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Performance evaluation of the Indian plastic processors supply chain: Implementing lean and green philosophies

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ABSTRACT

This paper aims at presenting supply chain metrics and proposing a fuzzy-based performance assessment method for the plastic green supply chain. Paper investigates the waste reduction policy and state of affairs of the supply chain to know the overall performance of the cost and environment sustainable plastic supply chain. As lean tools and techniques does apply in many of the supply chains, we suggest a set of metrics to evaluate the performance of supply chain. Furthermore, the performance of cost and environment sustainable plastic supply chain is evaluated in this paper using a fuzzy model. In case of uncertainty, fuzzy would be a suitable model method to implement. Also, it allows for modeling of a number of performance metrics across various supply chain components and processes. Sustainable or sustainable policy could be accomplished by making use of a distinct weight calculation for different individual supply chain scenarios. Research presents metrics for lean tools based green supply chain management. The proposed method is able to measure the performance of green supply chain management by means of a fuzzy approach and also by applying sustainable policies. The metrics that are selected for measuring the performance of lean tools based green supply chain management is particularly applicable for light weight, high volume and single use plastic products. By determining performance for every individual metric the current performance could be categorized and also improve it accordingly. This study offers a performance evaluation technique for the managers of supply chain to evaluate the outcome of lean tools and various sustainable or sustainable policies.

Key words: Green supply chain, Performance metrics, Performance categories, Plastic processors, Thermoforming.

1. INTRODUCTION

Supply chains are now a day's being viewed as extended activity linking firms in locations that are different and also enabling partners to get sustainable advantage. According to [29] supply chains are accountable for the whole life span of the product, from procurement of raw material, to production, distribution network, waste recycling and proper disposal of the product waste after its end of life. In the recent past, with the day-to-day management of operations, firms understood the capability of highly effective and efficient lean tools based green supply chain management (LTBGSCM). Although, many firms on the other hand fail to generate the metrics and effective measures of performance required to accomplish integrated supply chain management. To accomplish the supply chain objective of applying cost and environment effective policies for reduction of waste and pollutant releases, a supply chain has to engage itself in adopting sustainable policies and continuous improvement in all the involved processes. [2] stated that the sustainable advantage could be achieved only if there is an effective alignment of the organizations policies with that of its activities. Thus, to know how supply chains are competing, it's essential to interpret the overall performance of the green supply chain GSC. Another significant characteristic as regards to measures of the supply chain will be the strategic fit between policy of the supply chain and the sustainable performance. [14] revealed that supply chain performance is entirely based on the selection of competitively appropriate supply chain policy. They also asserted that the strategic fit involving the policy, leadership, alignment among sustainable scenarios and organizational culture can improve business performance. Therefore, to attain highly effective measures of performance the arrangement of supply chain players and market policy must be aligned with sustainable performance of the supply chain.

Lean tools based green supply chain management LTBGSCM philosophy is among many initiatives that most companies worldwide were developing to stay sustainable within the gradually increasing global market [36]. The emphasis of the LTBGSCM approach is on cost reduction by controlling process waste, pollutant releases and utilizing lean tools to maintain optimized and sustainable supply chain. The primary thrust of a LTBGSCM is creating a streamlined and highly effective system which creates finished products with minimum waste and pollutant releases. It also focuses on streaming the recycled end of use product waste and process waste into the manufacturing process. [23]. Lean does apply in most supply chains, especially those wanting to enhance performance by minimizing waste. For instance, cost and environment sustainable supply chains could gain from using lean to get rid of waste and also minimize costs. Moreover, companies using a continuous upgrading process to improve their core competitiveness utilizing supply chain management usually haven't prevailed in maximizing the potential of their supply chain since they have failed to foster the performance measures and metrics required to completely integrate the partners of their supply chain to optimize efficiency and effectiveness [4]. It is very critical to determine the measurement method while dealing with the inherent complexity of supply chain policy, supply chain measures and market competitiveness. Furthermore, [13] stated that typical methods had the disadvantages of being inclined to measure financial metrics, and also didn't incorporate lagging and intangible indicators. In this particular scenario, fuzzy is a suitable modeling method while dealing with qualitative and intangible measures.

Fuzzy logic is a professional, mathematical logic concept which uses linguistic values and fuzzy set theory and is applied widely in different aspects of supply chain management. In literature, number of studies, [27] has reported findings concerning performance measurement of supply chain with the application of fuzzy logic, fuzzy set theory and several linguistic variables in conjunction with other methods. Fuzzy modeling likewise makes it possible for many performance metrics to be viewed across various elements and processes within the supply chain. Therefore, a comprehensive framework for performance measures along with a fuzzy based performance evaluation method for measurement of overall supply chain is vital to deal with these challenges. Despite the vast research available on the measures of supply chain, the concept of performance metrics and measures remains underdeveloped for the following three reasons:

- an absence of good performance metrics pertaining to LTBGSCM and that of primary metrics [28];
- an absence of strategic relationship among performance metrics and sustainable policy while measuring the performance of cost and environment sustainable supply chain [28]; and
- deficiencies while taking into consideration linguistic variables and uncertainty in performance evaluation methods, particularly for LTBGSCM.

Thus, the research problem dealt with in this paper is the necessity to develop performance metrics for the supply chain and a method of evaluation to assess lean characteristics and sustainable supply chain policies. In this paper, performance measures of supply chain as well as its metrics are reviewed and pursued by examining the strategic alignment and sustainable policies of the company with its supply chain policy. Subsequently, the need for taking into account a cost and environment sustainable supply chain to minimise costs and reduce pollutant releases by means of various lean tools is also thought about with the intention to select matrics for the supply chain. The proposed performance metrics framework for supply chain is dependent on a theoretical framework mentioned by [28] and [16] wherein their metrics have been dependent on five supply chain phases of life cycle as plan, source, make, delivery and return.

