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RESEARCH ARTICLE

Performance Mapping of Mixed GSCM Architectures by using Holistic GTFs-PI-Degree of Similarity Approach

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Abstract

Background/Objective: The idea of Green Supply Chain Management (GSCM) gained the momentum among the current scholars to manage and control the pollution cum Global Warming (GW) of production industries 4.0. It is absorbed that standard or ideal GSCM performance of industry 4.0 can be gained by recognizing the current performance of GSCM architectures from ideal performance level. Recently, Performance Evaluation and Measurement (PEM) approaches towards mapping the performance of GSCM architectures industry 4.0 are still least explored by previous researchers. The objective of research work is diverted towards assisting the Green Entrepreneurs (GEs) of Industry 4.0 from a Generalized Trapezoidal Fuzzy set (GTFs)-based decision support system for recognizing the poor performing GSCM architectures industry 4.0. **Method:** The author proposed the holistic approach to provide the solution to aforesaid dilemma, where GTFs-PI (Performance Index) approach is executed to estimation the overall GSCM performance of each architectures at 2nd level (in the terms of GTFs-PI) and subsequently, DoS (Degree of Similarity) approach is employed for identifying the weak/poor performing GSCM architectures industry 4.0 (to be mileage up to standard/ideal performance of GSCM architecture industry 4.0). **Finding:** An empirical case study of a shaft production industry 4.0 (compliance the GSCM architectures), is demonstrated to validate the presented research activity. The architecture's performances are advised to accelerate up to 6.0564349626% or sp=0.88 (is considered as ideal as per holistic opinion of DMs). **Novelty :** The work is novel in the terms of development of model and holistic approach: (1) constructed model is creative, innovative in nature as dealt with universal GSCM strategies linked to architectures industry 4.0. (2) the approach package is holistic in nature, can be used to map the performance of each GSCM architectures and divide them as weak and strong performing architectures and suggesting insights to obtain mileage up the GSCM architectures 4.0 up to standard/ideal level.

Keywords: Green SC; Model; Linguistic Information; Performance Measurement (PM); GFNs-Performance Index (PI)

1 Industry 4 0-SCM

The industry 4.0 is known as an industrial revolution to industries, is primarily described as Internet of Things (IoTs) in industries. SCM defined as potential network among the supplier to end users. The industry 4.0 adapted by the many industries such as production, oil and gas supplier, energy, mining, metals etc., and become the efficient network for exciting the digital transformation across the industrial SCM. It is accepted as the digital transformation of information across the industrial horizontal and vertical SCM. Industry 4.0 escalates the automation in SCM by using the artificial intelligence network and the micro level sensors. Industry 4.0 is tangible and intended to include technologies and embedded processes in SCM. Industry 4.0 uses several SCM architectures in industries i.e., Enterprise Resource Planning (ERP), Manufacturing Execution Systems (MES) and Plant Control. The usage of architectures of industry 4.0 to speed up and optimize the SCM is called as SCM architectures industry 4.0. It is observed that today, SCM architectures industry 4.0 is contributing a lot towards addressing the defies of industrial modern SCM by adding the faster delivery to the ultimate customers under lead time. SCM architectures industry 4.0 is found as valuable practices under controlling of IoTs. SCM architectures industry 4.0 is performs the functions of procurement of raw material, transforming raw materials into intermediate and then into end-products for distribution and selling to customers. SCM architectures industry 4.0 dealt with processing the fast materials into finished products and making delivery rapid to ultimate end users. SCM architectures industry 4.0 is an integration of IoTs towards linking the suppliers, manufacturers, warehouses and stores in such as manner so that valuable products can be produced and distributed to the customers at right quantities, at right locations at right time under right cost.

It is perceived that SCM architectures industry.0 currently participating against reducing the environmental across SCM network is called as Green SCM (GSCM) architectures Industry 4.0. GSCM architectures industry 4.0 is respected as important strategy nowadays by researchers to manage the green or carbon liberty based industry 4.0. GSCM architectures industry 4.0 is used as significant strategy to cope with global warming and competition. Currently, PM (Performance Measurement) soft device or tools are highly popular for mapping performance and identifying the most crucial GSCM architectures industry 4.0. Performance Measurement used to accept the feedback or information against GSCM architectures Industry 4.0 attaining the green strategic goal of organization. Recently it is found by literature dossiers that research work related to fuzzy set modelling of GSCM strategies (linked to GSCM architectures Industry 4.0) for identifying and benchmarking the poor/ideal GSCM architectures is performed quite least. By peer-review of many Research Documents (RDs), it is robustly ascertained that a few research works are conducted and publications are limited. The necessity to fulfil below said is determined. There is need to introduce such as:

- Mixed strategies based GTFs-GSCM architectural model appended with PI approach to estimate the performance of GSCM architectures industry 4.0 in the terms of GTFs-PI (product of GTFs-aggregated ratings and weights).
- Identifying GSCM architectures Industry 4.0 by using the Degree of Similarity (DoS) approach.

