Supply Chain - Sustainability Index- An Approach towards Benchmarking Parameters for the Food Industry

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***Abstract*—Despite the optimistic outlook at the economy, the food industry has its share of shortcomings in the forefront of sustainable operations. SMEshave resource constraints such as inefficient data handling capacity, insufficient financial support and transparency issues. However, the major problem that must be addressed is the lack of 'technical know-how' about metric for measuring sustainability performance.The approach is based on the study of Global Reporting Initiatives (GRI) and Dow Jones Sustainability Indices (DJSI)to design parameters based on people, planet and profit indicators. In a global perspective, 25 organizations (small, medium and large enterprises) in the food industry are selected and data collection is carried out from sources like 'Sustainability report' and 'Annual report' of these organisations. Data Envelopment Analysis (DEA), is used to arrive at the relative efficiency scores and it is taken as input to the SISO (single input single output) type Fuzzy Model to arrive at an index.A case simulation to demonstrate the application, DMU with relative efficiency score of 34% was taken as input which resulted to output on sustainability index of 2 (on a scale of 1-5) indicating poor sustainability of the organisation. The novel work is based on parameter design for selecting the performance measure of sustainability and arriving at a unique index, providing a tool to measure the sustainability performance for the organisations.**

Keywords*— *Food Supply Chain, Data Envelopment Analysis, Fuzzy Model, Sustainability Index, Benchmark
JEL Classification: C15, C43, C65, Q50, Q55, Q56

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1. Introduction

Nearly, 50% of all the food harvested is lost or wasted before it reaches the consumer and similar situation is for post-harvest[1]. This is precisely why feedinsg the global population in 2050 is going to be a huge issue that will crop in the history of mankind despite the technological advancements. Businesses understand that sustainability is the need of the hour and organizations in the food industry are trying to address this issue by adapting the UN's SDGs(Sustainable development Goals) by working around the Sustainability Pillars (Social, Environment, Economic).However, MSMEs have various obstacles in adaptingsustainability starting from the lack of technological know-how and the cost affiliated to it [2] till the uncertainty of end consumer reception of sustainable products. Beyond all this, there is a gap in understanding how to quantify one's own sustainability performance along the food supply chain.

The research paper proposes a quantifiable method to benchmark sustainability, i.e., competitive benchmarking, in MSMEs and to develop a sustainability index. On that line, the research article has two parts to it: 1) Measuring the efficiency of sustainability with respect to other organizations in the same industry 2) Developing a sustainability index to understand their supply chain operations.

The research uses secondary data collected from **'Sustainability Reports' and 'Annual Reports'**of selected MNEs that have shown excellence in achieving the SDGs adapted by UNbased on the sustainability parameters identified from **DJSI (Dow Jones Sustainability Index) and GRI**

(Global reporting Initiative). These various companies become the DMUs whose sustainability data is fed as an input into the DEASolver. DEA (Data Envelopment Analysis) is used to measure and analyse the sustainability efficiencies along the food supply chain using the secondary data that has been collected. Having found the efficiencies, benchmarking cannot be random and should be substantiated with a valid schema. The research uses **SISO type Fuzzy Model and Inference System** to build a **sustainability index** which would help the organisations to understand the performance related to sustainable supply chain practices globally.

2. Literature Review

Deteriorated food quality along the supply chain is a major threat to sustainability. Food quality has an impact on all the 3 facets of sustainability, i.e., Environment, Social and Economic, directly or indirectly causing other sustainability issues along the food supply chain. Food wastage is one such outcome of the downturn in food quality in the length of supply chain[3], classifies food wastage as 'pre-harvest' and 'post-harvest' waste. According to [3],feeding a global population of nine billion by 2050 is going to be a major challenge to agriculture and food industry. Embracing sustainability as a bedrock for operations and logistics would address this issue. According to [4]**,** sustainability in food supply chain directs organizations into avoiding depletion of resources and its ecological footprint parallel to maintaining its economic viability. The conjuncture of profitability [5]and together consumption and expenditure [6] are the measurement inclusions that MSMEs should look for when measuring their individual sustainability performance. SMEs constitute 80% of the food industry and they contribute to major sustainable issues. This can be attributed to the lack of resource availability [7], upfront cost involved in the technological investment to track the sustainability performance within the length of food supply chain, the difficulty associated with data collection and handling, with relevance to environment sustainability **[8]** and inadequate time and management expertise to invest for sustainability agenda. Ref **[9]**mentioned that disturbances in supply chain create fluctuations in the process of demand and supply while disruption can beidentifies as an impactful sudden dissolution of a sustainable supply chain process.