Finally, it is proposed to evaluate performance of a cost and environment sustainable supply chain with the performance evaluation method based on fuzzy approach. Also, the proposed evaluation method takes into consideration the sustainable policies while optimizing the performance categories. The fuzzy based method permits modeling of a number of performance metrics across several processes and elements of a supply chain. The proposed method evaluates the performance of LTBGSCM enabling strategic configuration among sustainable policies and supply chain policy.

2. LITERATURE REVIEW

2.1 Metrics in GSCM and Performance measurement

Performance measurement is the procedure of quantifying the effectiveness as well as efficiency of activity where measurement is actually the task of quantification and activity leads to performance [28], [30]. Effectiveness is actually the extent to which process waste and pollutant releases are controlled and efficiency is actually a degree of exactly how economically a firm's resources are actually utilised when providing a pre-specified level of societal satisfaction. Performance measurement systems (PMS) are actually described as the general set of metrics utilized to quantify efficiency and also effectiveness of action [30]. The purpose of measuring industrial performance as per [13] is to recognize success; recognize whether environmental concerns are met; assist the industry to be aware of its processes and also to verify what they understand or disclose what they do not understand; know where problems, waste, harmful pollutant releases, bottlenecks, etc. subsist and identify the areas for necessary improvements; ensure decisions are completely based on facts and not on assumption, sentiment, belief or intuition; and illustrate if intended improvements actually occurred.

A PMS is composed of a many individual performance metrics or measures. The term “metric” refers to the meaning of the measure, how exactly it'll be calculated and the sources for obtaining the data [13]. For the last several years researchers have determined a considerable number of performance metrics that can evaluate the performance of supply chain. Many of the models in existence use ineffective or improper performance measures which are limited in the scope [6]. Considering different levels of decision making, [13] noticed that many models are short of an entire coverage of necessary performance measures and metrics. Although the wide-ranging literature, research has yet to address a number of important limitations:

(1) absence of strategic focus (the measurement process is not properly aligned with strategic objectives and organisation culture) [21], [11];

(2) absence of systematic approach so as to prioritize metrics and measures [18], [7] and

(3) how to continue PMS over a period of time so as to keep it aligned with the changing policies? [28].

Performance of the supply chain pertains to sustainable policy because competitiveness within the supply chain should be related to organisational goals. [12], [33] Recommended that, within a PMS, monetary and economic indicators can be complemented by non- monetary measures linked to environment, social, health and safety with the integration of strategic objectives of the management. Whereas, [2] observed PMS as a practice with two functions: communicating methods and controlling performance.

Furthermore, they also argued for the configuration of company's activities with that of its policies which leads to sustainable advantages. Thus, a sustainable policy is then a basis for defining the goals of the company. Performance metrics could be grouped into four different sustainable policies and in the evaluation section it will be reviewed and analyzed to be able to prioritize the policies. These sustainable policies have to be lined up with the PMS of the supply chain to satisfy organisational goals. To know therefore the competitiveness of a supply chain, it's essential to understand the entire performance of the supply chain. Another essential argument is the configuration of market policy with that of sustainable performance of the supply chain. From the latest research on different manufacturing sectors, [14] discovered that the option of supply chain policy as also sustainable policy influenced business of the company and performance of the supply chain. [39] Likewise emphasized synchronization between supply chains as well as business policy. In recent times researchers including [4] and [30] have attempted to react to all these

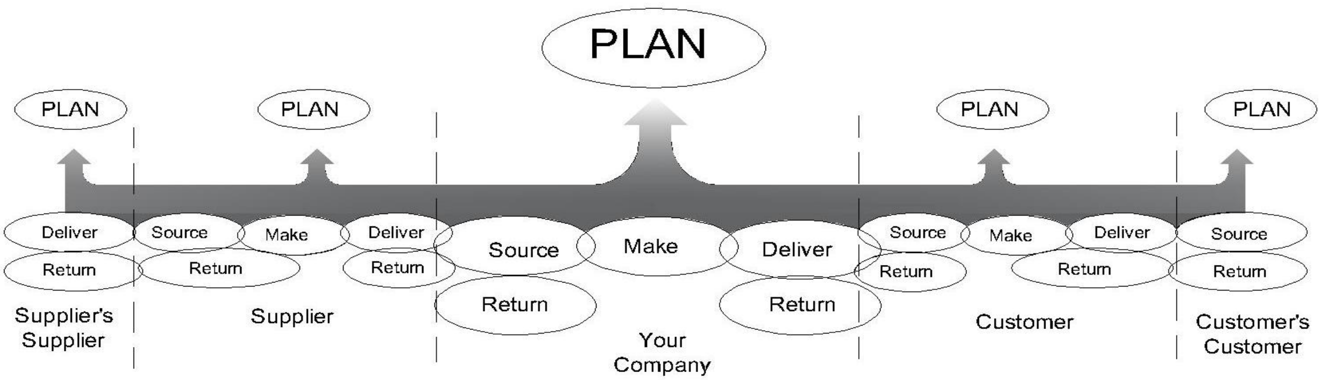

Figure 1: Reference model for supply chain operation [33]

arguments by developing systemic and well balanced PMS or perhaps a flexibility measurement approach [6]. Probably the greatest recognized of these is considering the different phases of the life cycle. It has been referred to as a 'systematic procedure for identifying, evaluating and monitoring performance of the supply chain [28]. Consideration of different phases of the life cycle which connect elements of company's process engineering, benchmarking and major practices into one framework. Thus, from the view point of manufacturer's suppliers continued through distributor- dealer network upto the customer, SCM is defined as a combination of all the phases of life cycle which are affiliated with that particular company's operational policy, work, material and information flows (see Figure 1).

Supply chain with the basic need for sustainable performance as well as its relationship with the market policy is discussed here. The above mentioned considerations result in a suggestion that a present analysis is necessary to build a framework of metrics plus performance measures that can be incorporated with sustainable policies and also modern manufacturing practices. And therefore, to integrate the synchronization with company's strategic goals and PMS, it's essential to address the effects of improvement practices on the performance metrics. Cost and environment sustainable supply chains similar to lean supply chains along with other improvement techniques are considered in the following section and then linked to synchronization. A performance measuring method is crucial to determine the outcome of improvements in addition to how a company's waste and pollutant-release minimization policy competes with the sustainable viewpoint which too is addressed in the evaluation section.