The above drawbacks are perceived as Research Gaps. The further relevant literature review is conducted to confirm the pre-RGs, few of them elaborated beneath:

The authors constructed a model of Lean, agile, resilience and green practices and solve a problem of sustainable Agri-food supply chain [(1)]. The authors audited the mediating outcome for Service Quality and latent association among the relational capital and organizational performance in a case study of mobile telecommunication setting [(2)]. The authors defined a rough set based MCDM approach under three decision makers of industry corresponding to five evaluation GSCM-PM metrics against candidate green suppliers. The authors have synchronized the previous work for evaluating and selecting the most suitable supplier for gearboxes Indian iron and steel industry [(3)]. The authors said that integrated best-worst strategies with VIKOR technique under interval type-2 fuzzy environment for green supplier need to be addressed. The appropriate green supplier is evaluated by employing the proposed integrated approach [(4)]. The authors proposed a digital supply chain model for Industry 4.0. The model is simulated by multi objective programming based barriers identification of approach [(5)]. The authors developed a multiple criterion appraisement model for supplier alternative evaluation and benchmarking under agile supply chain architectures [(6)]. The authors built a theoretical model of SCM industry 4.0 to barriers related to SCM industry 4.0 [(7)]. The authors audited the buyer-supplier relationships under SCM industry 4.0 in a case study of industry. The authors advised to improve it by using lean and alliance GSCM strategy [(8)]. The authors conducted a review on supply chain 4IR management strategy for quantifying the manufacturing society. The authors used the Google engine to conduct the literature review [(9)]. The authors identified by SCM industry 4.0 barriers to be addressed by conducting the literature survey in multi-perspective of SCM. The barriers are suggested to improve for lean supply chain only [(10)]. The author's identified the SCM barriers related to industry 4.0 technologies in a manufacturing sector and applied a MCDM method to analyze the inter-country comparative perspective [(11)]. The author's built a Stackelberg leader follower game strategies, where the vendors acted as stackelberg leader

and buyers acted as follow. The supplier's pricing decision is maximized by exploring the game-theoretic approach based strategies. It is suggested lastly that buyer's strategies should cooperate with supplier while investing the money for purchasing stuffs [12]. The authors depicted and analyzed the two sixty three survey of respondents of grocery's store such as managers under COVID-19 pandemic to identify the food SC strategies. The research indicated that SC strategies traceability and sharing data related to customers, positively controls the visibility of Indian market, while visibility influences the acceptance of sustainable indices for customers [13]. The authors conducted uncovering industry 4.0 challenges associated with technology for sustainable development of SCM industry 4.0 [14]. The authors quantified the behaviour intention of individuals in order to control SCM performance of a case study Indian organization by executing the cloud storage services based extended UTAUT2 technique [15]. The authors used the concept of the information scouting and internal improving in purpose to improve the cross-functional teams' culture in SCM [16]. The authors developed the digital barriers, allied to circular economy of production system and applied the fuzzy modelling over developed barriers to test the level of circular economy across production system. The authors suggested a few digital barriers need to be improved for enhancing the future sustainability via circular economy [17]. The authors advised the barriers of block chain technology to be adapted to boost up the green SCM of global industries [18]. In providing an extension support of previous authors, in 2023, again the authors suggested the authors to adapt the block chain technology to improve the performance of SCM [19]. The authors developed a novel fuzzy gain-loss computational technique and applied same to fuzzy based Decision support model for evaluating the resilient supplier in SCM [20]. The authors conducted the IIoT business architectures of SCM and quantified the research gaps of industry 4.0 SCM [21]. The authors explain the usage of fuzziness mathematical tools in decision-making scenarios [22]. The authors explored an idea of resilience SCM to identify the critical resilience factors for selecting the robust SCM infrastructure [23]. The authors audited the peruvian coffee SCM for flexibility, integration and agility concerns [24]. The authors highlighted the challenges associated with SCM for new generations and SCM researchers [25]. The authors proposed the decision-making framework; consisted of lean, agile, resilient, green environment and implemented the integrated MCDM technique for vendor evaluation and selection [26]. The authors proposed the graph-theoretic technique for benchmarking the leanness level of SCM of case study firm [27]. The authors highlighted the socially responsible SCM initiatives and their corresponding outcomes for taxonomy companies [28]. The authors proposed the SWOT analysis based block chain technological architectures to ensure the business SC capabilities and future sustainability [29]. The authors conducted the systematic literature review and classified the same for behavioural SC operations management and suggest that behavioural SC operations management helps the organization to control performance of future SC [30] .

