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Research Article

Environmental Supply Chain Performance Mapping of an Enterprise by Exploring a Novel Vague-Intellectual Approach

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The authors notified the two momentous Research Gaps (RGs) via conducting the relevant literature survey. The authors found as first RG that there are still no mathematical models that could address the generalized trapezoidal fuzzy set (GTFs) based green supply chain performance measurement (GSCPM) multi-level hierarchical index for computing the performance of a production enterprise in % except in the forms of GTF set/scale/crisp value. Next, as the second research gap, the authors identified that a few research articles are published in the extent of degree of similarity approaches. Entire approaches are limited to recognize the weak metrics under assessment of two GTFN sets from experts and also not competent to measure the performance gap of metrics from its ideal value. The objective of research work is turned to overcome the identified two RGs. To fulfill the first RG, the authors first of all proposed the two GTFN set-based mathematical models, which are executed to compute the priority weights and appropriateness ratings (PWsaARs) for 1st level measures from 2nd level PWsaARs of metrics (discarded the requirement of PWsaARs data for 1st level measures from experts). Furthermore, the authors developed GTFN set-based novel fuzzy performance index (NFPI) approach (by combining the crisp as well as fuzzy percentage rule over FPI) to compute the performance in %. To address the second RG, the degree of similarity (DoS) approach is modified by introducing idea of negative and positive ideal solution into DoS (eliminate the need for assessment of two GTFN sets from experts). Next, modified DoS is applied over evaluated FPII (fuzzy performance importance index) to identify the weak and strong metrics and also quantify the GSCP gap of metrics from its ideal value. Eventually, the research work is demonstrated with empirical case research of an automobile parts manufacturing industry.

1. Introduction

Industrial sustainability (IS) issue has gained the momentum among performance's auditors and current researchers. Three pillars such as economic, social, and environmental are mostly contributing towards IS. Supply chain management (SCM) is found one of the significant operations, which is the heart and ought to be healthy plan and develop for each pillar to ensure the future sustainability of industries at competitive edge. SCM is defined a circuit, where factories, warehouses, distribution centers, retailers, and end users conclave for fulfilling their mutual needs and profits [1]. Among SCM, recently the green supply chain management (GSCM) strategy is ascertained as one of the sparking pillar of sustainability and received the amorous attention from global warming researchers. It is observed that methodical and tactical GSCM practices fruitfully participate in environmental pillar of sustainability and highly attempting towards developing the IS [2, 3]. In today's era, entire manufacturing sectors are highly provoked for utilizing the GSCM strategy to overcome the pollution as well as global warming issues, i.e., reduction of hot emission, avoidance of carbon contents, reuse the energies, recycling the wastes, and heat recovery to cope up with competitive edge [4–6].

GSCM is an introduction of green (environmental) thoughts into SC network, including the product design, material resourcing and selection, manufacturing processes, and delivery of the final goods to the consumers [7–9]. GSCM is a channel where creativity and innovations in SCM and industrial purchasing are brought under environmental concern [10–12]. GSCM is a dynamic decision support tool to address the ecological defies such as global warming, air and water pollution, and acid rains [13–17]. GSCM is the introductions of green trends in the bin of global supply chain in purpose to restore the earth's resources and build the world pollution free [18]. GSCM can be gained by augmenting the renewable energy processes, recycling of waste cum hazard materials, recycling of waste water, over processing, most excellent production, effective movement, elimination of manufacturing of defective products, and minimization of reworking [19–23].

It is found that the performance measurement (PM) is one of the decision support system and is explored to calibrate the performance and benchmark the industries based on scores [24, 25]. Sustainability PM tools are executed by SCM researchers cum global industries to map the overall performance under pillars of sustainability [26, 27]. To evaluate the GSCM performance scores, subjective and objective information is used for the modeling of the GSCM-based multihierarchical index consisting of performance measures and their metrics. However, authors sensed on peer-review of published research articles that comprehensive research documents are published focused on objective data modeling of the GSCM-based multihierarchical index in evaluating the permanence scores [28, 29]. Next, the authors found that most of the GSCM researchers [18, 30–32] attempted to develop a triangular fuzzy set-based GSCM hierarchical index (included general measures or limited to single level hierarchy) and able to evaluate GSCM performance score of alternative industries (except individual or single industry) [19, 33–40]. Next, the authors probed that a few researchers attempted to calculate GSCM performance in Triangular, GTFN set, and crisp value [37–39]. In extensive of the literature survey, the authors also found that short of the research work is conducted in degree of similarly (DoS) approaches, and the entire DoS approaches are used to only identify the weak and strong measures and metrics under assessment of two GTFN sets from experts [20–23, 41–47]. Therefore, the peer-review provided significant clues to authors to frame the pre-RGs and shared the contribution to overcome the RGs.

(i) The pre-research contributions are summarized as follows:

  (1) To identify and frame the GTFN set-based GSCPM multilevel hierarchical index, it consisted of the advanced crucial measure-metrics and accepted the green challenge of current contemporary industries.

  (2) To structure the GTFN-based new mathematical models, which could assess the GSC performance of a firm in percentage (%) under assessment of least GTFN information.

  (3) To identify the weak and strong metrics and also quantify the GSCP gap of metrics and measures from its ideal value. To potentially shape the entire (1)–(3) research contributions, the authors visited industries and conducted the comprehensive/secondary systematic relevant literature survey, which are discussed in Table 1 briefly.

2. Literature Survey

2.1. Research Gaps and Contribution

2.1.1. Research Gaps. In the last decade, the miscellaneous pollutants, i.e., ill-biological particles, fossil fuels, hazard particles, toxic gasses, undesirable flumes, and unwanted mono-carbon elements/stuffs/materials are more populated in environment due to rapid production rate with incompliance of the green (environmental) issues [84–86]. After conducting the comprehensive/secondary (in-depth) literature review, the authors re-notified and confirmed the same (1)–(3) research RGs, observed on peer-review stage, and discussed end of the Section 1. The confirmed (1)–(3) research RGs are discussed with rationales as follows:

(1) The previous researchers introduced GTFN set-based GSCM crucial measures and their interrelated metrics to build only a single-layer GSCM hierarchical index. There is an essential necessity to build the multilayers GSCM hierarchical index by introducing advanced-green technological focusing crucial measure-metrics.

(2) As per the evidence of previous research studies, the managers are not facilitated to compute GTFN set-based PWsaARs of 1st level measures by using the assigned PWsaARs information of metrics (2nd level hierarchy). There is an essential necessity to build the GTFN set-based mathematical models, where the managers can compute PWsaARs of 1st level measures by availing the evaluated PWsaARs of metrics (2nd level hierarchy).

(3) The previous researchers ensured the managers to compute the performance of firm in the terms of triangular/GTFN set or scale and crisp value. Therefore, the managers are not facilitated with GTFN set-based new approach for computing the evaluated GSCM performance in %. There is the imperative necessity to build GTFN set-based new approach to address this identified RG.

(4) The previous researchers proposed DoS approaches, which are executed to identify the only weak and strong metrics under assessment of two GTFN sets from experts. Therefore, the managers are not ensure

Table 1: Conducted comprehensive/secondary systematic relevance in the context of GSCPM strategy, GTFN mathematical models, and degree of similarly mapping between the GTFN sets.