2.2 Green supply chain, improvement tools and techniques

The term, "Green" means many solutions or activities to eliminate waste and pollutant releases, bring down non value added operations and build up the value added practices. A green supply chain usually means the identification of waste and pollutant releases across the supply chain stream and taking measures to eliminate them [20], [37]. Among the useful methods to obtain value creation is reducing waste materials and also pollutant releases from every tier of the supply chain by using a fresh concept: Green supply chain management. [17] Identified certain features meant to the theory of green supply chain management - cost clarity and relationship evaluation - which may assist in green supply chain to supply chain management comparison.

The 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 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. For example, [16], [20] pointed out that Voice of Customer (VOC) and Cause and Effect did impact the plan stage by reducing process waste and hence improving productivity and reduction in pollutant releases. Likewise, the outcome of other lean tools on five different basic processes of supply chain are shown in Table 1 and examined afterward since the investigation of the impact of lean tools on performance metrics is actually noteworthy to develop the metrics for green supply chain study. [16] Studied the influence of lean tools on five basic processes of supply chain and then realized that various lean tools had a positive effect on process efficiency, societal satisfaction, environmental concerns, total cost and cost saving initiatives.

The influence could take place all through the overall process or maybe some interim supply chain process. Customers nowadays demand products which are economical and can be reused or recycled after its end use for environment sustainability. To respond to these challenges producers are required to take initiatives related to minimization of process waste, recycling of end of use product waste and control pollutant releases at each and every process of the supply chain. All these initiative facilitate manufacturers to serve the customers and society at large in a profitable and responsible manner [9]. Working on the theory of green supply chain management system, [22] considered increase in productivity by implementing standardised processes with lean principles and showed remarkable reduction in process wastage and pollutant releases.

The influence of lean tools based green techniques on the performance of supply chain or, more particularly, over every phase of the supply chain process (plan, source, make, delivery and return) is been discussed here. Improvements as regards to these tools and techniques have considerable influence on supply chain metrics. It thus becomes obvious that benefits of GSCM can be assessed by means of supply chain performance metrics along with various supply chain policies. Lean is actually applicable in most supply chains, especially those seeking to enhance performance by reducing waste. For instance, cost and environment sustainable supply chains could gain from using lean to remove waste and reduce costs. The green supply chain is able to mitigate the lack of coordination between lean tools and techniques and performance measures. However, in the following sections we will be discussing the performance metrics meant for cost and environment sustainable supply chains as well as understanding the alignment of sustainable policy with that of the supply chain policy by using the relative weights toward performance categories.

2.3 Supply Chain Metrics

There is substantial literature on SCM that works with performance management metrics. For effective and efficient performance evaluation of a supply chain, measurement objectives should represent the organizational objectives and the selected metrics must reflect a balance among financial as well as non-financial measures which can be correlated to strategic, operational and tactical levels of managerial decision making and control [4]. For more effectiveness in performance evaluation it is essential to relatively reduce the number of established performance metrics.

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

Supply Chain Phases	Lean Tools & Technique	Author References
Plan	Cause & Effect,	[20]
	Voice of Customer (VOC)	[16]
	Kaizen	[41]
Source	NA	
Make	Total Productive Maintenance	[23]
	Inventory Control	[16]
	5 S	[37]
	Single minute exchange of die (SMED)	[36]
	Kaizen	[41]
	Waste (Mudo)	[37]
Deliver	Kaizen	[41]
Return	Waste (Mudo)	[37]
	Kaizen	[41]

To evaluate the performance of cost and environment sustainable supply chain, all the metrics (see Figure 2) are selected based on existing research (e.g., [11], [22]). [28], [33] recommended a categorization of the performance measures (in terms of economic, environment, social, health and safety) using the five basic phases of supply chain. In this research, all the metrics are aligned according to five different phases of supply chain to evaluate individual performances at each process level and also the overall performance of supply chain. These supply chain phases spans all inclusive of raw material, work in progress, finished goods and return of recycled end-of-use waste. Additionally, it includes inbound and outbound logistic management, energy management, process waste management and public satisfaction for pollution control across the supply chain. We allocate metrics categories as economic, environment, social, health and safety - that are analysed as well as summarized from the latest literature and the metrics are categorized into lean and non-lean groups. Another significant characteristic is certainly the overall proportions which are ascribed to the performance metrics and categories. Our proposed ideal metrics are based upon the observations within the reviewed literature. As a result, 49 percent of the overall metrics are economic metrics while the rest i.e. environment, social, health and safety are 33, 9 and 9 percent respectively. Furthermore, quantitative measures are 52 percent of the total metrics in contrast to the 48 percent of qualitative measures. The metrics are primarily selected for supply chains that are cost and environment sustainable and the majority of the metrics are based on economic measures. In the case of five basic supply chain phases, plan comprises 22 percent ideal metrics and the remaining processes of source, make, delivery and return consists of 17, 22, 17 and 22 percent respectively.

Fuzzy is a suitable method when there is uncertainty and it

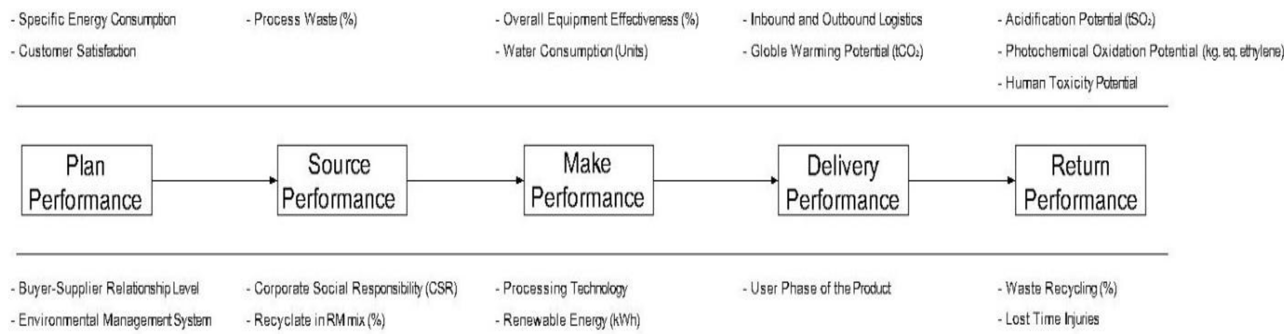

Figure 2: Metrics for evaluation of cost and environment sustainable supply chain