After completing the peer-review, it is confirmed that there is still mitigation of mixed strategies based GTFs-GSCM architectural model appended with GTFs-PI-DoS for quantifying the performance of GSCM architectures from ideal value for Industry 4.0.

2 Methodology

The methodology is executed in this research forum is known as Holistic GTFs-PI (Performance Index) with Degree of Similarity (DoS) approach. The presented method included such as GTFs based PI (Performance Index) Approach-2.1, which is executed in purpose to estimation the overall GSCM performance of each architecture industry 4.0. While, DoS approach-2.2, is employed in motive to identify the weak GSCM architectures industry 4.0.

2.1 GTFs-Performance Index (GFNs-PI) approach

A fuzzy set in $\tilde{A}$ in a universe of discourse $x$is characterized by a membership function $\mu_{\tilde{A}}(x)$ which associates with each element $x$in xa real number in the interval [0, 1]. The function value $\mu_{\tilde{A}}(x)$is termed the grade of membership of x in $\tilde{A}$. A trapezoidal fuzzy number can be defined as and the membership function, is defined as $\tilde{A} = (a_1, a_2, a_3, a_4; w_{\tilde{A}})$ and the membership function $\mu_{\tilde{A}}(x) : R \to [0, 1]$, is defined as follows [31–33]

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

Here, $a_1 \le a_2 \le a_3 \le a_4$ and $w_{\tilde{A}} \in (0, 1)$

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 trapezoidal fuzzy numbers, then the operational rules of the trapezoidal fuzzy numbers $\widetilde{a}$ and $\widetilde{b}$ are shown as follows:

Addition Operation:

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

Substation Operation:

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

Multiplication Operation:

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

Division Operation:

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

P_i= i^{th} 1^{st} level evaluation index; $i = 1, 2, \ldots, m$

p_{ij}=j^{th} 2^{nd} level evaluation index which is under i^{th} 1^{st} level evaluation strategy P_i; $j = 1, 2, \ldots, n$

Let suppose that $A = (a_1, b_1, c_1, d_1; w_{\tilde{A}})$ and $B = \left(a_2, b_2, c_2, d_2; w_{\widetilde{A}}\right)$are two GTFs proposed by K decision makers, next the aggregated Appropriateness Ratings (ARs) and Weights (Ws) against architectures corresponding to option are calculated as[10,33,34].

:

$$\begin{aligned} a &= \frac{1}{k} \sum_{k=1}^{K} a_{12} \\ b &= \frac{1}{k} \sum_{k=1}^{K} b_{12} \\ c &= \frac{1}{k} \sum_{k=1}^{K} c_{12} \\ d &= \frac{1}{k} \sum_{k=1}^{K} d_{12} \\ w &= \min(w_{1,2}) \\ \text{GTFs} - \text{PI} &= \text{GTFs(Wij)} * \text{GTFs(Rij)} * \end{aligned} \tag{6}$$

2.2 GTFs-Degree of Similarity (DoS) approach

The GTFs-Degree of Similarity (DoS) approach, which measures the distance between Generalized Trapezoidal Fuzzy Numbers (GTFN) and positive ideal solution based GTFs to compute the weights vs p_{ij} architectures[35,36].

Let, suppose that, the degree of similarity is measured A and B are discussed as follows:.

$$\frac{S(A,B)}{C_{ij\max} S(A,B)} = \frac{se \times sp}{C_{ij\max} S(A,B)} \tag{7}$$

Where,

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

Where, k, is the span deference, z is the centre deference, h is the centre width deference between A and B, respectively.

$$\begin{aligned} k &= |(a_4 - a_1) - (b_4 - b_1)| \\ z &= \left| \frac{(a_4 + a_1)}{2} - \frac{(b_4 + b_1)}{2} \right| \\ h &= |(a_3 - a_2) - (b_3 - b_2)| \\ &\text{and} \\ sp &= \frac{DP + \min(P(A), P(B))}{DP + \max(P(A), P(B))} \cdots \end{aligned} \tag{8}$$

Where,

$$\begin{aligned} P(A) &= \sqrt{(a_1 - a_2)^2 + w_a^2} + \sqrt{(a_3 - a_4) + w_a^2} \\ &+ (a_3 - a_2) - (a_4 - a_1) \\ P(B) &= \sqrt{(b_1 - b_2)^2 + w_b^2} \\ &+ \sqrt{(b_3 - b_4) + w_b^2} + (b_3 - b_2) - (b_4 - b_1) \end{aligned}$$

Where, *P(A)* and *P(B)* are the perimeters of A and B. *DP*, is an correction factor to diminish the zeros in the numerator and denominator, $DP \in (0, 0.1)$

3 Results and Discussion

The results and discussion included the research framework-3.1, depicts the procedure to be obeyed to conclude the results outputs. Model development-3.2 indicates the structure of model (mixed strategies and their GSCM architectures industry 4.0). GSCM architecture industry 4.0 performance measurements under mixed strategies-3.3, depicted the application of developed holistic approach towards solving the model (as a part of case study).

