Green Practices in the Supply Chain and their impact on Its Performance: In Perspective of Indian Plastic Processing Industry

Yogesh P. Deshmukh, Atul B. Borade

*Abstract***:** *Due to increased market competition in recent years, Indian plastic processing industries have realized their prospects of effective management of the supply chain to achieve cost-efficient operations with environment and social sustainability that can only be achieved through continuous improvement techniques. Lean tools and technique for managing the supply chain looks like an inevitable trend in enhancing the performance of plastic processing industries; while, performance evaluation is crucial in green supply chain implementation. Based on the management of green supply chain attributes, nineteen key performance metrics are prioritized and classified among four performance categories of economic, environmental, social and health & safety. A fuzzy-based method of evaluation of performance is proposed in this paper to assess the performance of lean tool based management of plastic supply chain. Supervisors of supply chain can anticipate aggregate performance of the cost and environment sustainable plastic supply chain. Sustainable strategies could be managed by considering dissimilar weights for diverse supply chain state of affairs.*

*Index Terms***:** *LTBGSC, LTBGSCM, Performance metrics, Supply chain management, Thermoforming*

I. INTRODUCTION

Supply chains are now seen as extended business activities that link companies in a variety of locations and make partners worthy of sustainable edge. In the management of routine operations, nowadays, the prospects for effective management of supply chain have been realized by companies [1]. Although, many enterprises eventually fail to design and develop highly effective performance measures and even failed to identify the metrics required to accomplish integrated management of supply chain. Measuring the quality of business process can assist in proper understanding of concerned activities across the supply chain, influencing motives of business players and enhancing its aggregate performance [2]. So as to effectively accomplish the supply chain objective of improving productivity and simultaneously conserving the environment and social values as compared to other companies, entire supply chain is required to get involved in continually improving the practices as well as developing sustainable methods. Consequently, it is essential to know the aggregate performance of the supply chain so as

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to know just how supply chains compete [3].

A proper planning involving supply chain policy and sustainable performance could be a significant characteristic as regards to the supply chain measures. [4] noticed that the choice of sustainable supply chain policy had an effect on performance of the supply chain. They also asserted that the strategic fit assuming the degree of relationship between sustainable policy, situation, leadership and organizational culture can develop healthier business performance. Thus, to obtain an impressive performance measures, the sustainable performance of a supply chain should be lined up together with the role of the supply chain players and market policy.

To stay sustainable in the increasingly worldwide market, lean philosophy is among the many initiatives which companies all over the world are been adopting [5], [6], [7]. The primary driving force leading to follow lean tools and techniques in greening the supply chain is to form an efficient and streamlined system that can control waste and pollutant releases at all levels of supply chain which satisfies the customers and the society at large [5], [7]. Lean does apply in most supply chains, especially those wanting to enhance performance by minimizing process waste and pollutant releases. For instance, cost and environment sustainable green supply chains could gain from using lean tools and techniques to get rid of all sorts of waste, and also minimize costs [8].

It is critical to formulate the supply chain performance measurement method because of complexities between supply chain policy, business competitiveness and supply chain measures. [9] observed that conventional measures which tend to measure financial metrics did not incorporate intangible indicators. To cope-up with qualitative and intangible measures fuzzy modeling technique is best suitable and is widely adopted in different aspects of supply chain management. Fuzzy oriented research on supply chain measurement can be traced through several studies in the literature. Performance metrics in substantial numbers can be considered in fuzzy modeling while considering the complexity of supply chain in terms of different elements and processes [10]. Therefore, a comprehensive framework for performance measures and also a fuzzy-based performance assessment method for entire supply chain measurement is crucial to deal with these challenges. Although, there exist a wide published research on supply chain performance measurement, it is still short of an effective performance metrics and measurement technique for two reasons, a) while

measuring the performance of supply chain which is cost and environment sustainable, strategic alignment is missing amongst sustainable policy and performance metrics [11], [12] and b) shortcomings while taking into account the linguistic terms as well as uncertainties involved in performance evaluation methods, particularly for lean tool based green supply chain [13]. Thus, the research issue dealt within this paper is, assessing lean characteristics and sustainable supply chain policies by consolidating the linkages between implementation of lean tools, green supply chain performance measures with sustainable policy, evaluation method and market position.

II. LITERATURE REVIEW

### A. Performance Metrics and Measurement in SCM

Performance measurement is described as the procedure of gauging the effectiveness along with efficiency of measures wherein measurement leads to quantification while action directs the performance [11]. Performance measurement systems are the comprehensive set of metrics that had to evaluate actions in terms of its efficiency and effectiveness [14], [15]. [16] identified four attributes for a good performance measurement system: all inclusiveness, its consistency, measurability and universality. The intent behind performance measurement of an organization is to (a) enable an entity to recognize it's processes as well as to verify how much they know or even disclose anything they don't understand; (b) determine where problems, pollutant releases, waste, bottlenecks, etc. are and just where improvements are necessary; (c) ensure there is no place for emotion, faith, or intuition in decision making, which should be solely based on facts; (d) planned improvements should be shown after actual happening; (e) identify whether consumers and societal requirements are met; and (f) specify success [17]. A performance measurement system is composed of substantial number of metrics or individual performance measures. The challenging roll has been to explore key performance measures linked with an organizational value adding segments. Despite the wide availability of literature, many important limitations are yet to be addressed by the researchers:

a. Proper alignment between performance measurement system and strategic goals is lagging [18].

b. Systematic approach in prioritizing the measures and metrics is required [5].

c. How to maintain consistency in performance measurement system while dealing with the dynamic environments and ever changing strategies? [9], [19].

