes to the sustainability-resilience relationship. To adapt supply chains (SC) to the needs of contemporary manufacturing processes, new trends and approaches in environmental protection and social welfare have been put into place. Even though sustainability and resilience have each been extensively examined separately, there aren't many concepts that combine them to determine supply chain performance. Therefore, this study is displaying the aspects of supply chain resilience and how it may affect sustainability triple bottom line. Moreover, this study presents an extension of analytic hierarchy process (AHP), α-Discounting multi-criteria decision-making (α-D MCDM) to evaluate the resilience aspects in more consistent manner. This study proposes an idea of utilization of α-D MCDM in different manner to solve several supply chain evaluation issues.

Keywords: Supply chain resilience; Supply chain sustainability; α-D MCDM

1. Introduction

Supply chain sustainability and resilience research has recently piqued the interest of academics and business executives. The dynamism that the global industrial environment exhibits as a result of economic turbulence, natural hazards, and the most recent health crisis is what led to the aforementioned events. In addition to that, the consistency of supply chains can be reduced, making them more susceptible to breakdowns and dangers due to decentralized supply chain activities, complicated supply chain networks, and turbulent market situations [1].

In order to better comprehend the components of the supply chain that are required to accommodate this dynamic, the phrase resilience of the supply chain has evolved. For instance, it is impossible for businesses to estimate in advance the scope of the COVID-19 pandemic's effects on business and the massive impact due to its rapid and huge size outbreak [2]. Companies must adapt their production systems, supply chain operations, and processes to deal with interruptions brought on by unforeseen events. Business professionals as well as academics are progressively realizing the benefits of enhancing supply chain resilience as a way to defend versus interruptions and lessen supply chain weaknesses [3].

Sustainable supply chain management was defined by Seuring and Müller (2008) as the management strategy that takes into account the three pillars of sustainable development (environmental, social, and economic) in order to satisfy stakeholder and customers' requirements [4]. While the supply chain sustainability (SCS) focuses on social and economic issues as well in order to increase the profitability of the SC, it is not just concerned with environmental issues.

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According to some academics, sustainability is a precondition of resilience and sustainability activities can increase resilience. Unless there are no studies that describe how resilience and sustainability interact to affect supply chain performance in the literature, which makes it difficult for decision-makers to develop plans that will benefit resilient-sustainable supply networks. It is unavoidable to use these new concepts to examine a supply chain's performance given how the implementation of sustainability and resilience principles in supply chains has affected their efficiency.

Since there is uncertainty surrounding the creation of sustainable and resilient supply chains, which is exacerbated by a lack of understanding concerning which strategies could be advantageous to both subjects, the connections and links between the two subjects are frequently inconsistent. There is still disagreement among academics on what exactly makes a sustainable and resilient supply chain, in addition to the previous efforts to establish sustainable and resilient supply networks by fusing the two ideas.

In this study, we present the relation between supply chain sustainability and resilience. First, we present the supply chain sustainability triple bottom line (economic, social, and environmental) and supply chain resilience factors (flexibility, velocity, visibility, and collaboration). Second, we discuss the extension of AHP which helps the decision maker to apply a consistent and efficient evaluation in more flexibility in comparison process by resolving the deficiencies of AHP. Finally, we proposed an idea that helps the management solve many evaluations process through hybridization of α-D MCDM with different MCDM methods.

This paper is organized as follows: a review of previous works on supply chain sustainability and resilience is displayed in Section 2. Some definitions and concepts is discussed in Section 3. Section 4 presents the proposed idea of evaluation based on α-D MCDM with different MCDM and how it may apply in several supply chain evaluations. Section 5 clarify the conclusion and future directions.

2. Related works

2.1 supply chain resilience

The ability of a supply chain to recover from a disruption and fulfil its commitments to its customers in a fair length of time is known as supply chain resilience [5]. The effects of disruptions could lower a business value and, to a larger extend, could result in a firm closure. Supply chains should be constructed so that they can react rapidly and effectively to interruptions in order to be able to return to the proper condition in a time frame that is appropriate [6].