3.1 Research framework

The structure of research dealt with the procedural adapted to successfully conducting the research work research. The Figure 1 demonstrates the research framework.

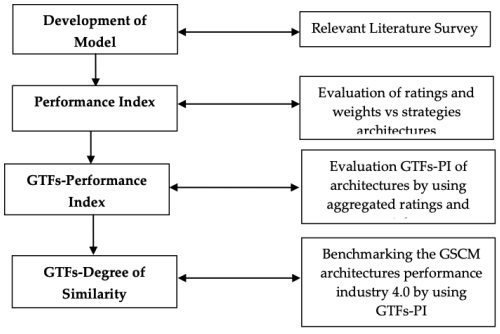

Fig 1. Research framework

- **Model:** The relevant literature survey assisted the author to construct the model, (includes four GSCM mixed strategies at 1st level and their interrelated GSCM architectures at 2nd level for industry 4.0).
- **GTFs-Performance Index Approach :** It assists to estimate PI (Performance Index) of each level architectures by using aggregated GTFs-ratings and weights.
- **GTFs-Degree of Similarity (DoS) Approach :** It helps for identifying the weak performing GSCM architectures industry 4.0, so that these can be mileage up to meet ideal/stand GSCM architecture industry 4.0.

3.2 Model development

The author conducted the literature review of sixty four (64) RDs in the context of GSCM architectures for industry 4.0 and its allied approaches by using Google engine. Over the 64 RDs, 20 were extruded due to their poor line up with target research objectives. Out of 44 RDs, 14 RDs assisted author to shape and establish the mixed strategies based GTFs based GSCM Industry 4.0 model and residue 30 added the value in the terms of building the significant holistic approach such as The GTFs-Performance Index (GFNs-PI) and Degree of Similarity (DoS) approach. The research presented only significant 36 research RDs out of 44 due to the concerns of length of research work. The RDs divergence summary and model is shown by Figures 2 and 3.

The constructed mixed strategies based GTFs based Industry 4.0 GSCM MCDM model is proposed in Table 1 and in Figure 2. The description of developed model is below.

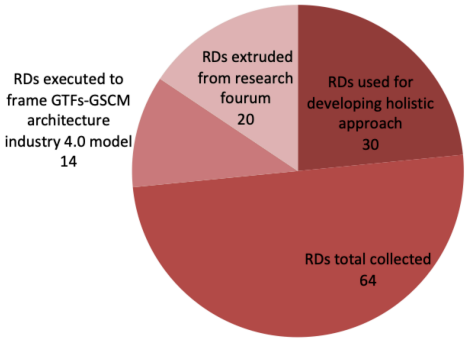

Fig 2. RDs divergence summary

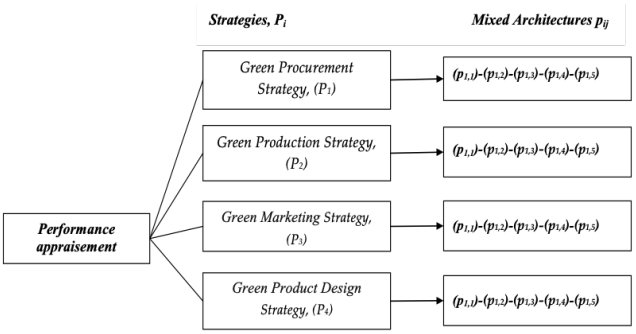

Fig 3. Model development

Incoming Stuffs evaluation and inspection for Green Production,($p_{1,1}$), Green Logistic,($p_{1,2}$), Green Documentation ,($p_{1,3}$), Green vendor's evaluation and selection,($p_{1,4}$), Store design for Green,($p_{1,5}$), Green equipment selection,($p_{2,1,}$), Machine evaluation and selection for Production,($p_{2,2}$), Establishing green assembly,($p_{2,3}$), Effort environmentally friendly Production,($p_{2,4}$), Effort toward environmentally friendly packages,($p_{2,5}$), Green marketing policy development,($p_{3,1,}$), Green documentation on advertisement,($p_{3,2}$), Green advertisement poster development,($p_{3,3}$), Green vehicles utilization on advertisement,($p_{3,4}$), Green Promotion,($p_{3,5}$), Green products design concern,($p_{4,1}$), Green layout design,($p_{4,2}$), Green manufacturing design,($p_{4,3}$), Green methods design,($p_{4,4}$) and Green recycling process design,($p_{4,5}$) are respected as architectures at level 2nd $p_{ij,}$. While, Green Procurement Strategy,(P_1), Green Production Strategy, (P_2), Green Marketing, Strategy, (P_3) and Green Product Design Strategy, (P_4) are respected as architectures at level 1st P_i.