Ref [10] defines **'**Green Supply Chain'as a multidisciplinary issue that gathers environmental management practices in the context of supply chain management and results from theresearch workof [11-12] and [6]show that green supply chain initiatives has a positive correlation between economic and environment performance for the organization.

2.1 Performance Measurement Approaches

Today, it is believed that businesses are more than just creators of economic value. Firms ought to have multi-dimensional responsibilities and a tool for measuring organizational performance emerged, i.e., the "Triple Bottom Line" approach[13]. The approach includes People, Planet and Profit aspects of performance measurement, which in the recent past, is being extended to sustainability. LCA (Life Cycle Assessment), an eco-efficiency tool, continues to be widely used in industry to quantify the eco-efficiency of products and focusses on reducing ecological footprint. The 'Cradle to Cradle' approach challenges the eco-efficiency approach by attempting to increase the positive footprint and focusses on absolute sustainability [14]. Higg Index, an internal self-assessment tool, is widely used to measure sustainability of various apparel products [15]. It is to be noted that all these performance measurement approaches incline themselves towards sustainability in product design and development except for the 'triple bottom line' approach.Further, despite the research done to analyse the various sustainability aspects of SMEs, like the issues in sustainability of SMEs and effect of firm's size on sustainability performance of Food SMEs [4]**,** a significant gap exists in the literature pertaining to food chain sustainability performance measurement in MSMEs. This gap was confirmed by [16], who suggested that measuring performaceof sustainability would be a sizeable challenge for SMEs. In addition, SMEs have a clear understanding of their own sustainability performance [17] and hence have a major obstacle to be overcome in terms of self-evaluation and upgradation. The right kind of assessment tool should be practical, flexible [18] and agile [19], enabling quantification and help to improve effectiveness of the actions initiated in the process of measurement (Shepherd and Gunter, 2006)[20]. According to Ref [21]**,**the measurement tool may be both qualitative or quantitative terms in which quantitative techniques such as benchmarking are frequently used by organisations and practitioners. However, approaching performance assessment from this aspect has two major setbacks. One to establish the complete requirements of data and secondly, its continuous source of database in an organisation [22]. These drawbacks pose a further limitation to the SMEs for the sustainability performance evaluation. Ref [23] pointed out that stakeholders might start holding firms responsible for non-sustainable supply chain issues.

Several performance measurement techniques like the SMART(1988), Performance measurement Matrix(1989), the Balance Scorecard(1992), the integrated dynamic PMS (1997) and the Performance Prism (PP) (2001) [18] have been studied across literatures. However, in the SMEscontext, there is a lack of substantial measurement approach and standard tool. Data Envelopment Analysis (DEA), a non-parametric measurement technique developed by [24], is a tool that can be used to define benchmarks against which SMEs can formulate a Performance Measurement System. In Ref [18], DEA has been used for bench marking flexibility in supply chain using a CRR Model. DEA typically uses Decision-Making Unit (DMU) to assign weights to input and output to formulate the efficiency benchmark score. DEA calculates relative efficiencies of the DMUs with multiple input and output parameters and estimates ideal weights to be assigned to each input and output parameter to maximize relative efficiency score.

2.2 Benchmarking of Sustainability in the Past

The field of sustainability benchmarking has witnessed a notable improvement in the past; however there is a huge scope for using various tools and methodologies to establish an effective performance measurement system [25-28] have developed a sustainability benchmarking system of food supply chain in the past. This method has the following procedures in sequence: developing sustainability indicators around the 3P's of sustainability, applying the indicators to various stages of supply chain, setting targets according to desirability of sustainability performance, and finally determining the relative importance between indicators. The procedure of rating the indicators based on the level of importance is done using Analytic Hierarchy Process (AHP). However, a sensitivity analysis of the results was done at the end of this method.