permits modelling of many performance metrics over various elements and processes involved in a supply chain. How these metrics get affected by employing various lean tools is already discussed earlier. These effects are computed in the following section by applying fuzzy-based methods of performance evaluation. The sustainable policies for supply chains of varied moulding processes are also used by considering different relative weights for the performance categories. As a result, the mutual effect of various lean tools and different sustainable policies on the performance of supply chain will be evaluated by means of proposed method of performance measurement.

2.4 Fuzzy-based measurement methods

Fuzzy set theory was first introduced by [25] and at first was applied in control system by [19]. Fuzzy set theory is basically quantifying and reasoning with the use of natural language having words with ambiguous meanings. Fuzzy logic is based on the observation that individuals make decisions depending on imprecise and linguistic information. It is a process which includes 0 and 1 as the extreme cases of truth but also includes a range of scenarios of truth in between.
For a defined crisp set A, this membership function allocates a value $\mu_A(x)$ to every x $\in$ X such that,

$\mu_A(x) = 1$ if $x \in A$

$\mu_A(x) = 0$ 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.

Fuzzy logic is a type of multi-valued logic and is a mathematical way of signifying vagueness and imprecise data which make use of fuzzy set theory. Fuzzy logic techniques has wide applications in many supply chain areas including: facility location, quality control, capacity planning, project management, inventory control, forecasting and purchasing, distribution, environment, purchasing and process design [24].

Here, we will be using linguistic variables for measuring the performance of qualitative measures. The values of linguistic variables are expressed in linguistic variables. Concept of the linguistic variable is much useful while dealing with very complex scenarios or the one which is not properly defined to be logically expressed in terms of conventional quantitative terms [3]. For example, the values of a linguistic variable 'weight' are very low, low, medium, high, very high, etc. These linguistic values can also be represented by fuzzy numbers. These weight values can be expressed by a fuzzy linguistic variable qualitatively by means of linguistic terms and also quantitatively with the use of pertinence function [10]. Several studies have described performance measurement of the supply chain using multiple linguistic variables, fuzzy logic and fuzzy set theory in combination with other methods. Referring to a review paper [37] and also other literature, many multi criteria decision making processes have been recommended for performance evaluation, as like fuzzy AHP [27], analytic network process, DEA, case-based reasoning, genetic algorithm, fuzzy set approach [10], fuzzy TOPSIS [27], [3] mathematical programming [31] and the SCOR model [10].

It is noticed that fewer attempts were made toward supply chain leanness evaluation in comparison to methods for supply chain performance evaluation. To assess the leanness in supply chains, researchers and lean practitioners have conducted different lean assessment surveys. Further, some researchers developed assessment with DEA, performance evaluation based on fuzzy logic as well as web based leanness assessment [20] and [24]. Majority of the models applied fuzzy logic while dealing with uncertainty, inexact input data and also the qualitative variables within the supply chain system. Fuzzy is a suitable method for modelling uncertain scenarios and also it permit modelling of a large number of performance metrics for various elements and processes within the supply chain. Our proposed method for performance evaluation is compatible for modelling the performance metrics and by using multiple linguistic variables and fuzzy membership functions can evaluate performance of the supply chain. Quantitative measures are to be converted into fuzzy membership values; while, to measure qualitative metrics fuzzy linguistic variables are used. The method of converting to fuzzy membership values and also the integration of supply chain and sustainable policies to evolve an evaluation model based on fuzzy is described in the following section.

3. PROPOSED PERFORMANCE MEASUREMENT METHOD

The framework which is proposed for the metrics and performance measures of the supply chain is completely based on the theoretical framework as endorsed by [16] as also by [28] considering five basic supply chain elements (plan, source, make, delivery and return) and implementation of LTBGSCM. Economic and environmental performance measures reflect supply chains ability towards a sustainable growth with due consideration towards pollution control measures while social measures indicate community responsibility for effective use and end-of-use disposal of the product. Corporate Sustainability is the main driving force for the success of supply chain and it is the driving force which determines the performance categories. Overall performance of the supply chain can be evaluated by considering all the performance categories. Another important contemplation is to study the effects of LTBGSCM. The metrics, which are in combination with both prime as well as lean metrics, will ultimately evaluate the cost and environment sustainable performance of the supply chain. Thus, performance categories will help out in formulating the sustainable policy which proves to be the main reason for company policy. As sustainable policy is required to be aligned with that of market policy, the cost and environment sustainable supply chain performance method should include all the essential metrics required to evaluate sustainable policy and also market policy.

Assuming $i = 1, 2, ...m$ signifies the supply chain policies; $j = 1, 2, ...n$ signifies performance categories of the supply chain; $k = 1, 2, ...t$ signifies the metrics for the supply chain while $I = \left(i_{1,}i_{2,...}i_{m}\right)$, $J = \left(j_{1,}j_{2,...}j_{n}\right)$, $K = \left(k_{1,}k_{2,...}k_{n}\right)$ where *I*, *J*, *K* signifies range of supply chain policies, performance categories and supply chain metrics with typical meanings. For quantitative metrics, let us assume, $x_{i_m j_n k_t 1}$, $x_{i_m j_n k_t 2}$,.... $x_{i_m j_n k_t d}$ metric values for *'d'* corresponding to policy i_m, criteria j_n, and metrics k_t.
Further, company applied various lean tools (standardised work, total preventive maintenance, inventory control, effective layout, 5S) and significant improvement was observed in the metric values.