3.3 GSCM architectures for industry 4 0 performance measurement under mixed strategies

An empirical case study of a shaft production industry 4.0 is demonstrated here to validate the conducted research forum. The said company perceived the necessity to map the GSCM architectures' performance against four strategies (under model) of own industry 4.0, shown in Table 1. To map such as GSCM architectures' performance, the company executed the proposed DSS (constituted by mixed strategies based GTFs-GSCM architectures model with 'holistic (GTFs-PI integrated with DoS) to measure the overall GSCM performance of each architectures and also identifying the poor performing GSCM architectures. The developed model is proposed and depicted in Figure 2. Next, to evaluate results, a committee of four expert's panel K_1, K_2, K_3 and K_4 is formed to express their ratings preferences as well as weights in the linguistic terms against 2nd level architectures p_{ij}.

The practical steps for measuring the GSCM performance of architecture of a case study industry 4.0 are presented below.

Step 1: Constructed of a team of decision making panel is constructed by inviting the decision making panel from the departments of case study industry 4.0.

Step 2: Evaluated and selected the appropriate linguistic scale for ratings and importance weights against evaluation strategies P_i and allied architectures p_{ij}.

Step3: Transformed the linguistic terms into Generalized Trapezoidal Fuzzy (GTFs), shown in Table 2.

Step4: Assessed linguistic ratings as well as weights against evaluation architectures p_{ij} by DMs panel are shown in Tables 3 and 4. The ratings and weights are aggregated by using equation-1-5.

Step 5: GFNs-PI mathematical approach (Equation.6) is used over evaluated aggregated GFNs-PI (evaluated by product of ratings and weights of 2nd level architectures p_{ij}) to calculate the GFNs-PI of GSCM architectures are shown with Ideal GTFs in Table 5.

Step 6: DoS (Equation. 7 and 9) is applied for identifying the weak GSCM architecture, is shown in Table 6. P_9 is found as the best and residue are suggested to be mileage up to the benchmarking level of ($p_{1,3}$) around 6.5% or sp=0.88 (is considered as ideal as per each DM).The results are shown by Pie chart, displayed in Figure 4.

The purpose of study is not to conduct the comparative analysis over previous studied results. While, the research work is organized to develop and illustrate the application of proposed novel mixed strategies based GTFs-GSCM model to solve the performance mapping performance of GSCM architectures of an individual industry 4.0 by proposing the novel methodology (holistic GTFNs-FPI-DoS approach). The research works exclusively focused on performance measurement of each GSCM architecture in the forms of PI (calibrated by GTFs ratings and weights) by usage of PI mathematical approach and also identifying weak and strong performance architecture by usage of DoS (suggest improving the weak GSCM architectures up to ideal architecture).