There are cross-sector benchmarking studies to identify 'the-best-of-class' standards that organizations can adapt irrespective of the field or business that the company is operating in [29-31]. A composite GLPI (Green Logistic Performance Index) was proposed by[32],which could be used by managers across various industries to benchmark their sustainability performance. The research, however, fails to address the issues faced particularly by SMEs.Ref [33] used DEA model to evaluate the efficiency score of supply chain performance by BSC (Balanced Score Card). Using DEA models help managers to better identify their supply chain inefficiencies and set benchmarks to improve these inefficiencies [34]. Despite the efforts, there exists a gap in benchmarking sustainability in SMEs in the Food Industry. There is a need for comparative benchmarking studies within food sectors to break down the complexity in the interdependence between the various stake holders and actors in the supply chain [35]. Also, research in the field of benchmarking using DEA doesn't address the feasibility of achieving the benchmark that is set. This is a major shortcoming in the benchmarking tools discussed in the past researches. Ref [36] evaluates the preventable risks, strategic risks and external risks that evaluate the resilience of the sustainable supply chain with respect to the organizational context.

A sustainability index is needed to decipher the right interpretation of the efficiency results.

2.3 Discussion on Variables

There are various parameters which is an indicator to evaluate the performance measure of sustainability. Ref [37] narrates that supply side , process side and demand side of the supply chain should be analysed with various theories like agency theory, contingency theory, cost transaction theory and have performance metrics that cover financial and non financial parameters

According to a research by [38], one third of the food produced (614 kcal/cap/day) is lost within the food supply chain. If the lowest food wastage along length of the distribution network is achieved globally, then the total food loss as food wastage can be halved. Life Cycle Assessment tool identifies disposal/recycling as an important stage in the food product life cycle that can be addressed to reduce the

impact on environment significantly [39] in terms of handling the food wastage issue.
Another important environmental hazard caused by Food and Drink Industry is the pollution caused by these sectors. The food and beverage sector contributes to 23% of global resource use, 18% of greenhouse gas emissions and 31% of acidifying emissions [40]. Thus, it is very important for both MNEs and MSMEs to reduce the impact that they have on the environment. Reducing greenhouse emissions is thus a very crucial issue that the companies should handle along their FSC.

A research work by [4], attempts a comparative study between Micro, Medium and Small enterprises on various performance measures on sustainability. Apart from Waste Generated, Gross profit margin and Production/operational/raw material cost or simply COGS has been important performance measurability parameter.
In the 'People' aspect of sustainability, managementdecision inculcates sustainability behaviour among employees, which is essentialto reduce the risk on a daily basis in the organisation[41]. Thus, training employees is essential in implementing sustainability and making it a way of work.

Reference	*Contribution*	*Weakness*
[32]	A Composite GLPI (Green Logistic Performance Index) which could be used by managers across various industries to benchmark their sustainability performance	The research fails to address the issues in sustainability performance faced particularly by MSMEs
[42]	To evaluate and compare sustainability performance, a multi- criteria framework is developed based on Fuzzy Entropy and Fuzzy Multi-attribute Utility (FMAUT).	The measurement devised has drawbacks of not being able to stand alone without an alert management to help decision makers on every parameter required for decision making.
[28]	Developed a sustainability benchmarking system that has the following procedures in sequence: developing sustainability indicators around the 3P's of sustainability, applying the indicators to various stages of supply chain, setting targets according to desirability of sustainability performance, and finally determining the relative importance between indicators.	Assigning different weights to the 3 dimensions of sustainability (Economic, environment and people) in the obtained sustainability index would change the obtained results.
[15]	Used Higg Index, an internal self-assessment tool, which is widely used to measure sustainability of various apparel products	Performance measurement approachinclines itself towards sustainability in product design and development
[33]	Used DEA model to evaluate the efficiency score of supply chain performance by BSC (Balanced Score Card).	Lacks a sustainability index to facilitate reliable benchmarking for organizations

3. Methodology

3.1 Problem Statement

"SME's in food supply chain operations do not have efficient means to measure the sustainability performance based on triple bottom line approach (people,planet and profit) which impacts the stakeholders and involves food wastage and increasedresource depletion."

