Neutrosophic Systems with Applications, Vol. 3, 2023
https://doi.org/10.61356/j.nswa.2023.17

Neutrosophic Model to Examine the Challenges Faced by Manufacturing Businesses in Adopting Green Supply Chain Practices and to Provide Potential Solutions

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Abstract: Several obstacles stand in the way of companies trying to adopt green supply-chain practices. The purpose of this research is to examine the challenges faced by the industrial industry in adopting green supply chain practices and to provide potential solutions. The information for this research was gathered via in-depth, personal conversations with manufacturing sector managers who are well-versed in green supply chain practices. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) technique was used in the evaluation phase to evaluate obstacles and assess efficient options for introducing green supply chain practices. The TOPSIS method is integrated with the neutrosophic set. The neutrosophic set is used to deal with uncertain data. This study used eight barriers to analysis and eight solutions to rank. We obtained collaboration as the best solution. To find places for improvement and garner support for sustainability efforts, it is helpful to work together with suppliers, customers, and other stakeholders.

Keywords: Neutrosophic Set; Supply Chain; Green Supply Chain; Barriers; Solutions.

1. Introduction

The beginning of the Industrial Revolution in the 1800s was a pivotal time in human history. Population estimates put the world's total inhabitants at 7.8 billion, up from a mere few million before the uprising. Since the dawn of industrialization, nature has been badly affected by the unchecked use of earth's resources and the many forms of pollution that have resulted from their usage. Before the Industrial Age, the number of greenhouse emissions in the atmosphere remained relatively constant at about 250–300 parts per million (ppm), but with the advent of industrialization, it has climbed to 400 ppm (for carbon dioxide) and doubled (for methane gas). Understanding of ecological issues has increased all across the world, particularly as a result of the spread of globalization. Consequently, concerns about the items' impact on the surroundings have grown in importance [1, 2].

The development of supply chains and leadership has resulted from the rise of globalization, industrialization, and environmental consciousness in recent years. As environmental problems have worsened, conventional supply chains have been blamed for adding to the problem by producing excessive quantities of waste and emissions. The importance of ecological consciousness has risen in recent years as the effects of ecological problems on people's level of life have become more obvious. Clients with a concern for the environment have started putting pressure on supply chains to improve

environmental sustainability. As a result of these shifts, businesses that wish to compete in the global market must prioritize protecting the planet.

To put it simply, the supply chain is the system through which raw materials are transformed into finished goods and then delivered to consumers. In order to address ecological issues in SCM, the notion of a "green supply chain" has evolved. As a result of rising consumer knowledge and environmental demands in the varied worldwide marketplace, modern companies are putting increased focus on ecologically conscious buying and sustainable practices throughout the supply chain. Reducing carbon dioxide (CO2) emissions and increasing energy savings throughout the supply chain management (SCM) system is what is meant by "green supply chain management" (GSCM) [3, 4].

Companies have been compelled to use green practices at all stages of production due to the broad recognition of the relevance of sustainable supply chains in a variety of circles. As participants in the supply chain have become more concerned about global warming, the fast depletion of the earth's resources, and the rising loss of biodiversity, a green supply chain has emerged to address these issues. Environmental issues in customer and supplier interactions are assessed as part of the GSCM procedure. The use of energy is integral to the manufacturing process, and as a result, carbon dioxide gas is released into the environment, contributing to air pollution.

Many businesses have made efforts recently to switch to environmentally friendly supply chain operations. Growing attention and acknowledgment of ecological responsibility among academics and supply chain managers is largely attributable to the increasing popularity of "green" ideas and government rules requiring the implementation of GSCM practices. However, businesses have hit roadblocks that prohibit them from deploying these cutting-edge apps in full. Some difficulties may arise throughout the process of GSCM implementation. However, companies struggle to both recognize and address the challenges they face when attempting to put GSCM into practice. It is up to individual companies to better themselves in order to triumph against the opposition. While it would be ideal to remove all obstacles simultaneously, this is obviously not achievable. So, in the first phases of GSCM implementation, organizations should pinpoint the obstacles that need to be removed [5, 6].