The authors	Their research contribution in the context of GSCP strategy
[48]	Introduced a mixed-integer linear programming-based framework for designing the sustainable SC. The proposed framework is explored to evaluate the tradeoffs between economic and environmental objective in case study of a firm. The results showed that the current legislation and the emission trading scheme must be strengthened and harmonized in order to drive a meaningful environmental strategy.
[49]	Used statistics package-based software for establishing the structural modeling of proposed green hypotheses and helping to analyze the performance mapping of sustainable material providers.
[50]	Developed an interpretive structural modeling to display the effects of GSCM drive over the performance of case study of a firm.
[51]	Identified the essential green manufacturing practices to build a GSCM framework, which is used for solving the supplier election problem in the context of Indian manufacturing industry. The relationships between the green supplier selection practices are studied.
[52]	Developed a GSCM framework by conducting the relevant literature survey in the context of GSCM from 2000 to 2010. The developed GSCM framework is used for measuring the GSC performance of a firm.
[53]	Applied a fuzzy-TOPSIS (technique for order preference similar to ideal solution) approach upon GSCM framework (included GSCM practices) for ranking the twelve suppliers. The obtained results are computed by fuzzy-TOPSIS and next compared with the ranks obtained by both the geometric mean and the graded mean methods for selection of the final supplier.
[54]	Developed a multicriteria decision-making hierarchical model (consisted of the traditional as well as green criteria) and implemented it along with an intellectual approach to evaluate the best green supplier for a Singapore-based plastic manufacturing company.
[55]	The empirical data were collected from members of NAPM (North American Portability Management) to know their awareness and frequent applications of "green" purchasing in their firms. They all suggested that environmental factor is a crucial factor in the supplier evaluation problem. Lastly, green purchasing was suggested as a powerful factor to reduce and eliminate the waste.
[56]	Recognized the twelve behavioral factors such as top management support, performance appraisal and reward, communication, green training, and employee empowerment in the context of mining GSCM. An interpretive structural modeling (ISM) has been explored to setup the interrelationships among the identified behavioral factors.
[20]	Presented an efficient supplier performance assessment index with GTFN set. A fuzzy overall evaluation index is estimated towards assessing the GSC performance of alternative suppliers.
[57]	Displayed that environmental metrics are key factors for evaluating, selecting, and maintaining any supplier. Case study of an auto industry is carried out to justify this assertion.
[58]	Highlighted and suggested a few factors, which may be considered as the initiatives of GSCM.
[59]	Developed a meditational regression model and applied it to find out the effect of green practices upon their interrelated practices. The model results depicted that supplier must be evaluated with cost and fast delivery with environmental concerns.
[60]	Proposed a double layers GSC efficient appraisement model for benchmarking the green alternative suppliers. A triangular fuzzy set is used to handle the vagueness associated with supplier's model and select the most significant supplier.
[61]	Investigated the GSC as retailer strategy. It is found that GSC aids the retailer to improve their retailing profit with low promotional efforts.
[62]	Determined during a case study of coal enterprise of China that various driving mechanisms, i.e., government regulations, enterprise resource capability, and supply chain aid the global industries to reach to the green innovation.

Table 1: Continued.

The authors	Their research contribution in the context of GSCP strategy
[63]	Developed a multiobjective decision making hierarchical model, which included the forward and reverse logistic practices. The model is used to optimize and reduce the recycling as well as manufacturing cost.
[64]	Investigated the benefits of the green innovation policy and pricing strategy for remanufacturing system of a firm. After investigation, green innovation policy and pricing strategy are applied in purpose to determine the competitive advantage of them.
[65]	Proposed a hierarchical evaluation model (consist of green performance parameters) towards evaluating as well as selecting the alternative green vendor.
[66]	Proposed a dynamic integrated model with platform ecosystem framework (consisted by formal taxonomy indicators) to find the interrelationships across formal taxonomy indicators of platform ecosystem.
[67]	Analyzed the impact of an effort cost coefficient of low-carbon product advertising across the dual-channel SC. It is found that sharing ratio of low-carbon product advertising effort cost impacts on the profit of a dual-channel SC
[68]	Applied the differential game theory investment strategy over vertical incentive scheme of manufacturing and retailing sectors to analyze benefit of cost subsidy.
[69]	Proposed a new decision support system (GSCM framework with grey-Delphi approach) and applied it for evaluating and selecting the best and weak criteria from various criteria. It is suggested to oil and gas industry to improve its performance for weak criteria.
[70]	Applied knowledge-based network for analyzing the impact of association among strategy, intellectual capital, and network and finance over organizational performance of Brazilian small- and medium-sized enterprise.
[71]	Applied the four techniques, i.e., statistics, machine learning, data mining, and optimization to map the GSCM performance of supplier organizations under internal environment management, green purchasing, customer green cooperation, and general criteria.
[72]	Proposed and applied a three-path group decision making technique with decision-theoretic rough set (DTRS) as well as hesitant fuzzy linguistic (HFL) to solve the green vendor evaluation and selection problem. The results explicated that proposed techniques can well handle the expert's assessment.
[73]	Built a judgment making decisional model to appraise the value of green suppliers under law and risk parameters. The proposed model enabled the organizations for managing the GSC. The authors extended research work with framing a new vague set-based approach for recognizing and predicting the relationships amongst the green supply risk parameters.
[74]	Conducted the relevant literature survey in the context of SCM and identified SC research areas, relationships among SC indicators, and emerging topics of SC.
[75]	Constructed the three pricing models and analyzed them simultaneously by changing the optimal profits of SC members and the optimal GSC degree of complementary products.
[76]	Identified the relationships among the green logistic operations, national economic, and environmental indicators and also ranked the best logistic countries over the period from 2007 to 2018.
[77]	Conducted the significant literature review on industry 4.0 SC strategies and identified and proposed the six research categories of industry 4.0 SC strategies with future research directions.
[78]	Recognized the vital relationship between the waste management practices and sustainability. The authors also evaluated the cause and effect relationship between them by using decision-making trial and evaluation laboratory (DEMATEL) approach.
[79]	Explored the qualitative survey to acquire in-depth knowledge by interviews against multisector organizations, which enable the authors to propose the areas where eco-innovation needs to be performed.
[80]	Proposed an integrated framework including digital project-driven supply chains (PDSC) indicators used to solve the multiple objective problems of architecture, engineering, construction, and operations and maintenance (AECOM) value chain.

Table 1: Continued.