Food quality and wastage issues are prior in food supply chain and it is largely governed by SME's be it at micro, medium or small scale enterprises. In a research on SMEs in Thailand [43], one out of 26 SMEs was able to outperform the benchmark set by large firms. These are mainly due to lack of resources, data handling capabilities, technological infrastructure and inefficiency in the supply chain. In Ref [17],the study based on Italian SMEs concludes that there was no mechanism to calculate the sustainability performance which resulted in lack of understanding on their own sustainability performance bearing to barrier on the implementation of sustainability performance concept implementation. This has direct and indirect impact on 3Ps (People, Profit & Planet) of the sustainability pyramid. There is no qualitative or quantitative methodology to understand the sustainable performance of the food supply chain using a triple bottom line approach.

3.2 Research Objective

- To conduct a competitive benchmarking of the food-based supply chain organisations.
- To arrive at a sustainabilityindex which help to define the performance of the food supply chain using triple bottom line approach.

3.3 Research Methodology

The variables were identified based on the study of various standards set by external agencies, for eg: GRI & DJSI. Post identification of variables, the data was collected from 25 organisations for the metrics selected from their annual reports and sustainability reports. The data set was then taken in DEA solver software by DEAP for the analysis inorder to measure the relative efficiency (E) and arrive at further improvement benchmarks for relatively inefficient DMU's. Inorder to benchmarking for a SME's operations, a SISO type fuzzy model is developed to arrive at sustainability index for the supply chain operations. The brief of the research methodology is diagrammatically represented in the figure 1 below.