As lean tools will have an appreciable effect on each and every metrics, the proposed method intentionally assumed different metric values. Considering quantitative metrics these values are now transformed into performance values (from 0 to 1) by means of fuzzy membership functions by using equations (1) and (2) [27]:

$$y_{i_m j_n k_t d} = \frac{x_{i_m j_n k_t d} - x_{i_m j_n k_t d^{\min}}}{x_{i_m j_n k_t d^{\max}} - x_{i_m j_n k_t d^{\min}}} \quad \text{for positive } k_t \qquad (1)$$

$$y_{i_m j_n k_t d} = \frac{x_{i_m j_n k_t d^{\max}} - x_{i_m j_n k_t d}}{x_{i_m j_n k_t d^{\max}} - x_{i_m j_n k_t d^{\min}}} \quad \text{for negative } k_t \qquad (2)$$

For qualitative metrics, triangular fuzzy linguistic variables and analogous membership values will be used. Here the linguistic variables are expressed by unit interval of the linear triangular membership functions for which membership grade is equal to 1 (Figure 3). As concerned to the qualitative metrics, we consider the membership value of 1 for any of the linguistic variables. For instance, if the linguistic term for 'Logistic optimisation to reduce distribution emissions' is termed as medium, then the membership value of that particular linguistic term will be calculate as 0.40. In the similar way, all of the qualitative metrics could be defined with linguistic variables and then converted into its membership values. Thus, all the metrics values are converted into functions of triangular fuzzy membership. Now, all the membership values are available with minimum and maximum limits (see Equations (1) and (2) and Table 2). Beyond these limits any metrics values will be of zero membership values. Within these limits, this method is used to evaluate different supply chain scenarios by taking into account different sustainable policies and LTGSCM implementation. The credibility of the supply chains is eventually determined in the industrial sector based on its performance competitiveness and environment protection commitment through extended producer responsibility (EPR) for the entire life-cycle of the product. Hence, societal satisfaction and understanding of marketplace are important elements to consider while attempting setting up a new supply chain policy [23]. Similarly, taking into account different sustainable policies along with company objectives which are directed towards better economic, environmental and overall social benefits, relative importance is used against the performance categories. For the same, we presume the relative weight vector for $x_{i_m j_n}$ which is defined as:

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

Where *u* is the number of weight vector for each category.

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

The focus of the LTBGSCM approach is basically to identify all types of waste and pollutant releases in the supply chain and applying the essential tools to remove them and increase the performance level of the system [5]; lean is all about extracting more with less. In the contexts where there are different types of plastic moulding processes processing diverse mix of raw materials forming range of products of varying size and shapes, a much higher amount of agility is necessary. Accordingly, based on above constraints, type of sustainable policies and pollution control measures, we need to apply variation in relative weight vector $w_{i_m j_n u}$ for varied metric categories. An illustration of four sustainable policies that are based on four customer requirements is shown in Table 3.

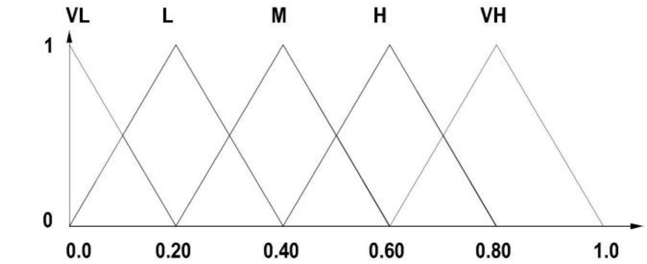

Figure 3: Triangular fuzzy numbers for linguistic terms

Based on varied sustainable policies, every individual supply chain will consist of different sustainable performance. As an example, P_c is the supply chains sustainable performance taking into account a set of performance metrics in the point of view of a sustainable policy laid down by a company. The sustainable performance is then calculated by

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

Linguistic Terms	Triangular Fuzzy number $\left(a_{i_m j_n k_{t''} r''}, b_{i_m j_n k_{t''} r''} \text{ and } c_{i_m j_n k_{t''} r''}\right)$
Very Low (VL)	0.00
Low (L)	0.20
Medium (M)	0.40
High (H)	0.60
Very High (VH)	0.80

taking the product of metrics performance and equivalent relative weights of a category of supply chain which is given by Equations (4-7), where, P_{c_e} ; $P_{c_{ev}}$; P_{c_s} ; P_{c_h} are the economic, environmental, social, health and safety sustainable performances and k_{t_e} ; $k_{t_{ev}}$; k_{t_s} ; $k_{t_{hs}}$ are the associated performance metrics:

$$P_{c_e} = \left(\sum_{k=1}^{t_e} y_{i_1 j_1 k_{t_e}} \right) * w_{i_1 j_1} \quad (4)$$

$$P_{c_{ev}} = \left(\sum_{k=1}^{t_{ev}} y_{i_1 j_2 k_{t_{ev}}} \right) * w_{i_1 j_2} \quad (5)$$

$$P_{c_s} = \left(\sum_{k=1}^{t_s} y_{i_1 j_3 k_{t_s}} \right) * w_{i_1 j_3} \quad (6)$$

$$P_{c_{hs}} = \left(\sum_{k=1}^{t_{hs}} y_{i_1 j_4 k_{t_{hs}}} \right) * w_{i_1 j_4} \quad (7)$$

Lastly, we evaluate the performance of overall supply chain by using Equation (8) [23], with the addition of average values of sustainable performances, performance metrics and equivalent relative weights taking into consideration both sustainable and supply chain policies:

$$P = U_{i=1}^{m} \left\{ avg(P_{c_e} + P_{c_{ev}} + P_{c_s} + P_{c_{hs}} \right\} * 100\% \quad (8)$$

The equation pertaining to performance evaluation of the overall supply chain has two branches. One is the membership value generation from primary data (quantitative metrics) and the fuzzy linguistic variables (qualitative metrics). Metrics will be having different membership values in varied supply chain policies. These variations in the values are in fact the direct outcome of LTBGSCM which is assumed to be put into practice in different supply chain policies. The relationships and effects of LTBGSCM over metrics were discussed in preceding sections. The second branch is related to the sustainable policies of the supply chain. The performance categories are required to prioritise in accordance with the sustainable standing of the company and its concern towards maintaining environmental standards throughout the supply chain. In view of prioritizing companies sustainable and pollution control requirements different relative weights are used for performance categories. The mutual effects of both these parts is incorporated in Equation (8) in order to evaluate the performance of overall supply chain. In Equations (4-7) we have considered sustainable policies by which supply chain policies could be measured by considering different values of $i = 1, 2, ...m$ or varied metric values in varied scenarios. In the same way, the effects of sustainable policies, supply chain policies and also the effects of the lean tools are included in the proposed GSC performance evaluation equation. The method also dealt with the strategic alignment in between the sustainable policy and supply chain policy. The performance of an individual metrics and also the whole supply chain can be calculated by the proposed approach. As a result of which any improvement in the overall supply chain is possible to be evaluated with this method.