Researchers are interested in multi-criteria decision-making (MCDM) approaches because of the enormous advantages they provide in tackling complex social and industrial challenges. Due to its better accuracy and dependability in resolving real-world difficulties, MCDM approaches have been extensively used by academics across a broad range of industries [7, 8].

Because of the inherent inconsistency and confusion associated with solutions in green supply chain selection, both linguistic and non-linguistic factors provide distinct benefits. Fang and Ye created linguistic neutrosophic numbers (LNNs) to handle MCDM situations with uncertain and contradictory linguistic information, combining the benefits of the two approaches. LNNs synthesize the benefits of both linguistic parameters and single-valued neutrosophic numbers (SVNNs) [9, 10].

2. Green Supply Chain

Evaluation and selection of green vendors, costing and procurement of substances, inbound and outbound logistics organizing, and resource shortage and demand balancing are all part of GSCM. In the manufacturing industry, essentials such as materials, parts, and outsourced procedures account for more than 60% of total revenue spent on suppliers. The results of a study done by Lo et al. showed that suppliers have an impact on the success of businesses and the long-term growth of enterprises. Research suggests that industrial processes are responsible for 45% of all greenhouse gases [11, 12].

Changes to the supply chain are a potential issue in the aftermath of COVID-19. Changes in the supply chain may have a significant influence on the availability of items and services because they lead to limitations of ingredients, parts, and completed products. Changes in the supply chain may

have a negative effect on a company's bottom line by increasing the price of inputs like raw materials, shipping, and others. Customers may become unsatisfied if they cannot receive the essential products or services as a result of supply chain interruptions, and companies may experience reputational harm if they are unable to satisfy orders or meet consumer expectations. It may be easier to deal with supply chain interruptions in a post-COVID-19 situation if vendors with the necessary expertise are identified [13, 14].

Up lately, ecological effects and loss of earth's resources were not major concerns for supply chains, which instead prioritized speedy product delivery at cheap prices. However, with a growing global population comes rising demand for already scarce assets such as water, power, metals, rocks, and land. Furthermore, as people become more aware that greenhouse gas emissions are contributing to global warming, they put increased pressure on businesses to adopt ecologically beneficial practices.

As environmental degradation accelerates, more and more people are interested in studying and implementing GSCs, which are an expansion of standard supply chains that involve steps to reduce a product's ecological impact at every stage of its existence. In order to meet the requirements of a rapidly expanding population, supply networks must improve their efficiency and raise output. Improvements in technology at the chain stage can be evaluated, and current logistics administration (including manufacturing, shipping, and inventory leadership) can be optimized, with the help of decision support tools that take into account product features such as, for example, higher dangers related to ambiguity in the market and effectiveness [15, 16].

Calculating trade-offs among financial and ecological factors and quantifying what is technically achievable are prerequisites for reducing redundancies and constructing GSCs. Our definition of eco-efficiency originates from this idea, and it's as follows: "preserving or enhancing the value of the economy while lessening the impact of business operations upon ecological systems." Therefore, an "eco-efficient approach" is one in which additional ecological damage can only be stopped at greater prices, combining the needs of ecology and the economy [17, 18].

Due to the inherent trade-offs inherent in the architecture of any Supply Chain (SC), researching eco-efficiency in GSCs necessitates the evaluation of numerous competing factors. Supply chains that include several criteria are a logical method to cope with the many facets of sustainability [19, 20].

3. Neutrosophic TOPSIS Method

For decision issues in a broad variety of domains, the TOPSIS has become a popular and commonly used MCDM approach owing to its straightforward methodology and user-friendliness. The methodology of this technique relies on measuring how far away the beneficial and detrimental ideal solutions are from the reference points used to narrow down the options under consideration. As a result, the optimal choice is the one that minimizes the distance between itself and the Positive Ideal Solution (PIS) [21]–[24]. This study employed the TOPSIS method with the single-valued neutrosophic set to rank the solution in the green supply chain. Figure 1 shows the steps of the neutrosophic TOPSIS method.