The authors	Their research contribution in the context of GSCP strategy
[81]	Presented a summary of existing literature survey conducted over on machine learning (ML) in logistics and supply chain management (LSCM). It is concluded after analyzing the current literature, data, contemporary concepts, and gaps that suggested that LSCM must be intensified towards future researchers for research.
[82]	Audited the merged effect of internal environmental management (IEM) and green human resource management (GHRM) for corporate reputation (CR), environmental performance (EP), and financial performance (FP). The further indirect effects of CR and EP are analyzed.
[83]	Extracted the data from 76 commercial banks of four countries, i.e., Pakistan, India, Bangladesh, and Sri Lanka for the period 2009–2018. The generalized method of moments (GMM) is used to analyze the results. It is found that supply chain always encompasses the risk variables and is covered by qualitative assessment.
The authors	Their research works related to measure the degree of similarly between GTFN sets.
[33]	Proposed a novel fuzzy set-based intellectual technique to map the degree of similarity between the two generalized fuzzy sets. The similarity was measured from the center of gravity points of trapezoidal to triangular generalized fuzzy sets.
[34]	Measured the similarity between the two GTFN sets by merging the concept of left and right apex angles with center of gravity. The similarly between the two GTFN sets are mapped based on area, perimeter, and height.
[35]	Developed a new fuzzy based arithmetical approach considering the least number of parameters for computing the degree of similarity between the two GTFN sets.
[36]	Merged the idea of the predictable interval with dice similarity measure of two vectors for calculating the degree of similarity between the two GTFN sets.
[37]	Proposed a new degree of similarity concept, which measured the centers of gravity and the geometric distance between the two GTFN sets.
[38]	Proposed a multicriteria decision making appraisement model (consist of green-lean-agile logistic activities) with fuzzy performance index approach to assess the overall performance of a firm.
[39]	Identified that the domestic smog adversely impact the environment. The authors proposed a mathematical method to analyze this problem and provided the multiple solutions to minimize the smog pollutions.
[40]	Conducted the relevant literature survey in the extent of logistic 4.0 sustainability to overcome the vagueness of identified previous research gaps. The literature assisted the authors to propose a framework for measuring the logistic, sustainability, and technological adaptation of a warehouse.
[19]	Presented a framework consisted of 25 drivers linked with 8 criteria for analyzing the performance of a smart manufacturing firm. An integrated grey technique for order preference by similarity to ideal solution (Grey-TOPSIS) is implicated to rank the drivers. The obtained ranking is also validated using "complex proportional assessment or grey (COPRAS-G)" approach.

to trace that how much % of performance of each metrics need to be augmented to become 100% fit or meet idea value. There is a necessity to introduce the concept of ideal solution to void the assessment of the two set and measuring the GSCM performance gap of metrics from its ideal value.

2.1.2. Research Contributions. The RGs are transformed into research contributions (RCs). Figure 1 depicts the virtual picture of formulated problems/quotation of RCs. The entire RCs are framed as follows:

(1) The authors committed to build the measure-metrics based double-layer GTFN set-based GSCPM hierarchical index, addressing the green challenge of industry 4.0

(2) The authors committed to develop and propose the two GTFN set-based mathematical models, which could aid the managers to compute PWsaARs of 1st level measures from availing the evaluated PWsaARs of metrics (2nd level hierarchy)

(3) The authors dedicated to develop and propose a GTFN set-based novel fuzzy performance index (NFPI) approach to transform the GTFN set or scale into %

(4) The authors planned to modify the DoS approach by introducing an idea of negative and positive ideal solution into DoS, which ensure the managers to trace that how much % of performance does each metrics needs to become 100% fit to its meet ideal value

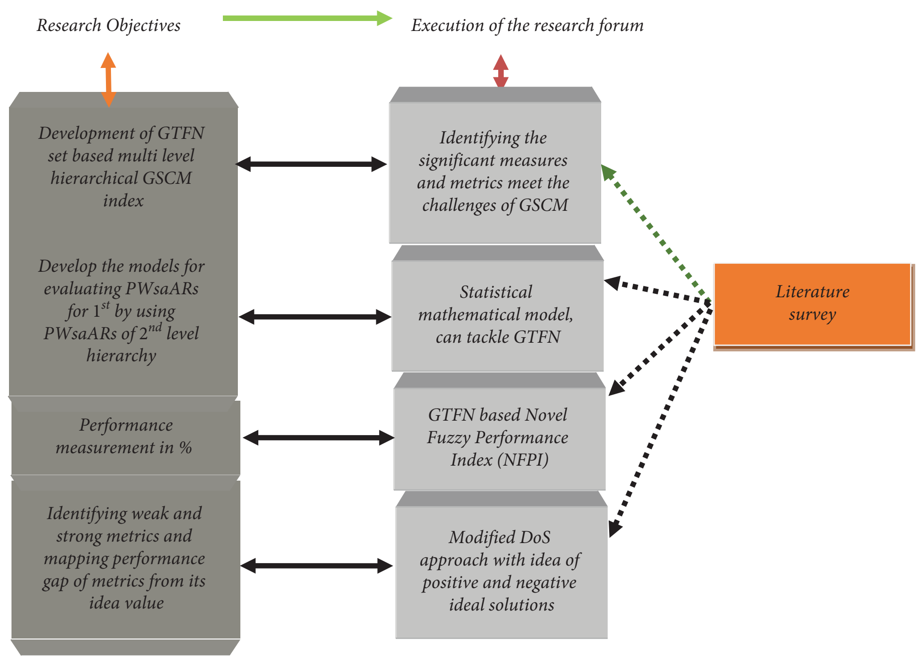

Figure 1: Problem formulation.

3. Fuzzy Logic and Set Theory

The fuzzy set theory was introduced by [87] in 1956 as well as [88] for addressing the problems associated with vagueness. It is considered as a mathematical tool for modeling the language and approximates the situations where fuzzy criteria exist [89]. In a universe of discourse X, a fuzzy subset A of X is defined by a membership function $f_A(x)$, where element (x) in universe of discourse X is represented by the real numbers in the closed interval $[0, 1]$. Here, the value of $f_A(x)$ for the fuzzy set A is called as the membership value or the grade of the membership. The membership value represents the degree of x belonging to the fuzzy set A [90–93]. The greater $f_A(x)$, the stronger the grade of membership for X in A. The linguistic value is used for approximate the reasoning within the framework of fuzzy set theory [87, 89, 94, 95] for handling an ambiguity, involved in linguistic expression, and normal trapezoid or triangular fuzzy numbers. We can define operations of fuzzy sets by using the extension principles [22, 60, 95–98].

Definition 1. Based on the extension principle, we can derive the arithmetic of fuzzy sets as shown in [87, 95, 97, 98].

A GTFN set can be defined as $\tilde{A} = (a_1, a_2, a_3, a_4;\ w_{\tilde{A}})$, and the membership function $\mu_{\tilde{A}}(x)\colon R \longrightarrow [0, 1]$ is expressed as follows:

$$\mu_{\tilde{A}}(x) = \begin{cases} \dfrac{x - a_1}{a_2 - a_1} \times \tilde{\tilde{w}}_A, & x \in (a_1, a_2), \\ \tilde{\tilde{w}}_A, & x \in (a_2, a_3), \\ \dfrac{x - a_4}{a_3 - a_4} \times \tilde{\tilde{w}}_A, & x \in (a_3, a_4), \\ 0, & x \in (-\infty, a_1) \cup (a_4, \infty). \end{cases} \tag{1}$$

Here, $a_1 \le a_2 \le a_3 \le a_4$ and $\tilde{\tilde{w}}_A \in (0, 1)$.