4. A CASE EXAMPLE

To demonstrate the application of the proposed method a case study was conducted conducive to a real life environment. We have selected a small scale thermoforming industry for our case study to evaluate the performance of supply chain. It produces thin-gauge, single use food packaging's 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.

Table 3: Linguistic terms for qualitative metrics and corresponding triangular numbers

Metric category	Corresponding relative weights	Priorities over sustainable policies
Economic	$w_{i_m j_1}$	$w_{i_m j_1} > w_{i_m j_2} > w_{i_m j_3} > w_{i_m j_4}$
Environmental	$w_{i_m j_2}$	$w_{i_m j_2} > w_{i_m j_3} > w_{i_m j_4} > w_{i_m j_1}$
Social	$w_{i_m j_3}$	$w_{i_m j_3} > w_{i_m j_4} > w_{i_m j_1} > w_{i_m j_2}$
Health & Safety	$w_{i_m j_4}$	$w_{i_m j_4} > w_{i_m j_1} > w_{i_m j_2} > w_{i_m j_3}$

Table 4: "Thermoforming" supply chain performance metrics and categories

Performance Categories	Metric Id	Performance Metrics (Units)	Metric Type
Economy	$x_{i_{11}}$	Specific energy consumption (SEC)	Quantitative/Cost
	$x_{i_{12}}$	Process waste %	Quantitative/Cost
	$x_{i_{13}}$	Waste recycling %	Quantitative/Benefit
	$x_{i_{14}}$	Recyclate in RM mix %	Quantitative/Benefit
	$x_{i_{15}}$	Overall Equipment Effectiveness (OEE) %	Quantitative/Benefit
	$x_{i_{16}}$	Inbound and outbound logistics	Qualitative/Benefit
	$x_{i_{17}}$	Processing technology	Qualitative/Benefit
	$x_{i_{18}}$	User phase of the product	Qualitative/Benefit
	$x_{i_{19}}$	Buyer- Suppliers relationship level	Qualitative/Benefit
Environment	$x_{i_{21}}$	Water consumption (1 unit = 1000 L)	Quantitative/Cost
	$x_{i_{22}}$	Global Warming Potential (GWP) tCO2	Quantitative/Cost
	$x_{i_{23}}$	Acidification Potential (AP) tSO2	Quantitative/Cost
	$x_{i_{24}}$	Photochemical Oxidation Potential (POP) kg eq. ethylene	Qualitative/Cost
	$x_{i_{25}}$	Environmental management system	Qualitative/Benefit
	$x_{i_{26}}$	Renewable energy kWh	Quantitative/Benefit
Social	$x_{i_{31}}$	Living environment	Qualitative/Benefit
	$x_{i_{32}}$	Extended producer responsibility	Quantitative/Benefit
Health & Safety	$x_{i_{41}}$	Lost-time injuries	Qualitative/Benefit
	$x_{i_{42}}$	Human toxicity potential	Qualitative/Cost

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, environment, social, health and safety. We selected nineteen performance metrics (column 3, Table 4) among four metric categories while six out of nineteen were cost measures. The second column shows metric id where, n = 1-4 and t = 1-19. Metrics could be of two types; one is quantitative metric which could be measured in numbers and qualitative metric which are in linguistic variables. Benefit metric is meant for more the better while cost metric is meant for the less the better. Performance metrics of all forms are specified in third column of Table 4. Different values for every performance metrics were collected and calculated for the supply chain policies of before lean implementations and after lean implementations. Before lean implementation, *i* = 1 (2-10 columns in Table 6), the metric values are same without any noteworthy improvements. 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. The influence of lean tools based green techniques on the performance improvement of thermoforming supply chain were applied among different functional areas. Table 5 provides the list of implemented lean tools.

For instance, cause and effect was applied for supply chain design for environment and ecosystem, implementing non-conventional energy sources, equal focus on forward and reverse supply chain management. In terms of five basic supply chain phases, improvement was observed in plan phase by reduced pollutant releases and end-of-use waste, enhanced company's goodwill in the society, energy conservation, pollution control, procurement of recycled material. Similarly, the improvements achieved in other functional areas with the implementation of LTBGSCM are highlighted in Table 5.

LTBGSCM had great improvements on the performance metrics particularly on reductions in wastage $\left(x_{212}\right)$, improvement in overall Equipment Effectiveness $\left(x_{215}\right)$ decrease in green warming potential (GWP) plant and logistics $\left(x_{222}\right)$ and enhancement in consumption of renewable proportion of energy. Conversely, adopting lean tools in GSCM also affects the cost component adversely. Application of lean tools (pollution control ancillaries, extended producers responsibility (EPR), training the employees and supply chain members) also marked increase in over head cost $\left(x_{217}\right)$, adoption of environmental practices $\left(x_{225}\right)$ and investment in EPR $\left(x_{232}\right)$. Accordingly, we incorporated all the values as regards to the performance metrics in evaluating the effects of LTBGSCM on the performance of supply chain.