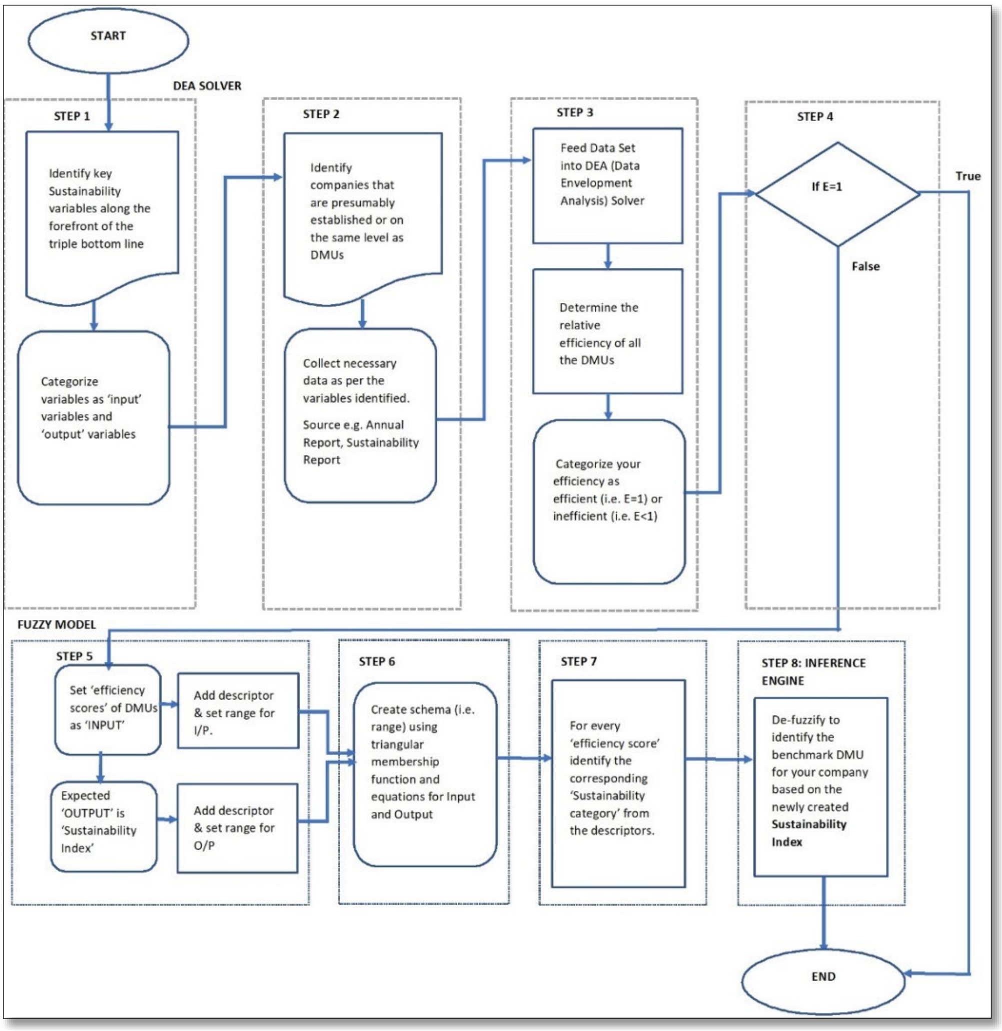


Figure 1- Diagrammatic representation on the proposed model

3.1 Variables Identified

Table – 1:*Input & Output variables with definition of variables for DEA approach*

Input: Resources		
Variables	**Denomination**	**Definition of variables**
Total Waste Generated	Tons	Total amount of waste sent to landfill
Pollution Generated (Air)	PM^	Total amount of pollution generated in the year related to Air & Water
Pollution Generated (Water)	pH scale	
Equity	currency	Amount of owner's capital & stake in the business
COGS	currency	Direct cost attributable to the production of goods sold in the organization
Avg. Inventory	no.	Median value of inventory at specific time period
Training Expenses	currency	It is the amount spent for training & development of employees to create a safer workplace.

^Particulate Matter

Output: Supply Chain Sustainability		
Variables	**Denomination**	**Definition of variables**
Recycling	metric tons	Total amount of waste is converted into reusable materials
Greenhouse Gas Reduction	ppm or micromole	The amount of carbon dioxide released in the atmosphere
Safer workplace	TRIFR*	TRIFR or TRIR or TRFR is the number of fatalities, lost time injuries, substitute work, and other injuries requiring treatment by a medical professional per million hours worked.
Sales	currency	No. of goods or services sold in a given time-period
Inventory turnover Ratio	percentage	Efficiency Ratio for time required by firm to convert its inventory into cash

*Total Recordable Injury Frequency Rate

The various parameters indicated in Table 1, are carefully taken post review of the sustainability report and annual reports of large, medium and small enterprises in order to get the accurate measure for measuring sustainability.

Table 2: Data Set

DMU	Name of Company	Input Variables							Output Variables				
		Total Waste Generated	Pollution Generated (Air)	Pollution Generated (Water)	Equity	COGS	Avg. Inventory	Training Expenses	Recycling	GHG reduction	Safer workplace	Sales	Inventory turnover Ratio
DMU1	Nestle	0.0	0.0	0.0	488.66	21.85	131.61	5.75	100.0	33.2	0.0	101,351.10	16.60
DMU2	HUL	2.0	1.8	2.0	1,010.71	4.94	33.72	7.14	98.0	47.0	20.0	357,870	14.64
DMU3	Starbucks	1.0	4.0	3.0	12.88	10.04	3.47	2.53	100.0	52.0	0.0	4,134.70	2.89
DMU4	Smithfield Foods Inc	1.3	10.0	8.0	9,894.00	419.88	2,153.25	132.47	90.0	5.7	8.0	14,438.40	19.50
DMU5	Coca Cola	6.3	3.2	0.0	12,975.00	10,126.60	2,025.40	576.60	100.0	8.2	1.6	26,912.00	4.97