Suppose that $\tilde{a} = (a_1, a_2, a_3, a_4;\ w_{\tilde{A}})$ and $\tilde{b} = (b_1, b_2, b_3, b_4;\ w_{\tilde{B}})$ are two GTFN sets, then the operational rules of the GTFN set $\tilde{a}$ and $\tilde{b}$ are shown as follows as per reference [96, 97]:

$$\tilde{a} \oplus \tilde{b} = (a_1, a_2, a_3, a_4;\ w_{\tilde{A}}) \oplus (b_1, b_2, b_3, b_4;\ w_{\tilde{B}}) = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4; \min(w_{\tilde{A}}, w_{\tilde{B}})), \tag{2}$$

$$\tilde{a} \ominus \tilde{b} = (a_1, a_2, a_3, a_4;\ w_{\tilde{A}}) - (b_1, b_2, b_3, b_4;\ w_{\tilde{B}}) = (a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1; \min(w_{\tilde{A}}, w_{\tilde{B}})), \tag{3}$$

$$\tilde{a} \otimes \tilde{b} = (a_1, a_2, a_3, a_4;\ w_{\tilde{A}}) \otimes (b_1, b_2, b_3, b_4;\ w_{\tilde{B}}) = (a_1 \times b_1, a_2 \times b_2, a_3 \times b_3, a_4 \times b_4; \min(w_{\tilde{A}}, w_{\tilde{B}})), \tag{4}$$

$$\tilde{a} \phi \tilde{b} = (a_1, a_2, a_3, a_4;\ w_{\tilde{A}}) \phi (b_1, b_2, b_3, b_4;\ w_{\tilde{B}}) = (a_1 \div b_4, a_2 \div b_3, a_3 \div b_2, a_4 \div b_1; \min(w_{\tilde{A}}, w_{\tilde{B}})). \tag{5}$$

4. GTFN Set-Based Variant Approach Fuzzy Approach

The authors proposed the GTFN set-based variant approach, which included four sub-associated section of section 4. The aggregation of appropriateness ratings and priority importance weights is shown in 4.1. The Novel Fuzzy Performance Index (NFPI), for which the results are calculated in percentage (%), is shown in 4.2. The computation of fuzzy performance importance index (FPII) is displayed in 4.3, and the modified degree of similarity (DoS) mathematical model used for Identification of weak and strong performing GSC metrics is exhibited in 4.4. The chief objective of the proposed approach is to overcome the previous drawbacks of research works and fruitfully fulfill the identified RGs. The pros of the approach are that the proposed GTFN set-based variant approach is capable to tackle the subjective information of experts accurately and precisely. The assigned information in the terms of linguistic scale corresponding to GTFN sets is bounded by four values under membership function, which deliver the precise as well as true results. The approach is able to address all research objectives and contributions. The cons are that the approach is so complex in nature and difficult to understand [99–103]. The computation in decision evaluation problems by using this approach is comprehensive in nature as set included the four values under GTFN membership function.

4.1. Aggregation of Appropriateness Ratings (ARs) and Priority Weights (PWs). The priority weight (PW) reflects the importance, while rating reflects the value of measure/metrics as per subjective perception of DMs [104–106]. It is observed in many studies that PW influences the decision making scenario. The assigned priority weight corresponding to metrics can fruitfully change the preference order of performance metrics. The high PW is assigned to the most significant metrics [107]. We can understand by analyzing a scenario model of supplier evaluation, if the supplier's performance is evaluated based on the two metrics such as purchasing cost (PC) and service (S). In this case, DMs assigned the PW such as purchasing cost (PC) = 0.55 and service (S) = 0.45 under sum of PW = 1 and assigned the same rating such as PC = 50 and S = 50 (out of rating = 100 point). Then, it is found by calculating score that supplier = $W * R$(PC) = 0.55 ∗ 50 = 27.50 and $W * R(S)$ = 0.45 ∗ 50 = 22.5. It is explicated that assigned different weights against metrics under same ratings can change the preference order of metrics in measuring performance of a firm.

On the other hand, in the benchmarking decision making process or mapping performance of alternative industries, assigned ratings by DMs can only change the alternative scores, while the PW does not affect because the weights of set of metrics are similar for considered alternatives.

The research documents [45, 108] are used to build equations (6) and (7), which are used to aggregate the appropriateness ratings and priority importance weights against metrics. Appropriateness ratings against (1st level) measures can be computed by the following equation:

$$R_i = \frac{\sum R_{ij}}{C_{ijn}} = \frac{R_{ij1} + R_{ij2} + R_{ij3} + R_{ij4} + R_{ij5} \ldots\ldots\ldots\ldots R_{ijn}}{C_{ijn}}. \quad (6)$$

The appropriateness rating R_i of 1st level measures is computed from 2nd level metrics by using equation (6). In the above expression, $\sum R_{ij}$ is denoted as submission of appropriateness ratings R_{ij} of j_{th} 2nd level metrics, which are under i_{th} R_i (1st level measures).

Similarly, the priority importance weight of 1st level measures is computed from 2nd level metrics by using the following equation:

$$w_i = \frac{\sum w_{ij}}{C_{ijn}} = \frac{w_{ij1} + w_{ij2} + w_{ij3} + w_{ij4} + w_{ij5} \ldots\ldots\ldots\ldots w_{ijn}}{C_{ijn}}. \quad (7)$$

In this expression, $\sum w_{ij}$ is denoted as submission of priority importance weights of $w_{ij} j_{th}$ 2nd level metrics, which is under $i_{th} w_i$ (1st level measures).

4.2. Novel Fuzzy Performance Index (NFPI) towards calculating the results in %

$$\text{FPI} = \frac{\sum U_i \otimes w_i}{\sum w_i}. \quad (8)$$

In this expression, U_i and w_i are denoted as computed aggregated appropriateness rating and aggregated fuzzy priority weight as GTFN set of 1st level measures.

The centroid formula for defuzzification of the GTFN set $[A_i]$ is proposed [109]:

$$A_i = [a.b, c, d, \omega] \text{ Here, } [\omega_i = 1],$$

$$\overline{x}_0(A) = \frac{1}{3}\left[a + b + c + d - \frac{dc - ab}{(d + c) - (a + b)}\right],$$
$$\overline{y}_0(A) = \omega\frac{1}{3}\left[1 + \frac{c - b}{(d + c) - (a + b)}\right]. \quad (9)$$

The crisp value $R(A)$ is as follows:

$$R(A) = \sqrt{\overline{x}_0 2(A) + \overline{y}_0^2(A)}. \quad (10)$$

In addition, the current performance and performance loss can be determined by the following [110]:

$$\text{NFPI} = \frac{R(A)_{\text{FPI}}}{R(A)_{\text{SFPI}}} \times 100\%, \quad (11)$$

$$\text{performance loss} = 100\% - \text{current performance } (\%). \quad (12)$$

Here, $R(A)_{\mathrm{FPI}}$ is the defuzzification of the fuzzy performance index and $R(A)_{\mathrm{SFPI}}$ is the defuzzification of the set/standard fuzzy performance index.