They are now dealing with new issues as a result of the recent COVID-19 epidemic, including a lack of supply, weak demand, fluctuating prices for raw materials and transportation costs, a blocked commodities, and a lack of funding. The confluence of these events has presented several operational difficulties for global supply chains [7]. Consequently, there are now stricter criteria for supply chain resilience as an inclusive capability of businesses in the case of crises or dangers for ensure the safety of supply procurement and efficient demand response. As a result, supply chain resilience is becoming more important as academics and business management contribute to lowering risk within the supply chain processes and assisting supply chains in encouraging positive with disruptions and modifications made on by risks [8].

2.2 supply chain sustainability

Supply chain sustainability is key topic in the field of supply chain management which has gained a considerable amount of interest in the recent times. In contrast to conventional beliefs, market demands have shifted in such a way that a company's environmental and social performance is now seen by customers as being just as significant as its economic conditions [9]. The establishment of environmental and social targets that are as significant to economic goals since, in the long run, taking steps to advance society and create environmentally friendly products would undoubtedly benefit a company's bottom line.

Organizations can accomplish sustainability by combining these three factors (economic, environmental, and social), but they also need to think outside of their own walls by implementing strategies for improved stakeholder involvement, risk management, and supplier operations efficiency. Another crucial practice standard for a sustainable supply chain in industries is to recycle, reuse, and reduce [10].

The impact of industry 4.0 technologies on sustainability is the subject of a new trend in study that focuses on supply chain sustainability in light of the current industry experience with globalization and technology. For instance, Patil et. al (2023) explore Big data-Industry 4.0 readiness factors for sustainable supply chain management [11]. Article of Cao et. al (2023) contributes to this emerging body of work by considering how to use blockchain to enable sustainable food supply chains [12].

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3. Definitions and concepts

3.1 supply chain sustainability factors

Planning and decision-making for the supply chain that takes into account sustainability factors for the economy, society, and environment is known as sustainable supply chain management. As a result, environmental, economic, and social factors are the three primary categories under which sustainability is defined as shown in Figure 1.

- *Economic*: this factor is mainly consider the ability of an organization to offer items at cheaper prices through sustainable innovation strategies. Moreover, recovery of financial resources (invested in sustainable practices) through a wide range of efforts including reuse, recycling, and selling of industrial wastes [13]. In other words, a collective effort by an organization to design items that use fewer materials and are therefore less expensive to produce. Also, delivering more advantages to consumers, either by lowering costs or improving features [14].
- *Environmental*: is focuses on interaction between various organizational functions and between organizations to share resources and technologies to create sustainable and green products. This can be applied if there is availability of technical know-how and research resources to oversee and execute eco-friendly business processes [15]. Also, the capacity of an organization to transfer, package, and distribute materials in an ecologically conscious manner. In addition to that, organizations must development and execution of multiple environmental rules and regulations inside organizations. Using renewable resources in product design helps reduce environmental effect and makes end-of-life recycling easier.
- *Social*: this factor focuses on every point related to employee and society. Such that, organizations' adoption and execution of social and environmental standards and guidelines. Efforts made by businesses to improve their marketability by creating goods that are sustainable [16]. Also, development of the organization and application of general ethical principles in support of social and environmental projects. It significant to refers to an organization's attempts to improve these standards in a sustainable way, as well as the health, safety, and rights of its employees.

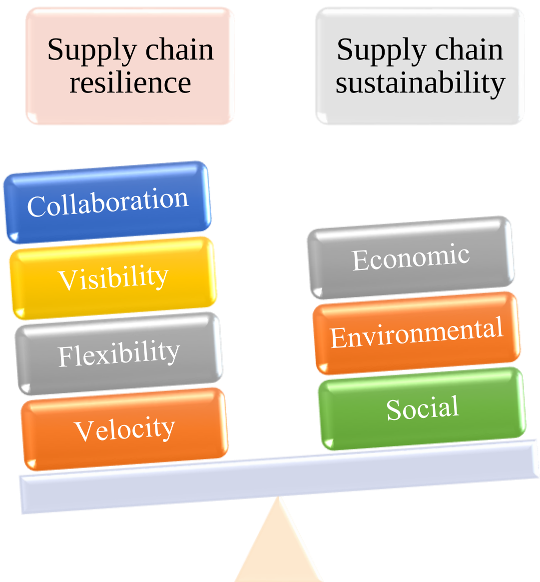

Figure 1: Relationship between supply chain sustainability and resilience

3.2 supply chain resilience factors

Flexibility, velocity, visibility, and collaboration have been highlighted in this study as specific supply chain resilience factors needed to create supply chain resilience as shown in Figure 1.