Table 5: GSCM practices for plastic thermoforming supply chain improvement

<table>
<tr><th>Basic components of supply chain</th><th>Department</th><th>Lean tools</th><th>GSCM practices</th><th>Improvement</th></tr>
<tr><td rowspan="7">Plan</td><td rowspan="7">Manufacturer</td><td rowspan="5">Cause and effect</td><td>Supply chain design for environment and ecosystem</td><td>Reduced environmental release and end-of-use waste</td></tr>
<tr><td>Implementing non-conventional energy sources</td><td>Enhanced company's goodwill in the society</td></tr>
<tr><td rowspan="2">Equal focus on forward and reverse supply chain management</td><td>Energy conservation, pollution control</td></tr>
<tr><td>Procurement of recycled material</td></tr>
<tr><td rowspan="2">Voice of customer (VOC)</td><td>Understanding customers experience</td><td>Effective disposable collection after end-of-use of product</td></tr>
<tr><td>Corporate social responsibility</td><td>Environmental hygiene</td></tr>
<tr><td>Source</td><td></td><td colspan="3">No improvement tools</td></tr>
<tr><td rowspan="6">Make</td><td rowspan="6">Production</td><td rowspan="2">Effective layout</td><td rowspan="2">Blending, finishing, assembly close to moulding section</td><td>Less human fatigue</td></tr>
<tr><td>Reduced spillage of resin and additives</td></tr>
<tr><td>Standardised work</td><td>Standard operating practices</td><td>Reduced demand and supply lead time</td></tr>
<tr><td>Total preventive maintenance</td><td>Prevention of problems that would halt production</td><td>Reduced machine idle time</td></tr>
<tr><td>5 S's</td><td>Right thing at the right place</td><td>Improved productivity and quality</td></tr>
<tr><td>Inventory control</td><td>Recording maximum and minimum stock level at all stages of supply chain</td><td>Maintaining optimum inventory level</td></tr>
<tr><td rowspan="2">Delivery</td><td rowspan="2">Dispatch</td><td rowspan="2">Kaizen</td><td>Selection of carriers operating on less polluting fuels</td><td>Significant curb on vehicle emission</td></tr>
<tr><td>Logistic scheduling</td><td>Utilization of same carriers in the reverse supply chain</td></tr>
<tr><td>Return</td><td>Scrap vendor</td><td>Waste (Muda)</td><td>Proportionate use of recyclate from the market</td><td>Resource conservation</td></tr>
</table>

Table 6 presents monthly values for various quantitative metrics. As, we observed two different supply chain policies; therefore the values also are measured in two distinct scenarios. Next, by applying equation (1) and (2), values of all quantitative metrics are converted to normalised metric values as mentioned in Table 6. For instance, cost metric $\left(x_{111}\right)$ (Specific Energy Consumption), $y_{i_m j_n k_{t_d}}$ the normalised metric value of which is calculated and shown in intersect of fourth column and third row of Table 7. Normalised metric values are obtained using Equation (2) by converting metric values of $\left(x_{111}\right)$ (Specific Energy Consumption) from Table 6 (SEC metric demonstrate negative behavior since it is a cost metric) and in Table 7, the average of all these values is mentioned at the intersect of its third row and fourth column.

Table 6: 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)								

As, the values of Specific Energy Consumption (SEC) are measured previous to lean implementations; we are using here, *i*=1; *j*=1 (economic category) and *k*=1. In a similar way, all other values as regards to quantitative metrics are readily converted to normalised metric values which are given in columns four and five of Table 7. Considering qualitative metrics, linguistic variables and there analogous membership values are used (Table 2). For instance, linguistic term only could be used to measure living environment ($x_{i_{31}}$). Case example illustrates, after implementing lean tools customer is contented as higher level, which was measured previously as medium level. We worked out both these linguistic variables using Table 2 as (0.40) and (0.80) and are given in Table 7.

Next, sustainable performance is calculated for lean and non-lean supply chain scenarios using Equations (4-7) wherein individual normalised metric values are multiplied with relative weights for respective performance categories. As an example, for economic category (P_{c_e}) and its non-lean scenario the sustainable performance is computed by averaging the normalised values of economic metrics; followed by multiplying sustainable policy (column 2 in Table 7) for economic category. For this particular case study, Sustainable policy values are selected from second row as given in Table 3 given that thermoforming involves producing a high-volume-low-price product. In a similar way, sustainable performances of other performance categories are calculated and given in sixth and the seventh column of Table 7. Now, with the use of Equation (8), overall performance of the supply chain for non-lean and also lean policy is computed and is mentioned in eighth and ninth column of Table 7. If we compare the values, one can notice that performance of lean supply chain is improved than that of non-lean scenario for supply chain of the thermoforming company.

Table 7: Overall performance of Non-lean & Lean supply chain scenarios

Metric Categories	Sustainable policy	Performance metrics	Normalised fuzzy values		Sustainable performance		Overall performance	
			Non-lean scenario (i =1)	Lean scenario (i =2)	Non-lean scenario (i =1)	Lean scenario (i =2)	Non-lean scenario (i =1)	Lean scenario (i =2)
Economy	Very high (0.80)	$X_{i_{11}}$	0.444	0.37	0.355	0.405	0.226	0.248
		$X_{i_{12}}$	0.483	0.319				
		$X_{i_{13}}$	0.502	0.481				
		$X_{i_{14}}$	0.626	0.571				
		$X_{i_{15}}$	0.534	0.616				
		$X_{i_{16}}$	0.2	0.4				
		$X_{i_{17}}$	0.4	0.6				
		$X_{i_{18}}$	0.4	0.6				
		$X_{i_{19}}$	0.4	0.6				
Environment	High (0.60)	$X_{i_{21}}$	0.589	0.618	0.264	0.296		
		$X_{i_{22}}$	0.587	0.601				
		$X_{i_{23}}$	0.539	0.505				
		$X_{i_{24}}$	0.4	0.4				
		$X_{i_{25}}$	0.2	0.4				
		$X_{i_{26}}$	0.322	0.431				
Social	Medium (0.40)	$X_{i_{31}}$	0.4	0.8	0.186	0.212		
		$X_{i_{32}}$	0.53	0.261				
Health and Safety	Low (0.20)	$X_{i_{41}}$	0.4	0.6	0.1	0.08		
		$X_{i_{42}}$	0.6	0.2				