Supply chain performance is relevant to sustainable strategies because supply chain competitiveness should relate to organisational goals. [32] remarked performance measurement system as a function of communicating the strategies and controlling the performance. Sustainable policy of a company can be defined relative to its competing companies in the form of consumer desires it tries to fulfill by its services and products [4]. Therefore, the basis for defining company goals is its sustainable policy. Sustainable strategies can be classified into: economic, environment, social and health & safety [4], [20]. To fulfill organizational objectives, supply chain performance measurement system needs proper alignment with each one of these sustainable strategies. To know the competitiveness of the supply chain, Understanding the entire supply chain performance is important.

In the current scenario researchers like [21], [22] developed a flexible, systemic and balanced performance measurement systems to counter justify these arguments. Probably the best accepted of these is considering the different phases of life cycle as plan, source, make, deliver and return [23]. Integration of all these phases has been expressed as an organized approach to identify, evaluate and monitor the performance of supply chain [22].
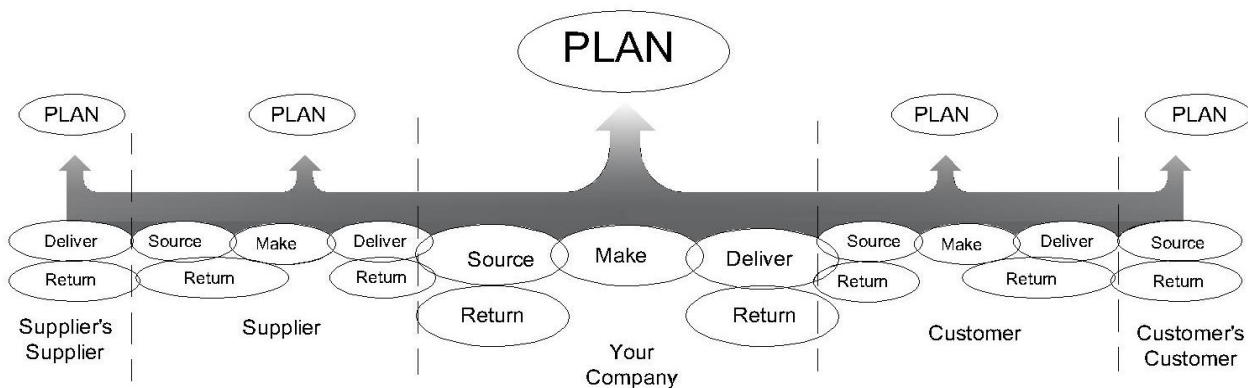
Figure 1: Reference model for supply chain operation [33]

These phases have the potential to combine different components of industrial engineering and most important practices into a single framework. Thus, from the view point of manufacturer's suppliers continued through distributor - dealer network upto the customers, supply chain management can be described as combined phases of life cycle aligned with company's operational policy (see Figure 1).

Supply chain with the basic need for sustainable performance and its configuration with the market policy is discussed here. Above deliberations result in the proposal to develop a

framework of performance metrics that could be aligned to the sustainable strategies and state-of-the-art manufacturing practices. And therefore, to achieve the synchronization between company's strategic goals and performance measurement system, the effects of best practices on performance metrics must be addressed. Cost and environment sustainable supply chains similar to lean tool based green supply chains and corresponding tools and techniques for improved performance are discussed at length in the following section.

B. Green Supply Chain Improvement Tools and Techniques

The term, "Green" means adopting best practices and series of activities to eliminate waste and pollutant releases, bring down non value added operations and develop value added practices. A green supply chain management usually means the identification of waste and pollutant releases across the supply chain stream and taking measures to eliminate them [6].

Lean concept in GSCM has experienced significant positive impacts on work productivity in various industries. Various phases of the life cycle can be utilized with the standard metrics to evaluate the performance of process and management practices which create bright performance. In this research five basic phases of the life cycle is actually the starting framework used to determine the best possible metrics to assess supply chain greenness and, because of this, the effects of various lean tools and techniques over five basic processes of life cycle are listed in Table 1.