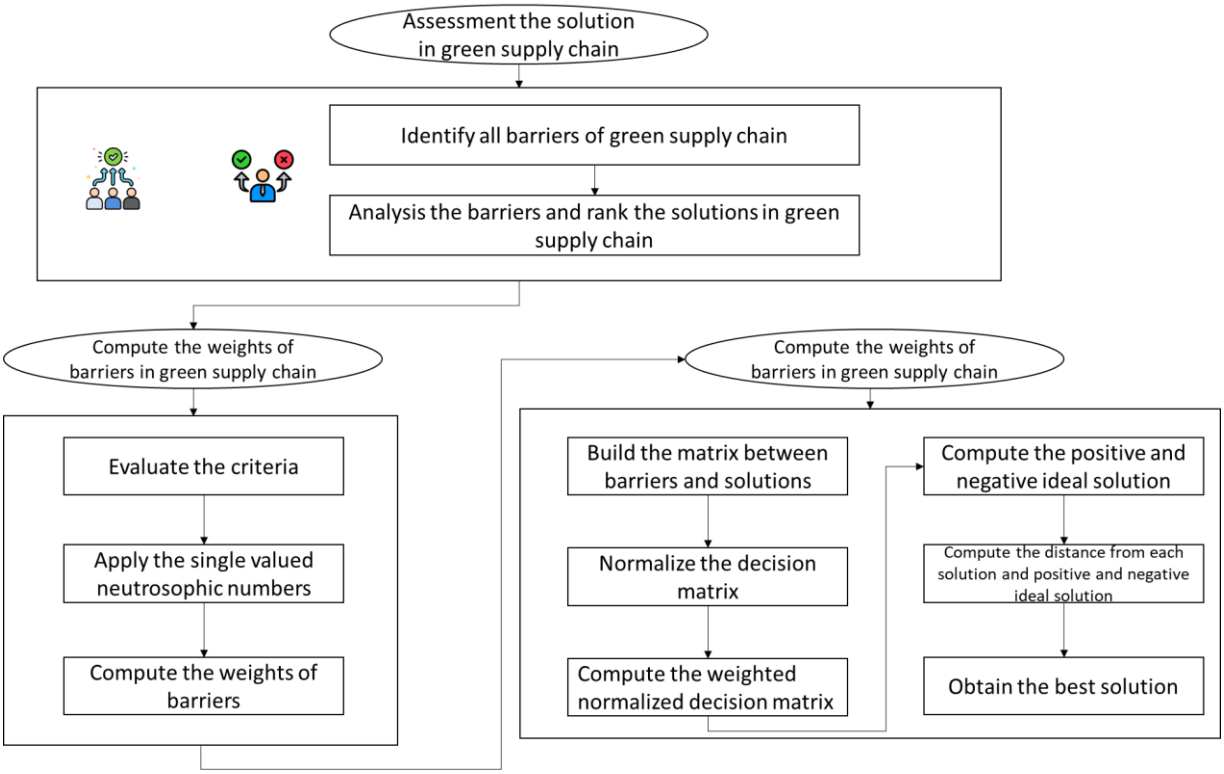

Figure 1. The phases of single valued neutrosophic TOPSIS method.

Build the matrix between barriers and solutions.

Normalize the decision matrix.

Normalize the data between barriers and solutions in green supply chain.

$$n_{ij} = \frac{a_{ij} - \min_j(a_{ij})}{\max_j(a_{ij}) - \min_j(a_{ij})} \quad (1)$$

$$n_{ij} = \frac{\max_j(a_{ij}) - a_{ij}}{\max_j(a_{ij}) - \min_j(a_{ij})} \quad (2)$$

Compute the weighted normalized decision matrix

$$t_{ij} = w_j * n_{ij} \quad (3)$$

Compute the positive and negative ideal solution

$$t_j^+ = \{t, t_2^+, \ldots . t_n^+\} = \left\{\max_j\left(t_j^+\right)\right\} \quad (4)$$