5. RESULT ANALYSIS

5.1 Selection of metric

In this research, a set of metrics has been proposed considering five different phases of the life cycle. Figure 2 illustrates that five basic phases of supply chain can appropriately take into account every metrics for evaluating the supply chain performance effectively. Both the metrics non-lean and lean are incorporated to measure the supply chain performance before and after the implementation of lean. Total 19 dissimilar metrics are categorized according to the stages in five basic phases of supply chain in which the strategic focus was effective and efficient supply chain. In view of the fact that lean tools reduce waste and pollutant releases and also optimize the overall effectiveness of the supply chain, we propose here cost and environment sustainable metrics of the supply chain for thermoforming company to investigate the proposed method of performance evaluation. Use of qualitative metrics makes it difficult to measure the metrics as it generates uncertain and imprecise data. As supply chains are by and large complex and are described by various activities which are stretched over multiple of stages, [5] cited the challenges in effective coordination of supply chain and its performance evaluation. Measuring of quantitative metrics is done on monthly basis before and after the implementing range of lean tools and techniques. For each metric we took seven observations to study the performance. Five basic supply chain processes are selected to examine the overall supply chain and also evaluate the supply chain performance.

Table 8: Sensitivity analysis for various supply chain scenarios

Exp. no.	Sustainable policies	Supply chain performance (%)	
		Non-lean scenario (i=1)	**Lean scenario (i=2)**
1.	$w_{i_m j_1} = 0.80 > w_{i_m j_2} = 0.60 > w_{i_m j_3} = 0.40 > w_{i_m j_4} = 0.20$	22.6	24.8
2.	$w_{i_m j_2} = 0.80 > w_{i_m j_3} = 0.60 > w_{i_m j_4} = 0.40 > w_{i_m j_1} = 0.20$	23.0	24.3
3.	$w_{i_m j_3} = 0.80 > w_{i_m j_4} = 0.60 > w_{i_m j_1} = 0.40 > w_{i_m j_2} = 0.20$	23.4	24.1
4.	$w_{i_m j_4} = 0.80 > w_{i_m j_1} = 0.60 > w_{i_m j_2} = 0.40 > w_{i_m j_3} = 0.20$	23.4	23.2

5.2 Effect of sustainable policy on the performance of the supply chain

As pointed out in Table 3 and to study the effect of sustainable policies on two supply chain conditions for different plastic processing types, in all four experiments which are conducted is shown in Table 7. The sole objective is to ascertain which of the sustainable policy is more effective for the lean based supply chain. Among all of the conducted experiments lean performance proves with best results. Performance of the lean supply chain records best performance (24.8 per cent) within experiment no. 1 in which economic category is mainly prioritized as compared to other policy but mentions least performance (23.2 per cent) within experiment no. 4 in which health and safety is mainly prioritized. The investigation highlights that the lean supply chain performances are far better as compared to non-lean scenario in environment and social sustainable policies than that of economic and health and safety. Consequently, one can firmly claim that said lean based supply chain performance evaluation model for "Thermoforming" supply chain is much more effective in environment and social sustainable policy.

6. CONCLUSION AND FUTURE SCOPE

Through this paper a set of supply chain metrics is proposed by us for the evaluation of performance to judge the effects of LTBGSCM and the sustainable policies. At the start of the discussion, we tend to highlight the latest literature on implementations. The outlined metrics and the method of performance evaluation are based on strong theoretical basics and are validated by implementing in a small scale plastic thermoforming company. Certainly it would be helpful for future researchers to examine the study in diverse scenarios; which could possibly be tested through multiple case study approach. This study represents the data from a wide range of the supply chain contexts. Data from the entire supply chain including suppliers, vendors, distribution channel and agencies involved in the reverse supply of recycled material will potentially assist with a valuable and more precise performance measures of the supply chain, necessity of alignment on strategic terms as also sustainable and the strategic oriented supply chains.

The effect of performance enhancement tools over supply chain performance measures was also discussed. Furthermore, we proposed metrics for the measures of supply chain. The metrics comprised basic measures of supply chain as also lean measures. Finally, to evaluate the impact of lean tools and the sustainable policies on the measures of supply chain, we are proposing a performance evaluation method which is based on fuzzy rules. The undertaken case example highlights the capability of the proposed method in measuring the metrics all through the multiple elements. Also, the proposed method supports the alignment of supply chain policy with that of the sustainable policy. Most important contribution of this research is to offer a set of the performance metrics. In the proposed framework we have included the performance metrics and also the impact of lean tools on stated metrics which seems to be an effective option in measuring the performance of supply chain for both the lean and non-lean scenarios, involving both quantitative and also qualitative metrics. An additional contribution of this research is the development of a mathematical model through which one can measure the effect of lean tools on the performance of supply chain. Different metric values which are composed from the cost and environment sustainable supply chain are used to measure the performances in both the scenarios that are before and after LTBGSCM

evaluation of green supply chain. In view of the fact that, this study is mainly focused on the data primarily collected within the manufacturing company, future study might also include the facts from suppliers and also from buyers and recyclers to better determine the degree of integration within the larger scope of supply chain including the upstream and downstream.

The apparent frame of this study appeared from different plastic processing industries. Future scholars could also orient their attention on other industries and judge the relationship between the performance of supply chain, products end-of-use position and selection of various lean tools. Further, future research could possibly include more number of performance metrics among other relevant contexts for more precise findings. Supplementary factors such as product life cycle and sustainable profit margin could also be considered with their effects on examined performance of supply chain. The method which is proposed can provide an insight to the managerial function for the selection of performance measures and also for the measurement of the improvements. The normalized values and then sustainable and also overall performance of supply chain derived from the metric values can be coded using Matlab, turns out to be a benefit for the engineers and managers so as to investigate the improvements in the performance of supply chain. It will be possible to provide a quick scenario of the performance of supply chain as also a clear idea of the business with the faster calculations.

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