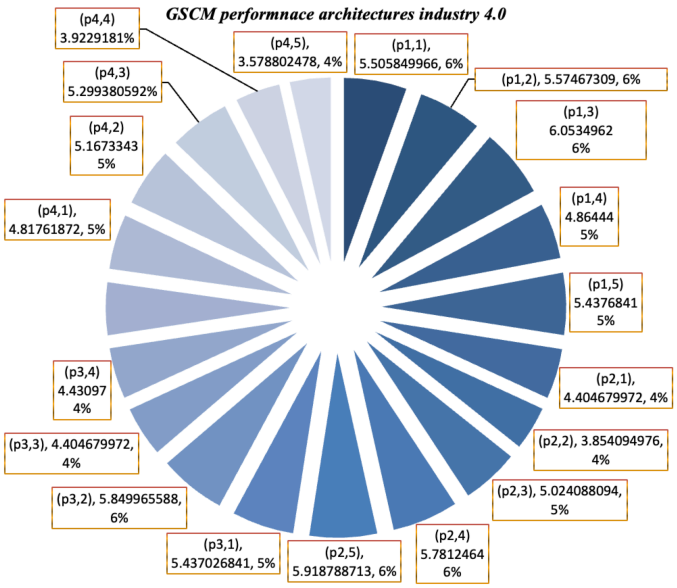

Fig 4. Performance box of GSCM architectures industry 4.0 by pie chart

Table 1. Mixed strategies based GTFs based GSCM architectures model

Goal (C)	Mixed strategies (Pi)	Interrelated architectures, (P_{ij})	Citations
Performance measurement of GSCM architectures industry 4.0	Green Procurement Strategy, (P_1)	Incoming stuffs evaluation and inspection for Green Production,($p_{1,1}$)	(2)
		Green Logistic,($p_{1,2}$)	(4)
		Green Documentation ,($p_{1,3}$)	(6), (11)
		Green vendor's evaluation and selection,($p_{1,4}$)	(7)
		Store design for green,($p_{1,5}$)	(9)
	Green Production Strategy, (P_2)	Green equipment selection,($p_{2,1,}$)	(12), (15)
		Machine evaluation and selection for Production,($p_{2,2}$)	(13)
		Establishing green assembly,($p_{2,3}$)	(14), (22)
		Effort environmentally friendly production,($p_{2,4}$)	(15)
		Effort toward environmentally friendly packages,($p_{2,5}$)	(16), (24)
	Green Marketing Strategy, (P_3)	Green marketing policy development,($p_{3,1,}$)	(2)
		Green documentation on advertisement,($p_{3,2}$)	(2)
		Green advertisement poster development,($p_{3,3}$)	(2)
		Green vehicles utilization on advertisement,($p_{3,4}$)	(2)
		Green Promotion ,($p_{3,5}$)	(2)
	Green Product Design Strategy, (P_4)	Green products design concern,($p_{4,1}$)	(2)
		Green layout design,($p_{4,2}$)	(2)
		Green manufacturing design,($p_{4,3}$)	(2)
		Green methods design,($p_{4,4}$)	(2)
		Green recycling process design,($p_{4,5}$)	(2)

Table 2. Set of linguistic variables and their corresponding GTFs

Linguistic terms for importance grade	Linguistic terms for performance rating	GTFs
DL: Definitely low	DL: Definitely low	(0.0, 0.0, 0.0, 0.0; 1.0)
VL: Very low	VL: Very low	(0.0, 0.0, 0.02, 0.07; 1.0)
L: Low	L: Low	(0.04, 0.10, 0.18, 0.23; 1.0)
ML: More or less low	ML: More or less low	(0.17, 0.22, 0.36, 0.42; 1.0)
M: Middle	M: Middle	(0.32, 0.41, 0.58, 0.65; 1.0)
MH: More or less high	MH: More or less high	(0.58, 0.63, 0.80, 0.86; 1.0)
H: High	H: High	(0.72, 0.78, 0.92, 0.97; 1.0)
VH: Very high	VH: Very high	(0.93, 0.98, 1.0, 1.0; 1.0)
DH: Definitely high	DH: Definitely high	(1.0, 1.0, 1.0, 1.0; 1.0)

Table 3. GTFs-appropriateness ratings in terms of linguistic variable for 2nd level GSCM architectures, (P_{ij})

GSCM architectures, (P_{ij})	K_1	K_2	K_3	K_4
($p_{1,1}$)	K_1_DH	K_2_DH	K_3_DH	K_4_DH
($p_{1,2}$)	K_1_MH	K_2_DH	K_3_DH	K_4_DH
($p_{1,3}$)	K_1_H	K_2_VH	K_3_VH	K_4_DH
($p_{1,4}$)	K_1_MH	K_2_MH	K_3_MH	K_4_DH
($p_{1,5}$)	K_1_DH	K_2_VL	K_3_L	K_4__MH
($p_{2,1}$)	K_1_MH	K_2_DH	K_3_DH	K_4_DH
($p_{2,2}$)	K_1_MH	K_2_VL	K_3_VL	K_4_DH
($p_{2,3}$)	K_1_MH	K_2_MH	K_3_MH	K_4_DH
($p_{2,4}$)	K_1_VL	K_2_MH	K_3_MH	K_4_MH
($p_{2,5}$)	K_1_ML	K_2_H	K_3_MH	K_4_MH
($p_{3,1}$)	K_1_DH	K_2_DH	K_3_DH	K_4_MH
($p_{3,2}$)	K_1_MH	K_2_DH	K_3_DH	K_4_MH
($p_{3,3}$)	K_1_MH	K_2_VL	K_3_VL	K_4_MH
($p_{3,4}$)	K_1_MH	K_2_MH	K_3_MH	K_4_MH
($p_{3,5}$)	K_1_DH	K_2_VL	K_3_VL	K_4_MH

Continued on next page

Table 3 continued

($p_{4,1}$)	**K** $_{1_}$MH	**K** $_{2_}$DH	**K** $_{3_}$DH	**K** $_{4_}$MH
($p_{4,2}$)	**K** $_{1_}$MH	**K** $_{2_}$VL	**K** $_{3_}$VL	**K** $_{4_}$MH
($p_{4,3}$)	**K** $_{1_}$MH	**K** $_{2_}$MH	**K** $_{3_}$MH	**K** $_{4_}$DH
($p_{4,4}$)	**K** $_{1_}$VL	**K** $_{2_}$MH	**K** $_{3_}$MH	**K** $_{4_}$DH
($p_{4,5}$)	**K** $_{1_}$ML	**K** $_{2_}$H	**K** $_{3_}$MH	**K** $_{4_}$DH

Table 4. GTFs-Importance weights in terms of linguistic variable for 2nd level GSCM architectures, (P_{ij})