Table 1: Effects of different lean tools and techniques over basic supply chain phases

Supply Chain Phases	Lean Tool & Technique	Author References
Plan	Cause & Effect,	[7]
	Voice of Customer (VOC)	[17]
	Kaizen	[24]
Source	NA	
Make	Total Productive Maintenance	[5]
	Inventory Control	[17]
	5 S	[26]
	Single minute exchange of die (SMED)	[25]
	Kaizen	[24]
	Waste (Mudo)	[26]
Deliver	Kaizen	[24]
Return	Waste (Mudo)	[26]
	Kaizen	[24]

In Table 1, we identified the effects of different lean tools over various tiers of supply chain with respective author references. Most authors have tried to find out about the potential effects of lean tools on five basic processes of supply chain. For example, [2], [4], [7], pointed out that Cause and Effect, Voice of Customer (VOC) and Kaizen had an impact on the plan stage by improving productivity, reducing waste and pollutant releases across the supply chain. Likewise, the effects of other lean tools on five different basic processes of supply chain are shown in Table 1. Later these effects are analysed to investigate the impact of lean tools on performance metrics which proves noteworthy to develop the best possible metrics

for green supply chain study. It thus becomes obvious that the advantages of lean tools can be measured using supply chain performance metrics and can also be used based on various supply chain strategies. Lean tools are applicable in most supply chains, especially those seeking to enhance performance by reducing waste and pollutant releases. For instance, cost and environment sustainable lean tool based green supply chains could gain by reducing costs through waste removal and enhance corporate image by curbing the pollutant releases. The relation between the key factors and performance of supply chain is proposed in Figure2.
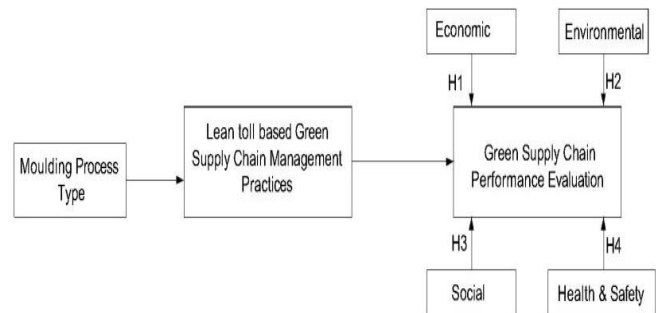
Figure 2: Conceptual framework of the research

In addition to above discussion it is recommended for more assessment of relations between, economic perspective, environmental concerns, social aspects, health and safety considerations and green supply chain performance. In order to determine the relation between these core factors, it would be important for cost and environment sustainable supply chain to investigate the hypothesises as under:

Hypothesis 1: Economic aspects influence supply chain performance.

Hypothesis 2: A holistic approach in managing the environmental impacts at upstream and downstream value chain stages improves the performance of supply chain.

Hypothesis 3: Workable solutions to improve the social conditions in the vulnerable areas affects supply chain performance positively.

Hypothesis 4: Promotion of occupational health and safety (OSH) requirements as an element of people dimension influences supply chain performance positively.

Performance metrics has both quantitative as well as qualitative measures. Qualitative metrics include linguistic behaviors which also comprises with non- financial measures. In a situation of uncertainty in decision making, fuzzy would be an appropriate method which enables modeling of a number of performance metrics across several processes and elements of a supply chain. Earlier description was based upon the effects of lean tools and techniques on these metrics and will be quantified by utilizing fuzzy based performance evaluation technique in the following section. Sustainable strategies for various supply chains based on products and processes will also be used by relating different relative weights to performance categories. So the proposed

performance measurement method will be used to evaluate the effect of sustainable strategies and different lean tools on the aggregate performance of supply chain.

III. PROPOSED PERFORMANCE EVALUATION METHOD

A. Select Supply Chain Optimal Metrics

For effective and efficient performance evaluation of a supply chain, measurement objectives should represent the organizat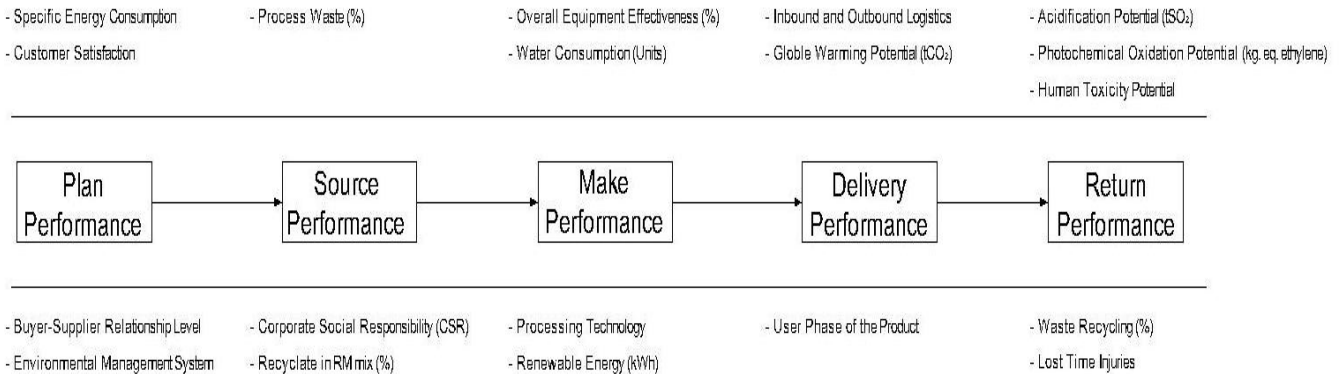ional objectives and the selected metrics must reflect a balance among financial as well as non-financial measures which can be correlated to strategic and operational levels of managerial decision making [8]. For more effectiveness in performance evaluation it is essential to reduce the relatively large number of established performance metrics into a few optimal metrics.