- *Flexibility*: Flexibility in the supply chain denotes its preparedness for crises. As a consequence, when companies react promptly to underlying changes in production problems and common or uncommon customer needs, a firm's supply chain performance may dramatically increase.
- *Velocity*: The term "supply chain velocity" refers to accelerating the operations of supply chains so they can react rapidly to underlying changes in the complex business conditions. By improving their velocity, businesses may respond quickly to unplanned variations on both the demand and supply sides, reducing the effect of interruptions.

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- *Visibility*: One of the key elements in enhancing supply chain resilience is visibility. The degree to which everyone in the supply chain have visibility to operational and management information about the supply chain to plan for potential uncertainties is known as supply chain visibility. The supply chain network's greater visibility is anticipated to greatly improve operational performance.
- *Collaboration*: In order for a company's supply chain to be able to adapt to disruptions in a manner where there is an information and intelligence association among the partners, collaboration is essential component of resilient supply chain orientation.

3.3 α-Discounting multi-criteria decision-making (α-D MCDM)

α-Discounting Method for Multi-Criteria Decision Making (α-D MCDM) was introduced by Smarandache (2010) as extension of AHP to deal with inconsistency and n-wise comparison. When used in conjunction with the Fairness Principle, the α-D Method produces the same outcome as AHP for pairwise comparison decisions that need consistency. Yet, when combined with the Fairness Principle, α -D produces a different outcome than AHP for weak inconsistent decision-making problems [17].

By applying non-null positive parameters $\alpha_1,\alpha_2,\alpha_3,\ldots,\alpha_n$ to the coefficients in the right-hand side of each comparison that reduce or raise them, α -D MCDM aims to transform the above linear homogeneous system of equations, which has only the null-solution, into a system having a specific non-null solution. The steps of the α-D MCDM as follows (But, if the problem is strongly inconsistent, this steps will not be useful and more the problem must be reformulated) [18]:

- Let $C = \{C_1, C_2, C_3, \ldots, C_n\}$, n≥2, be a set of criteria. The set of preferences are $P = \{P_1, P_2, P_3, \ldots, P_m\}$, m≥1. Linear homogeneous equation of each preference to a specific criteria as follows $P_i = f_i(C_1, C_2, C_3, \ldots, C_n)$. Then, construct a basic belief assignment (bba) for the weights of the criteria $m: C \rightarrow [0,1]$, where $m(C_i) = x_i, 0 < x_i < 1$ [19].

$$\sum_{i=1}^{n} m(C_i) = \sum_{i=1}^{n} x_i = 1$$

- Build $m \times n$ linear homogeneous system and its corresponding matrix as follows:

$$\begin{Bmatrix} x_{1,1}w_1 + x_{1,2}w_2 + \cdots + x_{1,n}w_n = 0 \\ \cdots \\ x_{m,1}w_1 + x_{m,2}w_2 + \cdots + x_{m,n}w_n = 0 \end{Bmatrix}$$

$$A = \begin{bmatrix} x_{1,1} & \cdots & x_{1,n} \\ \cdots & \cdots & \cdots \\ x_{m,1} & \cdots & x_{m,n} \end{bmatrix}$$

- Calculate the determinant $\det(A)$ of the matrix A.
  - If the $\det(A) = 0$ that means the problem is consistent.
  - If the $\det(A) \neq 0$ that means the problem is inconsistent.
    - ✓ Then, the system need to be parameterize the right hand side with α.
    - ✓ Use the Fairness principle to set all parameters with $\alpha_1 = \alpha_2 = \alpha_3 = \cdots = \alpha_p = \alpha > 0$.
    - ✓ Then, solve the system and find the solution.
    - ✓ Replace the parameters and secondary variables by 1 to obtain a certain result.
    - ✓ Divide each result by the summation of all result to normalize the solution.
    - ✓ The α value obtained is used to calculate the degree of consistency and inconsistency of the decision-making problem at the initial stage.

    If 0 < α < 1, then α is the degree of consistency and β = 1– α is the degree of inconsistency of the decision-making problem.