4.3. Computation of Fuzzy Performance Importance Index (FPII). After evaluating NFPI, the purpose of research work is to identify the weak and strong performing GSC metrics and measures and quantify their performances. The concept of computing FPII is over evaluated PWsaRs. It is found that the higher FPII of any metrics reflects the greater contribution towards GSC [96].

$$FPII_{ij} = w'_{ij} \times U_{ij}, \quad w'_{ij} = \left[[(1,1,1,1;1)] - w_{ij} \right], \tag{13}$$

where U_{ij} is the aggregated fuzzy appropriateness ratings and w_{ij} is the aggregated fuzzy priority weights of k_{th} 2nd level metrics under i_{th} 1st level evaluation measures [96]. Since, if we directly calculate FPII, the important weights w_{ij} will neutralize the performance ratings in computing FPII; in this case, it will become impossible to identify the actual weak performing areas (low performance rating and high importance). If w_{ij} is high, then the transformation $[(1,1,1,1,w_{ij}) - w_{ij}]$ is low. Consequently, to elicit the metrics with low performance rating under high importance weights, the formula is used. $\mathrm{FPII}_{ij} = [(1,1,1,1,w_{ij}) - w_{ij}] \otimes U_{ij}$.

4.4. Modified Degree of Similarity (DoS) Mathematical Model: Identification of Weak and Strong Performing GSC Metrics. The DoS approach enables the manager to measure the DoS between the two GTFN sets. The approach was only applicable to shortlist the strong and weak GSC metrics under the assessment of two GTFN sets by experts earlier. The existed DoS approach is modified by incorporating the scheme of negative and positive ideal solution. The modified DoS approach addressed the two drawbacks such as eliminate the requirement of two GTFN sets from experts and able to map the performance gap of metrics from its ideal value.

Let us suppose that, a degree of similarity between two fuzzy sets A and B is defined as follows:

$$S\,(A,B) = se \times sp, \tag{14}$$

where

$$se = \begin{cases} e^{-|a_1 - b_1|}, & a_1 = a_4 \text{ and } b_1 = b_4, \\ e^{-(k+z+h)}, & \text{otherwise}, \end{cases} \tag{15}$$

where k is the span deference, z is the center deference, and h is the center width deference between A and B, respectively.

$$k = \left| (a_4 - a_1) - (b_4 - b_1) \right|,$$
$$z = \left| \frac{(a_4 + a_1)}{2} - \frac{(b_4 + b_1)}{2} \right|, \tag{16}$$
$$h = \left| (a_3 - a_2) - (b_3 - b_2) \right|,$$

and

$$sp = \frac{DP + \min\ (P(A), P(B))}{DP + \max\ (P(A), P(B))},$$

$$P(A) = \sqrt{(a_1 - a_2)^2 + w_a^2} + \sqrt{(a_3 - a_4) + w_a^2} + (a_3 - a_2) - (a_4 - a_1), \tag{17}$$

$$P(B) = \sqrt{(b_1 - b_2)^2 + w_b^2} + \sqrt{(b_3 - b_4) + w_b^2} + (b_3 - b_2) - (b_4 - b_1),$$

where $P(A)$ and $P(B)$ are the perimeters of A and B. DP is an amending zero in the numerator and denominator $DP \in (0, 0.1)$:

$$\text{Preference orders of metrics in\%} = \frac{\{S\,(A,B)\}}{\mathrm{Max}\{S\,(A,B)\}} * 100. \tag{18}$$

The computation of positive and negative ideal solution from defined FPII sets is as follows:

$$\mathrm{IFPII}_{ij} = \max\left[\mathrm{FPII}_{ij}\left[a_{ij}, b_{ij}, c_{ij}, d_{ij}\right]\right] B \in, \tag{19}$$

$$\mathrm{IFPII}_{ij} = \min\left[\mathrm{FPII}_{ij}\left[a_{ij}, b_{ij}, c_{ij}, d_{ij}\right]\right] C \in. \tag{20}$$

$\mathrm{maxFPII}_{ij}$ is the defined maximum value evaluated from defined FPII sets of each metrics, $B \in$ is the beneficial metrics, and $C \in$ is the cost/nonbeneficial metrics.

5. Empirical Case Research (Data Analyses)

This is an assumed empirical case study of automobile parts (gears and pistons) manufacturing industry, which is located at south part of Zambia. This company supplies the said attribute of parts to its partner's companies. The case study company realized the necessity to evaluate as well as measure own GSCM performance in the terms of GTFN set/scale, crisp value, and % and also identify the weak and strong performing metrics with quantifying their performance gap from ideal value under expert's opinion. From this contemplation, the authors conducted the literature review and audited the GSCM of case study industry and proposed a GTFN set-based theoretical GSCPM multi-level hierarchical index. The index consisted of measures and their interrelated metrics, in which green purchasing (C_1), green marketing (C_2), green production (C_3), green design (C_4), green packaging (C_5), and green recycling (C_6) are considered as measures at 1st level and disseminated into 2nd level metrics. The proposed index is displayed in Table 2, and definitions are shown in Table 3.

Later, equations (14), (18), and (19) are utilized to compute the weak and strong performing measures and metrics (by using backward rule [96]), depicted in Table 10, which assisted the managers to augment the GSC performances up to 100% by hunting the weak defined metrics.

The procedural steps for measuring the GSC performance are summarized as follows:

Table 2: A GTFN set-based GSCPM multilevel hierarchical index.

Measures (C_i)	Metrics (C_{ij})	References
Green procuring (GP), C_1	Fulfillment of state environmental regulations, $C_{1,1}$	[41, 111]
	Fulfillment of federal environmental regulations, $C_{1,2}$	[41, 112]
	Buying firm's environmental mission, $C_{1,3}$	[14, 113]
	Supplier's commitment in providing environmentally friendly packages, $C_{1,4}$	[55]
	Environmental audit for suppliers' internal management, $C_{1,5}$	[21, 114]
Green advertisement (GA), C_2	Green announcement, $C_{2,1}$	[115]
	Green delivery, $C_{2,2}$	[96, 115, 116]
	Collaboration with customers, $C_{2,3}$	[117]
	Green strategy of substitute product producers, $C_{2,4}$	[115]
	Anticipating improvement in product functional quality, $C_{2,5}$	[44, 115]
Green production (GPr), C_3	Internal multinational policies leading to advantage over competitors, $C_{3,1}$	[48, 101, 118]
	E-logistics and environment, $C_{3,2}$	[115]
	Skill policy entrepreneurs, $C_{3,3}$	[51, 119]
	Integration with green product suppliers, $C_{3,4}$	[120, 121]
Green design (GD), C_4	Design of products for reuse, recycle, recovery of material, and component parts, $C_{4,1}$	[59, 122]
	Public disclosure of environmental record, $C_{4,2}$	[11, 123–125]
	Reduction in environmental emissions, $C_{4,3}$	[123, 126]
Green packaging (GP), C_5	Integrating environmental thinking and innovation in packaging, $C_{5,1}$	[14, 120, 127]
	Eco-labeling of products or packaging, $C_{5,2}$	[52, 128, 129]
	Reduction in packaging weight, $C_{5,3}$	[57, 58, 123]
Green recovery (GR), C_6	Recycling degree to ensure full usage of resources, $C_{6,1}$	[117, 130]
	Recycling revenues, $C_{6,2}$	[49, 50, 131, 132]
	Returning product ratio, $C_{6,3}$	[8, 56, 133]

Table 3: Definitions of green supply chain performance metrics.