Based on the prevailing research, the best possible metrics are proposed by us (see figure 3) to evaluate the overall performance of cost and environment sustainable supply chain; for eg. [10], [27]. [2] recommended classification of

- Specific Energy Consumption
- Customer Satisfaction
- Process Waste (%)
- Overall Equipment Effectiveness (%)
- Water Consumption (Units)
- Inbound and Outbound Logistics
- Globle Warming Potential (tCO₂)
- Acidification Potential (tSO₂)
- Photochemical Oxidation Potential (kg. eq. ethylene)
- Human Toxicity Potential

Plan Performance → Source Performance → Make Performance → Delivery Performance → Return Performance

- Buyer-Supplier Relationship Level
- Environmental Management System
- Corporate Social Responsibility (CSR)
- Recyclate in RM mix (%)
- Processing Technology
- Renewable Energy (kWh)
- User Phase of the Product
- Waste Recycling (%)
- Lost Time Injuries

Figure 3: Metrics for evaluation of cost and environment sustainable supply chain

the performance measures in the form of economic, environment, social, health & safety using the five basic processes of supply chain. In this research, all the metrics are aligned according to five different processes of supply chain to evaluate individual performances at each process level and also the aggregate performance of supply chain.

The proposed metrics consists of crisp and linguistic values. Fuzzy enables modeling of large proportion of performance metrics across several stages of a supply chain. Initially we transform all the quantitative metric values in terms of triangular fuzzy numbers while qualitative metrics are expressed in linguistic terms. Performance of whole supply chain is evaluated by fuzzy TOPSIS after the conversion of both quantitative and qualitative metric values into their fuzzy numbers. After the conversion of both quantitative and qualitative metric values into their fuzzy numbers, performance of whole supply chain is evaluated by fuzzy TOPSIS taking into account the distance of non- lean and lean tools based green supply chain conditions from positive and negative ideal solutions. The particulars of fuzzy set theory, generation of triangular fuzzy number and details on fuzzy TOPSIS method are elaborated in the following sections.

B. Fuzzy Set Theory

Fuzzy set theory was proposed by [28] and it was first applied in control systems by [29]. This theory is basically concerned with the logic to take into account the vagueness in human thinking and emulate it with suitable mathematical tools. The process by which objects in a universal set X are worked out to be either members or non-members of a crisp set is defined by a discrimination function. For a particular crisp set A, this function allocates a value $\mu_A(x)$ to every x $\in$ X such that,

$$\mu_A(x) = 1 \text{ if } x \in A$$

$$\mu_A(x) = 0 \text{ if } x \notin A$$

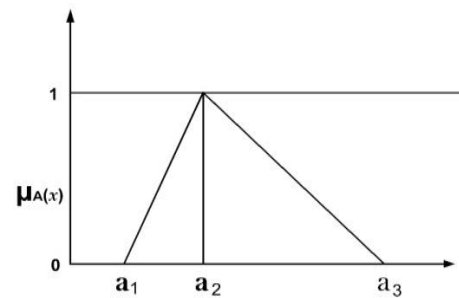Where, X is the universal set given in a particular problem which assumes values in the range from 0 to 1.

Figure 4: Triangular fuzzy number, A

C. Convert Metric Values into Triangular Fuzzy Number

All the metric values are required to be converted to triangular fuzzy numbers. First task is to collect the values of every individual metric before and after implementation of LTBGSCM. Assuming $i = 1, 2, ...m$ represents the varied situations of the supply chain before and after implementation of LTBGSCM. $j = 1, 2, ...n$ represents different performance categories of the supply chain and $k = 1, 2, ...t$ represents different metrics. Therefore,

$$I = (i_1, i_2, \ldots i_m) \; ; \; J = (j_1, j_2, \ldots j_n) \; ; \; K = (k_1, k_2, \ldots k_t) \; .$$

Assuming $x_{i_m j_n k_t 1}, x_{i_m j_n k_t 2}, \ldots x_{i_m j_n k_t t}$, are different values of d percentage of in-house recycling (per month) of plastic scrap for metric k_t under situation i_m and category j_n. Here k_t = percentage of process waste recycled, j_n = economic, i_m = after LTBGSCM implementation. Conversion of performance metrics values into quantitative as well as qualitative triangular fuzzy number will be discussed in the following two sub-sections. For conversion of metric values into triangular fuzzy numbers an algorithm is discussed as under and shown in figure 5.

D. Triangular Fuzzy Number for Quantitative Metric Values

Data required in terms of quantitative metrics is to be collected from relevant supply chain members. Since we assumed $x_{i_m j_n k_t 1}, x_{i_m j_n k_t 2}, \ldots, x_{i_m j_n k_t d'}$, which are different

values of d' percentage of process waste recycling for metric k_t under situation i_m and criteria j_n, these values are converted into triangular fuzzy number with the application of following algorithm.