GSCM architectures, (P_{ij})	**K_1**	**K_2**	**K_3**	**K_4**
($p_{1,1}$)	$K_{1_}$MH	$K_{2_}$MH	$K_{3_}$VL	$K_{4_}$DH
($p_{1,2}$)	$K_{1_}$MH	$K_{2_}$MH	$K_{3_}$MH	$K_{4_}$DH
($p_{1,3}$)	$K_{1_}$MH	$K_{2_}$H	$K_{3_}$MH	$K_{4_}$DH
($p_{1,4}$)	$K_{1_}$VL	$K_{2_}$DH	$K_{3_}$MH	$K_{4_}$MH
($p_{1,5}$)	$K_{1_}$ML	$K_{2_}$DH	$K_{3_}$DH	$K_{4_}$MH
($p_{2,1}$)	$K_{1_}$DH	$K_{2_}$VL	$K_{3_}$DH	$K_{4_}$MH
($p_{2,2}$)	$K_{1_}$MH	$K_{2_}$MH	$K_{3_}$VL	$K_{4_}$MH
($p_{2,3}$)	$K_{1_}$MH	$K_{2_}$VL	$K_{3_}$MH	$K_{4_}$MH
($p_{2,4}$)	$K_{1_}$MH	$K_{2_}$MH	$K_{3_}$VL	$K_{4_}$MH
($p_{2,5}$)	$K_{1_}$DH	$K_{2_}$MH	$K_{3_}$MH	$K_{4_}$MH
($p_{3,1}$)	$K_{1_}$MH	$K_{2_}$H	$K_{3_}$MH	$K_{4_}$DH
($p_{3,2}$)	$K_{1_}$MH	$K_{2_}$DH	$K_{3_}$MH	$K_{4_}$DH
($p_{3,3}$)	$K_{1_}$MH	$K_{2_}$DH	$K_{3_}$DH	$K_{4_}$DH
($p_{3,4}$)	$K_{1_}$MH	$K_{2_}$VL	$K_{3_}$VL	$K_{4_}$VL
($p_{3,5}$)	$K_{1_}$VL	$K_{2_}$MH	$K_{3_}$MH	$K_{4_}$MH
($p_{4,1}$)	$K_{1_}$ML	$K_{2_}$VL	$K_{3_}$VL	$K_{4_}$MH
($p_{4,2}$)	$K_{1_}$DH	$K_{2_}$MH	$K_{3_}$DH	$K_{4_}$VL
($p_{4,3}$)	$K_{1_}$MH	$K_{2_}$MH	$K_{3_}$VL	$K_{4_}$VL
($p_{4,4}$)	$K_{1_}$MH	$K_{2_}$H	$K_{3_}$MH	$K_{4_}$VL
($p_{4,5}$)	$K_{1_}$MH	$K_{2_}$DH	$K_{3_}$VL	$K_{4_}$VL

Table 5. Computed aggregated GTFs appropriateness ratings and importance weights for 2nd and 1st level GSCM architectures, (P_{ij})

GSCM architectures, (P_{ij})	**Computed GTFs-PI-Ratings for 2nd level**	**Computed GTFs-PI-Weights for 2nd level**
($p_{1,1}$)	(0.50,0.50,0.51,0.54;1.00)	(0.58,0.63,0.80,0.86;1.00)
($p_{1,2}$)	(0.25,0.25,0.27,0.30;1.00)	(0.25,0.25,0.27,0.30;1.00)
($p_{1,3}$)	(0.26,0.28,0.31,0.34;1.00)	(0.26,0.28,0.31,0.34;1.00)
($p_{1,4}$)	(0.25,0.25,0.27,0.30;1.00)	(1.00,1.00,1.00,1.00;1.00)
($p_{1,5}$)	(0.25,0.25,0.27,0.30;1.00)	(0.25,0.25,0.27,0.30;1.00)
($p_{2,1}$)	(0.50,0.50,0.51,0.54;1.00)	(0.58,0.63,0.80,0.86;1.00)
($p_{2,2}$)	(0.25,0.25,0.27,0.30;1.00)	(0.25,0.25,0.27,0.30;1.00)
($p_{2,3}$)	(0.69,0.72,0.85,0.90;1.00)	(0.69,0.72,0.85,0.90;1.00)
($p_{2,4}$)	(0.69,0.72,0.85,0.90;1.00)	(0.69,0.72,0.85,0.90;1.00)
($p_{2,5}$)	(0.76,0.80,0.91,0.95;1.00)	(0.76,0.80,0.91,0.95;1.00)
($p_{3,1}$)	(0.26,0.28,0.31,0.34;1.00)	(0.26,0.28,0.31,0.34;1.00)
($p_{3,2}$)	(0.25,0.25,0.27,0.30;1.00)	(1.00,1.00,1.00,1.00;1.00)
($p_{3,3}$)	(0.25,0.25,0.27,0.30;1.00)	(0.25,0.25,0.27,0.30;1.00)
($p_{3,4}$)	(0.50,0.50,0.51,0.54;1.00)	(0.58,0.63,0.80,0.86;1.00)
($p_{3,5}$)	(0.25,0.25,0.27,0.30;1.00)	(0.25,0.25,0.27,0.30;1.00)
($p_{4,1}$)	(0.69,0.72,0.85,0.90;1.00)	(0.69,0.72,0.85,0.90;1.00)
($p_{4,2}$)	(0.26,0.28,0.31,0.34;1.00)	(0.26,0.28,0.31,0.34;1.00)
($p_{4,3}$)	(0.69,0.72,0.85,0.90;1.00)	(1.00,1.00,1.00,1.00;1.00)
($p_{4,4}$)	(0.25,0.25,0.27,0.30;1.00)	(0.25,0.25,0.27,0.30;1.00)
($p_{4,5}$)	(0.50,0.50,0.51,0.54;1.00)	(0.58,0.63,0.80,0.86;1.00)