Compute the distance from each solution and positive and negative ideal solution

$$E_i^+ = \sqrt{\sum_{j=1}^{n}\left(t_{ij} - t_j^+\right)^2} \quad (5)$$

$$E_i^- = \sqrt{\sum_{j=1}^{n}\left(t_{ij} - t_j^-\right)^2} \quad (6)$$

Obtain the best solution

The best solution is computed by

$$S_i = \frac{E_i^-}{E_i^- + E_i^+} \quad (7)$$

4. Ranking Solutions in Green Supply Chain

This section provides the ranking of solutions to overcome the barriers in the green supply chain. We collected the barriers and solutions from previous studies. There are eight barriers and eight solutions. The barriers of this study are:

The environmental effects of their supply chain may not be well understood, and many businesses may not see the advantages of adopting sustainable practices.

Financial constraints: Some businesses may struggle to implement a green supply chain because of the time and money needed to invest in new technology, procedures, and staff training.

Employees and stakeholders may be resistant to change if implementing a green supply chain requires altering current processes and procedures.

The availability of sustainable raw materials and providers that can satisfy organizations sustainability needs is limited.

Organizations that operate in many areas or countries with varying environmental requirements may find it difficult to execute sustainable supply chain practices due to regulations and rules.

Insufficient teamwork: Different supply chain parties need to work together to implement a green supply chain. It might be difficult to successfully apply sustainable practices if there is a lack of teamwork and communication.

Organizations may apply a variety of strategies to build a green supply chain and overcome obstacles. The cost and technical are also barriers of green supply chain.

This study used eight solutions as:

In order to enhance environmental performance and establish sustainability goals, it is recommended that businesses conduct a sustainability assessment.

Create a plan for long-term sustainability that details the organization's sustainability aspirations and the steps that will be taken to realize them.

Organizations should actively involve their suppliers in order to discover sustainable options and promote the adoption of sustainable practices.

Organizations may invest in renewable energy, smart logistics, and sustainable packaging, all of which can help lessen the supply chain's negative effects on the environment.

Give your workers some education on how they may lessen the supply chain's environmental effects by learning about and implementing sustainable practices.

Working together with consumers, regulators, and NGOs may help businesses determine where they will have the most effect and how to garner public support for sustainability programs.

Businesses should make environmental responsibility a top priority and incorporate green thinking into every step of the supply chain.

Organizations should monitor and assess their environmental performance to determine whether or not they are meeting their sustainability targets and where they may make changes.

The experts and decision-makers are evaluated the barriers and solution in green supply chain. The TOPSIS method is used with the single valued neutrosophic set to rank the proposed solutions in the green supply chain. The data between barriers and solutions. Then normalize the data between barriers and solutions as shown in Table 1. Then compute the weighted normalized matrix as shown in Table 2. Then compute the positive and negative ideal solution. Then compute the distance between solutions and the positive and negative ideal solution. Then compute the closeness value as shown in Figure 2.

Table 1. The normalized data between barriers and solutions in green supply chain.

	GSB_1	GSB_2	GSB_3	GSB_4	GSB_5	GSB_6	GSB_7	GSB_8
GSS_1	0.194467	0.412729	0.641527	0.28105	0.150034	0.306796	0.132317	0.435881
GSS_2	0.30406	0.412729	0.16236	0.68244	0.513441	0.722509	0.438825	0.23344
GSS_3	0.30406	0.412729	0.16236	0.180435	0.150092	0.306796	0.441348	0.161953
GSS_4	0.738562	0.287344	0.16236	0.28105	0.558063	0.212845	0.438825	0.1493
GSS_5	0.301424	0.264974	0.253859	0.43338	0.213837	0.102764	0.440885	0.378311
GSS_6	0.30406	0.412729	0.590962	0.194983	0.213837	0.306796	0.29152	0.496992
GSS_7	0.195208	0.288575	0.253859	0.197268	0.137285	0.306796	0.329118	0.416838
GSS_8	0.101922	0.287344	0.176738	0.28105	0.519236	0.213593	0.122016	0.378311

Table 2. The weighted normalized data between barriers and solutions in green supply chain.