E. Triangular fuzzy number for qualitative metric values

To generate qualitative metrics we make use of triangular fuzzy numbers derived from different triangular fuzzy linguistic terms. In this case the linguistic terms are expressed by an interval of two units of triangular membership functions as given in Table 2, where
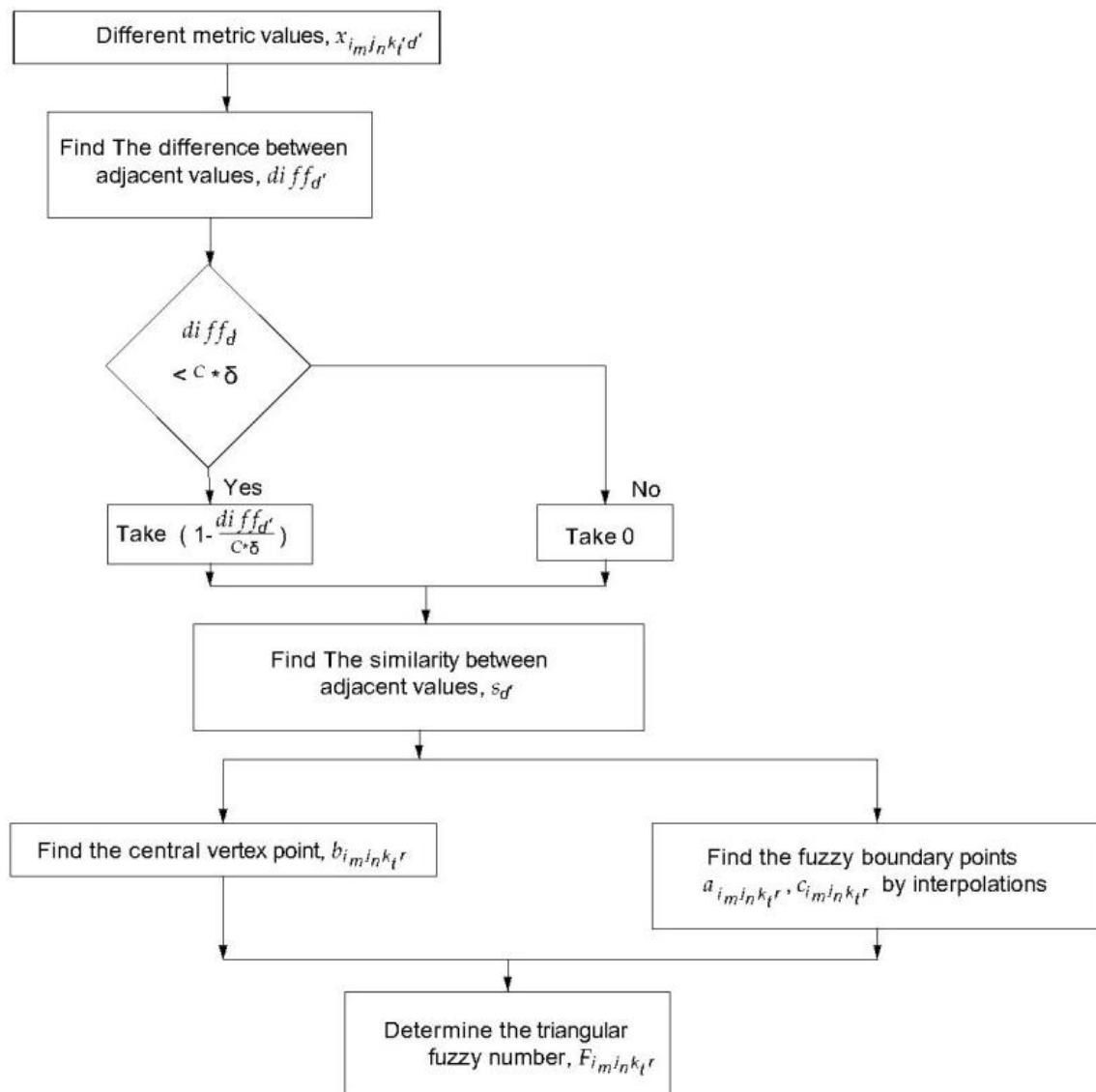

Figure 5: Model algorithms based on metric values to evaluate the triangular fuzzy

$a_{i_m j_n k_t r''}$, $b_{i_m j_n k_t r''}$ and $c_{i_m j_n k_t r''}$ are the three nodes of triangular fuzzy number corresponding to the
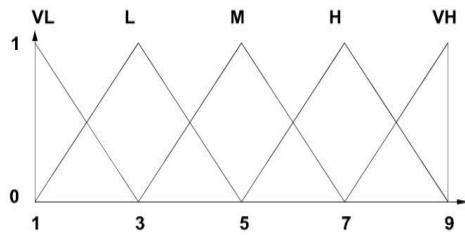
linguistic terms representing qualitative metrics.

Figure 6: Triangular fuzzy numbers for linguistic terms

Table 2: Linguistic terms for qualitative metrics and corresponding triangular numbers

Linguistic Terms	Triangular Fuzzy number $(a_{i_m j_n k_t"r"},\ b_{i_m j_n k_t"r"}$ and $c_{i_m j_n k_t"r"})$		
Very Low (VL)	(1, 1, 3)		
Low (L)	(1, 3, 5)		
Medium (M)	(3, 5, 7)		
High (H)	(5, 7, 9)		
Very High (VH)	(7, 9, 9)		

Triangular fuzzy numbers which are generated with the above method will be considered in Fuzzy TOPSIS method for the performance evaluation of different situations in supply chain. While in Fuzzy TOPSIS method performance is obtained by measuring their distances from positive and negative ideal solutions.