Notations	Descriptions	Notations	Descriptions	References
C_1	GP reflects the receiving of the eco-friendly materials/stuffs from vendors or purchase the materials from vendors under environmental practices.	$C_{1,1}$	It measures that the firm is able to maintain the level of pollution as per state environmental regulations. Its main objective is to protect human social life.	[41, 111]
		$C_{1,2}$	It measures that the firm is following the national environmental regulations. In order that, the firm can control the air, water, and on land pollution.	[41, 112]
		$C_{1,3}$	It measures that the firm able to take action for purchasing the products/services under green concerns. The environmental mission ensures the firm for a healthy environment for current and future generation.	[14, 113]
		$C_{1,4}$	It measures that the commitment of supplier must be ethical towards its partners regarding supplying of the raw/finished goods with eco-friendly packing.	[55]
		$C_{1,5}$	It measures the periodic performance evaluation scheme of the firm's partners/suppliers. It ensures the firm about its efficient internal management system towards purchasing the eco-friendly materials.	[21, 114]
C_2	GA directs the organization to execute the eco-friendly practices during the promotion of the goods/services towards public via media.	$C_{2,1}$	It measures the ability of firm to periodically declare the green policy across firm' employees as well as customers.	[115]
		$C_{2,2}$	It measures the ability of firm to provide the delivery of products to its partners/customers under environmental practices.	[96, 115, 116]
		$C_{2,3}$	It measures the customer's feedback system of firms' about firm's business, products, and different services.	[117]
		$C_{2,4}$	It measures the firm' efforts towards adopting the green practices to sale its substitute of identical product.	[115]
		$C_{2,5}$	It measures the planning of the firm towards improving the functionality of products/services.	[44, 115]
C_3	GPr states that manufacturing process should be designed to reduce the waste and high energy emission, resource's consumption, and so on.	$C_{3,1}$	It deals with the preplanned internal multinational policy of the firm to address the dynamic competitive global business environment.	[48, 101, 118]
		$C_{3,2}$	It measures the adaption of E-logistic software and technique for carting the data (documents) from firm to its trading partners without couriers.	[115]
		$C_{3,3}$	It measures that level of firm's recruitment policy to recruit only skill entrepreneurs, which help firm to survive at competitive market.	[51, 119]
		$C_{3,4}$	It measures that does the firm has interaction with other GSC suppliers.	[120, 121]
C_4	GD is concerned with the eco-design of entire production process.	$C_{4,1}$	It measures the ability of firm to recycle the recovered products after its useful life or can be refined on recovery.	[59, 122]
		$C_{4,2}$	It mapped that does the firm used to share the environmental policy and records with its suppliers or customers.	[11, 123–125]
		$C_{4,3}$	It mapped that does the firm able to reduce the substances, which leak and mix with environmental air.	[123, 126]

Table 3: Continued.

Notations	Descriptions	Notations	Descriptions	References
C_5	GP states that wrapping of manufactured products must be eco-friendly.	$C_{5,1}$	It measures that does the firm has green innovative idea and thinking and idea for acting on green packaging practice.	[14, 120, 127]
		$C_{5,2}$	It measures the degree of quality of eco-labeling/packing of products.	[52, 128, 129]
		$C_{5,3}$	It measures the ability of firm towards adapting the practice regarding reducing the weight of packing's material.	[57, 58, 123]
C_6	GR states that industries must compile the environmental protection policies and solutions in order to maintain the level of pollution as per the legal norms.	$C_{6,1}$	It measures the ability of firm for effective utilization of green recycling practices.	[117, 130]
		$C_{6,2}$	It measures the ability of firm to obtain the high revenue by green recycling products.	[49, 50, 131, 132]
		$C_{6,3}$	It measures the ability of firm to act swiftly to repair the returned products under the green practices.	[8, 56, 133]

Table 4: The scale for assigning ratings and weights against metrics.

Linguistic terms (Metrics ratings)	Linguistic terms (Priority weights)	GTFN sets
Absolutely poor (AP)	Absolutely low (AL)	(0, 0, 0, 0; 1.00)
Very poor (VP)	Very low (VL)	(0, 0, 0.02, 0.07; 1.00)
Poor (P)	Low (L)	(0.04, 0.1, 0.18, 0.23; 1.00)
Medium poor (MP)	Medium low (ML)	(0.17, 0.22, 0.36, 0.42; 1.00)
Fair (F)	Medium (M)	(0.32, 0.41, 0.58, 0.65; 1.00)
Medium good (MG)	Medium high (MH)	(0.58, 0.63, 0.80, 0.86; 1.00)
Good (G)	High (H)	(0.72, 0.78, 0.92, 0.97; 1.00)
Very good (VG)	Very high (VH)	(0.93, 0.98, 1.00, 1.00; 1.00)
Absolutely good (AG)	Absolutely high (AH)	(1.00, 1.00, 1.00, 1.00; 1.00)

Table 5: Appropriateness ratings (ARs) assessed by decision-makers against 2nd level metrics.

Measures (C_i)	Metrics (C_{ij})	ARs						
		DM_1	DM_2	DM_3	DM_4	DM_5	DM_6	DM_7
C_1	$C_{1,1}$	VG	AG	F	AG	MG	VG	AG
	$C_{1,2}$	VG	MG	AG	AG	AG	F	AG
	$C_{1,3}$	VG	AG	MG	MG	MG	AG	AG
	$C_{1,4}$	AG	MG	G	G	AG	MG	MG
	$C_{1,5}$	VG	MG	G	G	MG	G	G
C_2	$C_{2,1}$	F	MG	G	G	MG	G	G
	$C_{2,2}$	G	MG	G	G	MG	G	G
	$C_{2,3}$	F	G	MG	G	MG	G	G
	$C_{2,4}$	G	MG	G	G	G	MG	G
	$C_{2,5}$	VG	MG	G	G	MG	G	G
C_3	$C_{3,1}$	MP	MG	MG	VG	MG	G	G
	$C_{3,2}$	F	MG	VG	G	MG	MG	VG
	$C_{3,3}$	F	G	G	VG	MG	VG	G
	$C_{3,4}$	F	MG	VG	F	G	G	VG
C_4	$C_{4,1}$	F	MG	G	G	MG	VG	F
	$C_{4,2}$	F	MG	G	MG	MG	G	G
	$C_{4,3}$	MP	MG	G	G	MG	G	MG
C_5	$C_{5,1}$	F	G	MG	G	MG	G	G
	$C_{5,2}$	MP	MG	G	MG	G	MG	G
	$C_{5,3}$	MP	G	G	MG	MG	G	MG
C_6	$C_{6,1}$	MG	G	AG	AG	G	G	MG
	$C_{6,2}$	AG	VG	G	G	G	AG	AG
	$C_{6,3}$	VG	VG	VG	VG	VG	G	G

Table 6: Priority weights (PWs) assessed by decision-makers against 2nd level metrics.