Table 6. Computed GTFs-PI & ideal Computed GTFs-PI and performance orders of 2nd level GSCM architectures

GSCM architectures, (P_{ij})	Computed GTFs-PI	Computed Ideal GTFs-PI	sp	Preference Orders
($p_{1,1}$)	(0.80,0.50,0.51,0.54;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.80	6
($p_{1,2}$)	(0.82,0.65,0.27,0.30;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.81	5
($p_{1,3}$)	(0.87,0.68,0.31,0.34;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.88	1
($p_{1,4}$)	(0.59,0.69,0.37,0.30;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.71	11
($p_{1,5}$)	(0.80,0.68,0.31,0.34;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.79	7
($p_{2,1}$)	(0.50,0.50,0.51,0.54;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.64	15
($p_{2,2}$)	(0.50,0.55,0.27,0.30;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.56	17
($p_{2,3}$)	(0.69,0.72,0.85,0.90;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.73	10
($p_{2,4}$)	(0.75,0.72,0.85,0.90;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.84	4
($p_{2,5}$)	(0.79,0.80,0.91,0.95;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.86	2
($p_{3,1}$)	(0.80,0.68,0.31,0.34;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.79	7
($p_{3,2}$)	(0.82,0.25,0.27,0.30;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.85	3
($p_{3,3}$)	(0.25,0.65,0.27,0.30;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.64	15
($p_{3,4}$)	(0.50,0.50,0.51,0.54;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.65	14
($p_{3,5}$)	(0.25,0.25,0.27,0.30;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.67	13
($p_{4,1}$)	(0.69,0.72,0.85,0.90;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.70	11
($p_{4,2}$)	(0.26,0.68,0.31,0.34;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.75	9
($p_{4,3}$)	(0.69,0.72,0.85,0.90;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.77	8
($p_{4,4}$)	(0.40,0.65,0.27,0.30;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.57	16
($p_{4,5}$)	(0.25,0.50,0.51,0.54;1.00)	(0.82,0.80,0.91,0.95;1.00)	0.52	18

4 Conclusions

PM is determined as a significant DSS and executed in purpose to map the efficiency as well as effectiveness of GSCM architecture industry 4.0. Effectiveness measures that degree of excellence of the mixed strategy to address the customer's requirement, while efficiency measures that performance of mixed strategies under cost concerns. It is probed that Multi Criterion Decision Making (MCDM) is ascertained as dynamic PM soft device, which helped to frame the decision making DSS.

The research work proposed a mixed strategy based GTFs-GSCM GSCM architecture model, which is executed to map the performance of each GSCM architecture from ideal value. The presented model consisted of twenty p_{1-20} architectures aligned with four P_{1-4} mixed strategies. The model experienced the linguistic information of four experts in the terms of linguistic ratings and weights assessment (address the subjectivity of architectures at p_{1-20}). The author employed the holistic approach; consisted of two approaches (GTFNs-PI-DoS) to provide the dynamic solution the model in a case study of shaft manufacturing industry 4.0. The GTFNs-PI (Performance Index) approach is applied to estimate the performance of each GSCM architecture industry 4.0. Subsequently, DoS approach is executed on aggregated GTFs-PI for identifying the weak architectures from ideal value. P_9 is recommended as the best architecture and residue are recommended to be mileage up to (p1,3)=6.0564349626%.. As part of managerial implication, the proposed DSS; consisted of (holistic approach with model) is dynamic in nature, can be executed to estimation the weak/poor performing SCM architectures of industry 4.0. The unique features of work exist in the developed model and holistic approach. From the future prospects, the work is assisting the GSCM industry 4.0 researchers and entrepreneurs to map the performance of other industry 4.0 under proposed model with approach.

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