F. Fuzzy TOPSIS

TOPSIS (Technique for Order Preference by Similarity to Ideal Situation) is a multi criteria group decision making method. Fuzzy TOPSIS proposed by Ching-Lai Hwang and Yoon is a method that can assist in objective and methodical evaluation of alternatives against multiple criteria. Fuzzy TOPSIS approach is to identify the positive ideal solution and negative ideal solution. The Fuzzy positive ideal solution (FPIS) maximizes the benefit metrics but minimizes the cost metrics, while the Fuzzy negative ideal solution (FNIS) maximizes the cost metrics but minimizes the benefit metrics. The best performance value for each alternative is the one which is nearest to the positive ideal solution and farthest from the negative ideal solution. A detailed description on fuzzy TOPSIS method by several researchers [13], [30] is adapted and steps involved in fuzzy TOPSIS are as presented below.

a. Normalize triangular fuzzy number

While dealing with the quantitative and qualitative metrics, two more important types of metrics to be dealt in are cost and benefit metrics. Benefit entails more the better whereas cost means less the better. To compare the metrics with each other, they need to be normalized for finding the performance of supply chain. Normalisation methods for cost and benefit metrics are as follows:

$$N_{i_m j_n k_t r} = \left(\frac{a_{i_m j_n k_t r}}{c_r^{max}}, \frac{b_{i_m j_n k_t r}}{c_r^{max}}, \frac{c_{i_m j_n k_t r}}{c_r^{max}} \right) \text{ and}$$

$$c_r^{max} = max\left(c_{i_m j_n k_t r}\right) \qquad \text{(Benefit metrics)} \qquad (1)$$

$$N_{i_m j_n k_t r} = \left(\frac{c_r^{min}}{c_{i_m j_n k_t r}}, \frac{c_r^{min}}{b_{i_m j_n k_t r}}, \frac{c_r^{min}}{a_{i_m j_n k_t r}} \right) \text{ and}$$

$$c_r^{min} = min\left(a_{i_m j_n k_t r}\right) \qquad \text{(Cost metrics)} \qquad (2)$$

b. Prioritize sustainable policy over metric category

As regards to different sustainable strategies and stated company objective towards economic and environment sustainability in perspective of plastic moulding, we exercise relative importance to performance categories. So, the relative weight vector which is considered for performance category is defined as,

$$W_{i_m j_n} u = w_{i_m j_1} + w_{i_m j_2} + w_{i_m j_3} + w_{i_m j_4} + \ldots\ldots + w_{i_m j_n} \qquad (3)$$

Where, u = number of weight vector for metric category,

$$\text{and} \sum_{u=1}^{U} w_u = 1, where\ ,\ w_u \in [0,1]$$

c. Compute weighted normalized fuzzy value

The weighted normalized fuzzy value $V_{i_m j_n k_t v}$ of metrics is calculated by taking the product of sustainable priority weights ($W_{i_m j_n u}$) of metric category and the normalized triangular fuzzy numbers ($N_{i_m j_n k_t r}$) as,

$$V_{i_m j_n k_t v} = N_{i_m j_n k_t r} * W_{i_m j_n u} \qquad (4)$$

$$= (a'_{i_m j_n k_t v}, b'_{i_m j_n k_t v}, c'_{i_m j_n k_t v})$$

Where, v = number of weighted fuzzy numbers

d. Identify fuzzy positive ideal solution (FPIS) and fuzzy negative ideal solution (FNIS)

After calculating the weighted normalized fuzzy value ($V_{i_m j_n k_t v}$), FPIS and FNIS can be calculated by using following equations,

$$S_{k_t}^\bullet(FPIS) = max\ (c'_{i_m j_n k_t v}) \qquad (5)$$

$$S_{k_t}^-(FNIS) = min\ (a'_{i_m j_n k_t v}) \qquad (6)$$

where, $S_{k_t}^\bullet$, $S_{k_t}^-$ are FPIS and FNIS for performance metrics k_t.

e. Calculate the distance of non-lean tool based green supply chain and lean tool based green supply chain situation from FPIS and FNIS

To calculate the distance ($D_{k_t}^\bullet, D_{k_t}^-$) of both the supply chains from FPIS and FNIS,

following equations are used;

$$D_{k_t}^{\bullet} = \sqrt{\frac{1}{3}\left[\left(a'_{i_m j_n k_t v} - S_{k_t}^{\bullet}\right)^2 + \left(b'_{i_m j_n k_t v} - S_{k_t}^{\bullet}\right)^2 + \right.}$$

$$\left. \left(c'_{i_m j_n k_t v} - S_{k_t}^{\bullet}\right)^2 \right] \qquad (7)$$

$$D_{k_t}^{-} = \sqrt{\frac{1}{3}\left[\left(a'_{i_m j_n k_t v} - S_{\bar{k_t}}^{-}\right)^2 + \left(b'_{i_m j_n k_t v} - S_{\bar{k_t}}^{-}\right)^2 + \right.}$$

$$\left. \left(c'_{i_m j_n k_t v} - S_{\bar{k_t}}^{-}\right)^2 \right] \qquad (8)$$