Measures (C_i)	Metrics (C_{ij})	PWs						
		DM_1	DM_2	DM_3	DM_4	DM_5	DM_6	DM_7
C_1	$C_{1,1}$	AH	MH	VH	VH	AH	AH	H
	$C_{1,2}$	AH	MH	VH	VH	AH	AH	H
	$C_{1,3}$	MH	AH	VH	VH	AH	AH	H
	$C_{1,4}$	AH	MH	VH	VH	AH	AH	H
	$C_{1,5}$	AH	MH	VH	VH	AH	AH	H
C_2	$C_{2,1}$	VH	VH	MH	VH	MH	VH	ML
	$C_{2,2}$	MH	VH	VH	VH	MH	VH	ML
	$C_{2,3}$	MH	VH	VH	VH	MH	VH	ML
	$C_{2,4}$	VH	VH	MH	VH	MH	VH	ML
	$C_{2,5}$	VH	VH	MH	VH	MH	VH	ML
C_3	$C_{3,1}$	M	MH	M	MH	VH	VH	ML
	$C_{3,2}$	M	MH	M	MH	VH	VH	ML
	$C_{3,3}$	MH	M	M	MH	VH	VH	ML
	$C_{3,4}$	M	MH	M	MH	VH	VH	ML

Table 6: Continued.

Measures (C_i)	Metrics (C_{ij})	PWs						
		DM_1	DM_2	DM_3	DM_4	DM_5	DM_6	DM_7
C_4	$C_{4,1}$	M	MH	M	M	MH	ML	VH
	$C_{4,2}$	M	MH	M	M	MH	ML	VH
	$C_{4,3}$	M	MH	M	M	MH	ML	VH
C_5	$C_{5,1}$	VH	VH	AH	M	MH	ML	VH
	$C_{5,2}$	AH	VH	VH	M	MH	ML	VH
	$C_{5,3}$	VH	VH	AH	M	MH	ML	VH
C_6	$C_{6,1}$	MH	H	VH	AH	VH	VH	H
	$C_{6,2}$	H	MH	VH	AH	VH	VH	H
	$C_{6,3}$	MH	H	VH	AH	VH	VH	H

Table 7: Computed aggregated PWsaARs against evaluation 2nd level metrics.

Measures, (C_i)	ARs	PWs
C_1	(0.823, 0.857, 0.911, 0.930, 1.000)	(0.661, 0.712, 0.807, 0.841, 1.000)
	(0.833, 0.860, 0.911, 0.930, 1.000)	(0.661, 0.712, 0.807, 0.841, 1.000)
	(0.810, 0.839, 0.914, 0.940, 1.000)	(0.661, 0.712, 0.807, 0.841, 1.000)
	(0.740, 0.779, 0.891, 0.931, 1.000)	(0.661, 0.712, 0.807, 0.841, 1.000)
	(0.710, 0.766, 0.897, 0.930, 1.000)	(0.661, 0.712, 0.807, 0.841, 1.000)
C_2	(0.623, 0.684, 0.837, 0.893, 1.000)	(0.822, 0.869, 0.946, 0.971, 1.000)
	(0.680, 0.737, 0.886, 0.939, 1.000)	(0.822, 0.869, 0.946, 0.971, 1.000)
	(0.623, 0.684, 0.837, 0.893, 1.000)	(0.822, 0.869, 0.946, 0.971, 1.000)
	(0.680, 0.737, 0.886, 0.939, 1.000)	(0.822, 0.869, 0.946, 0.971, 1.000)
	(0.710, 0.766, 0.897, 0.943, 1.000)	(0.822, 0.869, 0.946, 0.971, 1.000)
C_3	(0.611, 0.664, 0.800, 0.886, 1.000)	(0.796, 0.851, 0.930, 0.955, 1.000)
	(0.663, 0.720, 0.843, 0.917, 1.000)	(0.796, 0.851, 0.930, 0.955, 1.000)
	(0.703, 0.763, 0.877, 0.871, 1.000)	(0.796, 0.851, 0.930, 0.955, 1.000)
	(0.646, 0.710, 0.829, 0.851, 1.000)	(0.796, 0.851, 0.930, 0.955, 1.000)
C_4	(0.596, 0.660, 0.800, 0.877, 1.000)	(0.767, 0.805, 0.905, 0.940, 1.000)
	(0.603, 0.636, 0.820, 0.844, 1.000)	(0.767, 0.805, 0.905, 0.940, 1.000)
	(0.581, 0.684, 0.900, 0.893, 1.000)	(0.767, 0.805, 0.905, 0.940, 1.000)
C_5	(0.623, 0.636, 0.837, 0.844, 1.000)	(0.857, 0.890, 0.952, 0.973, 1.000)
	(0.581, 0.636, 0.789, 0.844, 1.000)	(0.857, 0.890, 0.952, 0.973, 1.000)
	(0.760, 0.800, 0.789, 0.947, 1.000)	(0.857, 0.890, 0.952, 0.973, 1.000)
C_6	(0.870, 0.903, 0.900, 0.987, 1.000)	(0.777, 0.818, 0.916, 0.950, 1.000)
	(0.870, 0.923, 0.966, 0.991, 1.000)	(0.777, 0.818, 0.916, 0.950, 1.000)
	(0.760, 0.800, 0.789, 0.947, 1.000)	(0.777, 0.818, 0.916, 0.950, 1.000)

Table 8: Computed aggregated PWsaARs for 1st level measures.

Measures (Ci)	ARs	PWs
C_1	(0.617, 0.648, 0.723, 0.746; 1.000)	(0.661, 0.712, 0.807, 0.841, 1.000)
C_2	(0.663, 0.722, 0.869, 0.921; 1.000)	(0.822, 0.869, 0.946, 0.971, 1.000)
C_3	(0.656, 0.714, 0.837, 0.881; 1.000)	(0.796, 0.851, 0.930, 0.955, 1.000)
C_4	(0.593, 0.660, 0.900, 0.871; 1.000)	(0.767, 0.805, 0.905, 0.940, 1.000)
C_5	(0.655, 0.691, 0.805, 0.878; 1.000)	(0.857, 0.890, 0.952, 0.973, 1.000)
C_6	(0.833, 0.875, 0.855, 0.975; 1.000)	(0.777, 0.818, 0.916, 0.950, 1.000)

Step 1. Collection of experts' opinion (in linguistic terms) based on the priority importance weight and appropriateness ratings scale for individual evaluation metrics: The proposed index is simulated by the subjective assessment of a committee of seven experts. The experts such as DM_1, DM_2, DM_3, DM_4, DM_5, DM_6, and DM_7 were evaluated and selected from the case study industry. One executive was selected from each department such as purchasing-1, marketing-2, production-3, design-4, packaging-5, material recycling-6, and environmental protection-7 on the basis of their experience, interaction with the manufacturing activities, and strong qualification cum decision making capabilities. Entire DMs were at the top management hierarchy, which daily contributed their efficiency to supervise, oversight,

Table 9: Computed fuzzy performance importance index (FPII).