	GSB_1	GSB_2	GSB_3	GSB_4	GSB_5	GSB_6	GSB_7	GSB_8
GSS_1	0.013187	0.04376	0.171889	0.029798	0.011161	0.032528	0.009767	0.086292
GSS_2	0.020618	0.04376	0.043502	0.072356	0.038195	0.076604	0.032392	0.046214
GSS_3	0.020618	0.04376	0.043502	0.019131	0.011165	0.032528	0.032578	0.032062
GSS_4	0.050082	0.030466	0.043502	0.029798	0.041514	0.022567	0.032392	0.029557
GSS_5	0.02044	0.028094	0.068018	0.045949	0.015907	0.010896	0.032544	0.074895
GSS_6	0.020618	0.04376	0.15834	0.020673	0.015907	0.032528	0.021519	0.09839
GSS_7	0.013237	0.030596	0.068018	0.020915	0.010213	0.032528	0.024294	0.082522
GSS_8	0.006911	0.030466	0.047355	0.029798	0.038626	0.022646	0.009007	0.074895

Collaboration is the best solution ranked by the TOPSIS method. In order to find places for improvement and garner support for sustainability efforts, it is helpful to work together with suppliers, customers, and other stakeholders.

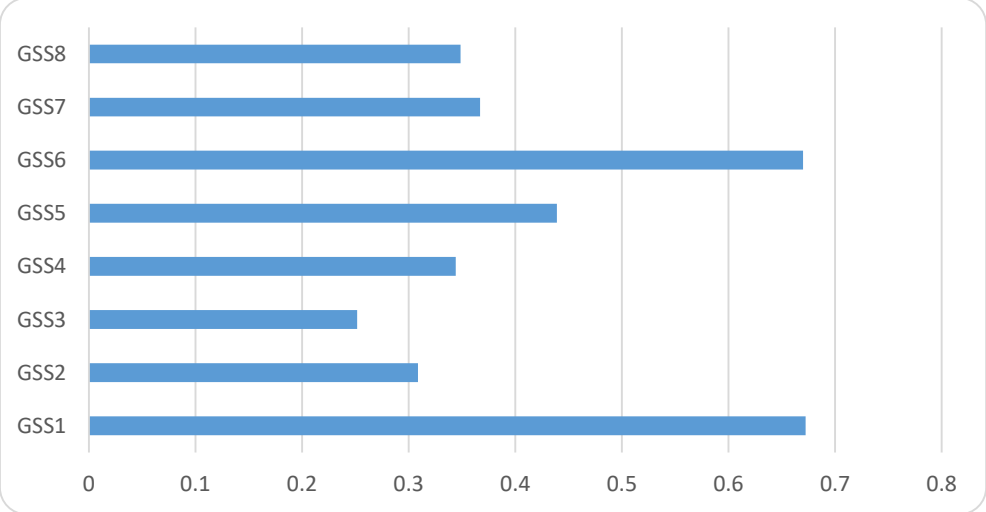

Figure 2. The score of eight solutions.

5. Conclusion

A green supply chain functions economically and has minimal negative effects on the environment. It entails including environmental concerns throughout the whole production process, from sourcing raw materials to final disposal. A green supply chain employs a variety of measures to lessen its negative effects on the environment. But the green supply chains have many barriers. So this paper analysis the barriers and give the various solutions and ranked them. This study used the TOPSIS method to rank the solutions and analysis the barriers. The TOPSIS method is used with the neutrosophic set to deal with uncertain data. We achieved coloration as the best solution from eight solutions. To find places for improvement and garner support for sustainability efforts, it is helpful to work together with suppliers, customers, and other stakeholders.

Data availability

The datasets generated during and/or analyzed during the current study are not publicly available due to the privacy-preserving nature of the data but are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare that there is no conflict of interest in the research.

Ethical approval

This article does not contain any studies with human participants or animals performed by any of the authors.

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Received: Aug 18, 2022. Accepted: Mar 22, 2023