Where, $D_{k_t}^{\bullet}, D_{\bar{k_t}}^{-}$ are the distance measurements of supply chain situations from FPIS and FNIS for performance metric k_t.

f. Compute the closeness coefficients for each supply chain situation

The closeness coefficient (CC_{i_m}) signifies the distances of both the supply chain situations from the FPIS ($S_{k_t}^{\bullet}$) and FNIS ($S_{\bar{k_t}}^{-}$) simultaneously. Calculation of CC_{i_m} value for each supply chain situations is done by using,

$$CC_{i_m} = \frac{D_{k_t}}{D_{\bar{k_t}}^{-} + D_{k_t}^{\bullet}}$$

g. Calculate the performance of non- lean and lean supply chain

Since, closeness coefficient evaluates the distance of each supply chain situation between FPIS and FNIS; it gives the value nearest to FPIS and farthest to FNIS. So, the performance value for both supply chain situations (before and after implementation of lean tool based green supply chain management) can be computed by,

$$P_{i_m} = CC_{i_m} * 100\%$$

IV. A CASE EXAMPLE

We have selected a thermoforming industry for our case study. It produces thin-gauge, single use food packaging like cups, plates and containers. Thermoforming industry is selected to evaluate green supply chain performance as lean tools and techniques are being implemented by this supply chain. Thermoforming is indeed a sustainable technology. Thermoformed food packaging is particularly produced from high impact polystyrene material.

It competes with roll-sheet steel, expanded polystyrene foam, paper, paperboard, plastic-coated paper, aluminum foil and paper pulp considering thin gauge forming [31]. Thermoforming process technology also competes with injection molding, plastics extrusion, stretch-blow molding, compression molding and injection-blow molding. There are many advantages of thermoforming over other moulding technologies; molds are less expensive as compared to

injection molds being single sided; broad range of mold materials can be used; quite shorter cycle time and wide variety of polymer films can be processed.

Table 3: "Thermoforming" supply chain performance metrics and categories

Performance Categories	Metric Id ($x_{i_m j_n k_t}$)	Performance Metrics (Units)	Metric Type
Economic	x_{i11}	Specific Energy Consumption (SEC)	Quantitative/Cost
	x_{i12}	Process waste (%)	Quantitative/Cost
	x_{i13}	Waste recycling (%)	Quantitative/Benefit
	x_{i14}	Recyclate in RM mix (%)	Quantitative/Benefit
	x_{i15}	Overall Equipment Effectiveness (OEE) (%)	Quantitative/Benefit
	x_{i16}	Inbound and outbound Logistic	Qualitative/Benefit
	x_{i17}	Processing technology	Qualitative/Benefit
	x_{i18}	User phase of the product	Qualitative/Benefit
	x_{i19}	Buyer- Suppliers relationship level	Qualitative/Benefit
Environment	x_{i21}	Water consumption (1 unit =1000 ltrs.)	Quantitative/Cost
	x_{i22}	Green Warming Potential (GWP) (tCo$_2$)	Quantitative/Cost
	x_{i23}	Acidification Potential (AP) tSO$_2$	Quantitative/Cost
	x_{i24}	Photochemical Oxidation Potential (POP) kg eq. ethylene	Qualitative/Cost
	x_{i25}	Environmental management system	Qualitative/Benefit
	x_{i26}	Renewable energy (kWh)	Quantitative/Benefit
Social	x_{i31}	Living environment	Qualitative/Benefit
	x_{i32}	Extended producer responsibility (EPR) (Rs.)	Quantitative/Benefit
Health & Safety	x_{i41}	Lost-time injuries	Qualitative/Benefit
	x_{i42}	Human toxicity potential	Qualitative/Cost

Aluminum being lightweight and relatively inexpensive is mostly preferred as mold material; it is easy to cast and machine and also high in thermal conductivity. Processing temperatures and pressures are low in thermoforming process. Thermoformed parts has extremely high ratio of surface area to wall thickness [31].This supply chain is a multi-stage chain of supplier, manufacturer, dealer-distributor network, end users, and end-of-use waste recyclers. This supply chain is selected to evaluate its green performance. As we mentioned earlier, cost and environment sustainable or green supply chain had four major performance categories - economic, environmental, social, health and safety. Metrics could be of two types; one is quantitative metric which could be measured in numbers and qualitative metric which is in linguistic terms. Benefit metric is meant for more the better while cost metric is meant for less the better. Different performance metrics are specified in third column of Table 3. Different values for every performance metrics were collected and calculated for the supply chain strategies of before and after implementation of LTBGSCM.