Measures (C_i)	FPII (fuzzy performance importance index)	Positive ideal solution (PIS)
C_1	(0.279, 0.247, 0.176, 0.148; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.282, 0.248, 0.176, 0.148; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.275, 0.242, 0.176, 0.149; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.251, 0.224, 0.172, 0.148; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.241, 0.221, 0.173, 0.148; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
C_2	(0.111, 0.090, 0.050, 0.026; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.121, 0.097, 0.053, 0.027; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.111, 0.090, 0.050, 0.026; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.121, 0.097, 0.053, 0.027; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.126, 0.100, 0.054, 0.027; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
C_3	(0.125, 0.099, 0.056, 0.040; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.135, 0.107, 0.059, 0.041; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.143, 0.114, 0.061, 0.039; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.132, 0.106, 0.058, 0.038; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
C_4	(0.139, 0.129, 0.076, 0.053; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.140, 0.124, 0.078, 0.051; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.135, 0.133, 0.086, 0.054; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
C_5	(0.089, 0.070, 0.042, 0.023; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.083, 0.070, 0.039, 0.023; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.109, 0.088, 0.039, 0.026; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
C_6	(0.200, 0.164, 0.076, 0.049; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.200, 0.168, 0.081, 0.050; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)
	(0.175, 0.146, 0.066, 0.047; 1.000)	(0.282, 0.248, 0.176, 0.149; 1.000)

and manage the middle and bottom level management activities.

Step 2. Approximation of the linguistic evaluation information by using GTFN set: Then, the expert's panel was instructed to choose the linguistic variables corresponding to GTFN set. The expert's panel elected 1–9 point linguistic scale, which transformed into the GTFN set as pointed out in Table 4. Next, the committee was instructed to express their subjective preferences (valuation score) in linguistic terms against 2nd level GSC metrics for determining fuzzy PWsaARs, depicted in Tables 5 and 6.

Step 3. Performance measurement: loss and gain: Then, the fuzzy performance index (FPI) is computed by employing equation (8), which used the evaluated PWsaARs data of 1st level measures. Therefore, the evaluated fuzzy performance index (FPI) is computed as (0.556, 0.653, 0.918, 1.061, and 1.000), which is compared with FPI (0.640, 0.780, 0.980, 1.250, and 1.000) proposed/set by the top management (considered corresponding to ideal performance-100%). Then, equations (11) and (12) are utilized to compute an overall GSC performance of firm, which was found 87% out of 100% (ideal performance). Therefore, the firm was suggested to hike 13% GSC performance to gain ideal performance limit.

Step 4. Classification of weak and strong performing metrics and its performance gap: After computing the Novel fuzzy performance index of industry, it became really essential to quantify the performance of measure and metrics and from its ideal value (100%) and also identify the weak and strong performing 2nd level metrics. To evaluate results, the fuzzy performance important index (FPII) and positive ideal solution (as entire metrics are beneficial in nature) against 2nd level metrics are computed by usage of equations (13) and (19), respectively. The results are revealed in Table 9.

6. Managerial and Practical Implications

The proposed research work assisted the manager to manage as well as improve the GSCP of own industry (if it is found beneath the proposed or expected GTFN set scale). The two conduits are fruitfully presented here and assisted the manager to manage and control the GSCP.

(1) The *managerial implication* is that the developed two GTFN set-based mathematical models with NFPI approach are executed over the proposed index, which assisted the manager to measure the performance of own industry in three forms such as crisp value, GTFN set scale, and %. The specialty of the proposed models is that these two models make the DMs trouble-less in terms of sharing bulk GTFN set information against metrics. Models are able to estimate the PWsaARs of 1st level measures by availing the subjective information of their interrelated metrics. The *practical implication* is that the same models can also be executed in future to tackle the extended hierarchy of index, i.e., 3rd, 4th, 5th, and other levels of hierarchy in mapping the same GSC performance of the same or different industry. To understand more practically, in case of 4th level

Table 10: Computed ranking order against evaluation 2nd level metrics.

Metrics (metrics, C_{ij})	GSC performance of metrics (%)	Performance gap from ideal value of metrics (%)	Preference orders
$C_{1,1}$	99.50	0.50	2
$C_{1,2}$	100.00	0.00	1
$C_{1,3}$	98.20	1.80	3
$C_{1,4}$	93.19	6.8	4
$C_{1,5}$	91.09	8.9	5
$C_{2,1}$	79.08	20.9	11
$C_{2,2}$	80.78	19.2	9
$C_{2,3}$	79.08	20.9	11
$C_{2,4}$	80.78	19.2	9
$C_{2,5}$	81.68	18.3	8
$C_{3,1}$	80.28	19.7	10
$C_{3,2}$	82.08	17.9	8
$C_{3,3}$	83.785	16.2	7
$C_{3,4}$	81.78	18.2	8
$C_{4,1}$	81.98	18.0	8
$C_{4,2}$	82.08	17.9	8
$C_{4,3}$	81.08	18.9	9
$C_{5,1}$	75.48	24.5	12
$C_{5,2}$	74.67	25.3	12
$C_{5,3}$	79.08	20.9	11
$C_{6,1}$	91.39	8.6	5
$C_{6,2}$	92.89	7.1	4
$C_{6,3}$	88.69	11.3	6

GSCPM index, DMs have to assign PWsaARs against solely 4th level metrics, while the PWsaARs information of 3rd, 2nd, and 1st level can be computed under back-propagation.

(2) The *managerial implication* is that the proposed modified DoS accompanied with FPII is executed over the proposed index to assist the manager for both objectives such as to trace the weak and strong metrics and measure the performance gap and closeness to its ideal performance. The introduction of PIS and NIS idea on FPII data helped the DMs to assign only one linguistic variable against each metrics to attain said both objectives; therefore, DMs would not be requested to assign two linguistic variables. The *practical implication* is that the manager can explored the same modified DoS along with FPII on extended GSCP metrics or different GSCP indexes of different industries for addressing the said objectives.

7. Conclusions

The conclusion of the research work strikes over the attainment of IS by usage of the GSCM strategy or architecture. The conclusion section enrolled the results, future research directions, and limitation of the proposed research work.

7.1. Results. The results of the research work are split into two parts as discussed. The GSC performance of case study firm is found 87%, which need to be improved up to 13% to satisfy the ideal value (100%) or meet the expected performance. The performance gaps of metrics are presented in Table 10. The authors recommended that weak metric's GSCP should be brought up to $C_{1,\,2}$. The authors also advised the managers to fulfill performance gap of metrics to attain the ideal GSC performance.

7.2. Future Directions. From future directions perspective, the extensive multilevel hierarchical index (intended to 1st, 2nd, 3rd, and 4th level) can be constructed and utilized with the proposed approach to measure the performance in different quotations. The manager is facilitated to improve own firm's GSCP if the performance is ascertained below the ideal limit/expected level by ramping up metrics GSC performance's gap. The industries, who utilize the GSC metrics as a strategy to sustain at competitive market, would gain the maximum benefit from the proposed research work. The industries can explore the presented idea periodically for measuring the performance and can improve the same if performance is found weak. GSCM scholars can utilize presented research work to boot up their wisdom about green measures and their metrics contribution towards sustainability, metrics identification new approach, and idea to build the advance/extended index.

7.3. Limitation. The research work ensures the managers to solve the performance measurement problem of metrics such as the weak metrics evaluation and identification problem and overall performance mapping of individual industry under the GTFN set-based GSCM index. Therefore, the multiobjective optimization, linear regression, and data forecasting problems cannot be solved using proposed mathematical models, approach, and index. The managers can write the C and JAVA programming for measuring the performance of own firm in different terms and also identify metrics performance gaps and closeness to ideal value in short span of time.

Data Availability

The data used to support the findings of this study are available in Tables 1–10.

Disclosure

This article is the part of remote employment research.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

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