    If α > 1, then 1/α is the degree of consistency and β = 1– (1/α) is the degree of inconsistency of the decision-making problem.

4. Application of α -D MCDM in supply chain problem

In this section we will utilize α -D MCDM method to measure the resilience supply chain factors and how it may affect the sustainability. In order to apply this method, we investigate one of the supply chain management expert to inform us about the priority of each resilience factor from his preference. The expert preference as follows:

- Flexibility is as important as 2 times of velocity plus 3 times of visibility minus one time collaboration.
- Velocity is half as important as flexibility.
- Visibility is one third as important as flexibility.
- Collaboration is one forth as important as flexibility.

Let's suggest that flexibility is *x*, velocity is *y*, visibility is *z*, and collaboration is *m*.

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$$\begin{cases} x = 2y + 3z - m \\ y = \frac{1}{2}x \\ z = \frac{1}{3}x \\ m = \frac{1}{4}x \end{cases} \qquad A = \begin{bmatrix} 1 & -2 & -3 & -1 \\ -\frac{1}{2} & 1 & 0 & 0 \\ -\frac{1}{3} & 0 & 1 & 0 \\ -\frac{1}{4} & 0 & 0 & 1 \end{bmatrix}, \qquad \text{Det}(A) = -3/4 \neq 0$$

Let's parameterize each right-side coefficient to obtain the system's overall solution.

$$\begin{cases} x = 2\alpha_1 y + 3\alpha_2 z - \alpha_3 m \\ y = \frac{1}{2}\alpha_4 x \\ z = \frac{1}{3}\alpha_5 x \\ m = \frac{1}{4}\alpha_6 x \end{cases}$$

where $\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6 > 0$. Then, we will solve the system by substitute *y*, *z*, and *m* equations in the *x*:

$x = 2\alpha_1 \left(\frac{1}{2}\alpha_4 x\right) + 3\alpha_2 \left(\frac{1}{3}\alpha_5 x\right) - \alpha_3 \left(\frac{1}{4}\alpha_6 x\right)$

$1 = \alpha_1\alpha_4 + \alpha_2\alpha_5 - \frac{1}{4}\alpha_3\alpha_6$ Set 1 to the secondary variable

Using the Fairness Principle, discount all coefficients with the same α value.

Let $\alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = \alpha_6 = \alpha$

$1 = \alpha^2 + \alpha^2 - \frac{1}{4}\alpha^2$ (Parametric equation)

$\alpha = \sqrt{4/7}$

$S = \begin{bmatrix} 1 & \frac{3}{8} & \frac{3}{12} & \frac{3}{16} \end{bmatrix}$ (Priority vector)

The priority vector must be normalized to find the weight of each criteria where the sum of the weights equal 1.

$W = \begin{bmatrix} \frac{5}{9} & \frac{1}{5} & \frac{1}{7} & \frac{1}{9} \end{bmatrix}$

As we find from the application of α -D MCDM method in order to weight the four factors of supply chain resilience and based on the expert preferences, the flexibility is the superior factor with weight 0.55. The velocity, visibility, collaboration comes next with weight 0.21, 0.14, and 0.10, respectively. In this section we apply α -D MCDM method in order to deal with the first preference of the expert that is not pairwise comparison.

5. Conclusion and future direction

Research on the elements and mechanisms that affect supply chain resilience has grown in popularity in recent years, and it is important from both a theoretical and practical standpoint. This study demonstrated the relationship between supply chain sustainability and the benefits of supply chain resilience. This study displays the aspects of supply chain sustainability (economic, environmental, and social). In addition to that, the factors of supply chain resilience was discussed. Also, the relationship between resilience factors and supply chain sustainability was clarified according to a supply chain management expert by utilizing an efficient α -D MCDM that translate the expert's preference in sufficient manner and find the weights of the factors. We can propose the hybridization of α -D MCDM method with different MCDM methods such as the technique for order preference by similarity to ideal solution (TOPSIS) method, Vlse Kriterijumska Optimizacija Kompromisno Resenje (VIKOR) method, Decision making trial and evaluation laboratory (DEMATEL), or any other method in order to evaluate and rank alternatives. This hybridization may be efficient idea to improve evaluation process for hierarchy structured problems and provide consistent and efficient results.

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