Table 4: Performance Measurement values – before and after LTBGSCM Implementation

Performance Metrics	Metric Values																
	Before GSCM implementation (i = 1)									After GSCM implementation (i = 2)							
	Year 2015							Year 2016		Year 2016							Year 2017	
	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Jun	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb
Specific Energy Consumption SEC	2.64	2.648	2.646	2.64	2.638	2.634	2.633	2.634	2.639	2.344	2.348	2.346	2.29	2.354	2.26	2.293	2.316	2.335
Process waste %	1.82	1.734	1.23	1.34	1.561	1.2	1.136	1.78	1.624	1.47	1.384	0.88	0.99	1.211	0.85	0.786	1.43	1.274
Waste recycling %	80	82.16	82.25	81.05	83.1	80.24	81.36	82.91	83.72	83.8	85	87.05	86	84	85.7	88.3	85.83	88
Recyclate in RM mix %	0.38	0.38	0.3	0.32	0.38	0.27	0.3	0.37	0.35	0.48	0.47	0.36	0.40	0.48	0.36	0.44	0.50	0.47
Overall Equipment Effectiveness (OEE) %	71.04	72.09	71	73.5	73.02	69.56	72	72.77	70	76.16	78.52	77.7	78	75.07	75.34	73	76.84	78.86
Inbound and outbound Logistics	Low (L)			(1, 3, 5)						Medium (M)			(3, 5, 7)					
Processing technology	Medium (M)			(3, 5, 7)						High (H)			(5, 7, 9)					
User phase of the product	Medium (M)			(3, 5, 7)						High (H)			(5, 7, 9)					
Buyer- Suppliers relationship level	Medium (M)			(3, 5, 7)						High (H)			(5, 7, 9)					
Water consumption (1 unit=1000 L)	130	105.5	111.5	103	78	82	85.5	90	109	105	92	75	78.5	74	76.5	78.74	88.26	104.5
Green Warming Potential (GWP) tCO_2	850.58	860	844.29	870	842.89	861.16	853.06	849.2	855.62	826	835	819	845.5	818.5	836	828	824	831.5
Acidification Potential (AP) tSO_2	8.63	8.33	8.95	7.80	8.43	8.43	8.25	7.85	8.30	7.59	7.28	6.87	6.77	7.43	7.21	6.90	7.03	7.50
Photochemical Oxidation Potential (POP) kg eq. ethylene	Medium (M)			(3, 5, 7)						Medium (M)			(3, 5, 7)					
Environmental management system	Low (L)			(1, 3, 5)						Medium (M)			(3, 5, 7)					
Renewable energy kWh	0.75	0.85	1.05	0.8	0.87	0.75	0.85	0.8	0.9	2.05	2.13	2.05	2.06	2.12	2.09	2.11	2.05	2.1
Living environment	Medium (M)			(3, 5, 7)						Very High (H)			(7, 9, 9)					
Extended producer responsibility	12700	9500	12300	11500	12000	12000	9500	10000	11250	19500	11000	14000	14500	13000	13000	11000	11000	12000
Lost-time injuries	Medium (M)			(3, 5, 7)						High (H)			(5, 7, 9)					
Human toxicity potential	High (H)			(5, 7, 9)						Low (L)			(1, 3, 5)					

Later, we thoroughly examined the entire supply chain and different lean tools were employed to improve the ratings of performance metrics as also the supply chain performance. Table 3 presents different quantitative metrics with their monthly average values. As, we have assessed two supply chain situations; therefore values for two different situations are measured. By using algorithms given in Figure 5, quantitative metrics are converted to triangular fuzzy numbers (TFN). In the same way, by using the values shown in Table 2 all of the qualitative values are collected and readily converted to TFN. At last, by following equations 1 to 10, the performance of pre and post implementation of GSCM (see table 4) has been calculated as 40.13 % and 49.37 %.

V. DISCUSSION & CONCLUSION

In view of the fact that, a supply chain by its own is an integrated process which involves supply of raw materials, manufacturing the products, dispatch to customers through distribution channel and fetching recycled end-of-use waste, the intricacy of the supply chain occurs due to the number of layers in the chain. In view of this intricacy in an ordinary supply chain, choosing suitable performance metrics and the performance measurement model intended for the analysis of supply chain is a critical task. At first, the linkages between basic phases of supply chain and effects of various lean tools have been ascertained. For evaluating the supply chain performance, fuzzy TOPSIS method is implemented and results prove that performance of lean tools based green supply chain management (LTBGSCM) is better than without green. The results also explain that, LTBGSCM with its tools and techniques influence the performance of supply chain positively. Similarly, performance of the supply chain also influences the sustainable policy positively. Aggregate performance of the supply chain can be enhanced by the managers by improving the sustainable strategies across the supply chain. Furthermore, performance of the lean tools based green supply chain (LTBGSC) can be evaluated and predicted by the managers. Notably this offers a method for measuring aggregate performance of the supply chain instead of measuring the performance of a particular business unit. By understanding the impact of lean on the overall performance of the supply chain, company managers are facilitated in making better informed decisions. Managers would be able to demonstrate the performance benefits obtained due to introduction of LTBGSCM to most of the supply chain members. By revealing the aggregate benefit it can increase the acceptance of such improvement initiatives. Fuzzy is also used to point out which areas will benefit, for example economic or environment from implementation of green initiatives; thereby stressing more on economic and environment metrics as sustainable qualifiers for the supply chain.

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