DMU6	**AB InBev**	2.0	4.7	4.0	80,220.00	147.74	4,004.00	131.31	72.0	7.5	6.0	35,058.00	3.69
DMU7	**Kellogg Co**	20.0	15.0	26.0	2,851.00	2,293.00	1,227.50	210.72	96.0	15.0	12.0	129.69	1.76
DMU8	**Danone**	11.0	11.0	42.0	1,712.64	6,113.00	1,558.00	63.55	50.0	10.0	23.0	80.09	3.90
DMU9	**AmulDairy**	40.0	10.0	5.0	80,570.00	18,657.00	6,659.50	137.65	60.0	9.0	17.0	88,365.58	2.80
DMU10	**Hormel Foods**	22.0	33.0	7.0	43,907.00	6,461.00	2,532.00	82.60	57.0	11.1	32.0	91.78	0.06
DMU11	**Fetzer Wines**	1.0	7.0	12.0	2,001.99	781.11	397.68	212.05	98.0	16.9	27.5	5,641.05	4.13
DMU12	**Lindt&Sprungli**	16.0	20.0	30.0	4,195.00	407.00	3,968.00	886.40	77.0	40.0	11.0	4,087.56	1.01
DMU13	**Fraser and Neave**	18.0	11.0	7.0	84,301.00	12,366.00	24,722.00	129.30	63.0	13.4	13.0	1,898.24	5.00
DMU14	**Cargill Meat & Poultry**	23.0	14.0	9.0	330.00	267.00	398.00	68.80	70.0	30.1	3.7	114.69	11.23
DMU15	**Olam International Ltd**	15.0	17.0	16.0	558.64	253.21	679.53	19.80	80.0	18.0	16.0	26.27	3.73
DMU16	**GrupoArcor Mexico**	21.0	23.0	34.0	27,096.00	11,208.00	2,552.00	101.33	66.0	40.0	12.2	18,023.00	3.96
DMU17	**Goodricke Group**	8.0	13.0	18.0	21.60	190.58	145.45	8.12	70.0	23.7	8.0	751.64	1.31
DMU18	**Ajinomoto Group**	31.0	19.0	28.0	720.55	765.65	184.09	11.14	99.0	3.4	3.0	1,151.67	4.15
DMU19	**Mondelez International**	37.0	16.0	36.0	31,915.00	15,831.00	2,513.00	335.06	57.0	15.0	26.0	258.73	6.30
DMU20	**Lotte Foods**	17.0	12.0	11.0	1,086.38	20,279.90	4,725.91	173.95	69.0	32.0	9.0	39.45	4.29
DMU21	**Kirin Brewery Co Ltd**	21.0	30.0	30.0	10,659.59	6,755.29	1,817.92	128.22	88.0	39.0	1.2	14,207.40	3.72
DMU22	**Suntory Holdings Limited**	19.0	12.0	15.0	13,715.11	9,720.68	3,516.74	179.68	81.0	20.0	6.1	21,575.31	2.76
DMU23	**The Kraft Heinz Co**	15.0	15.0	15.0	66,241.00	16,529.00	2,749.50	570.13	62.0	17.0	1.1	262.32	6.01
DMU24	**PepsiCo**	5.0	20.0	25.0	10,981.00	28,785.00	2,835.00	284.01	85.0	8.0	2.5	635.25	10.15
DMU25	**Dunkin brands Inc**	32.0	28.0	20.0	84,477.00	12,036.00	1,506.00	653.46	70.0	7.7	19.9	860.50	5.83

The data set is prepared from various reports and the values are obtained based on analysis of financial statements and sustainability reports published by Global Reporting Initiatives (GRI) standards.

4. DEA model

There are 7 input variables and 5 output variables which are considered in the DEA model. The model function is as follows:

$$\textbf{Maximize } \left(\sum_{k=1}^{s} v_k\, y_{kp}\right)\left(\sum_{k=1}^{s} v_k\, y_{kp}\right)$$

$$\text{s.t.}\left(\sum_{j=1}^{m} u_j\, x_{jp} = 1\right), \left(\left(\sum_{k=1}^{s} v_k\, y_{ki}\right) - \left(\sum_{j=1}^{m} u_j\, x_{ji} = 1\right)\right) \leq 0\ \forall i \text{ and } v_k, u_j \geq 0\ \_\forall j, k \qquad (1)$$

Where:

k = 1 to s; j = 1 to m; I = 1 to n
y_{ki} = Amount of output 'k' produced by DMU 'i'.
x_{ji} = Amount of input 'j' used by DMU 'i'.
v_k = Weight given to output 'k'.
u_j = Weight given to input 'j'.

The above linear programming problem will identify the relative efficiency scores of all the DMUs. Weights of input and out variables are selected by the DMUs in such a way that the efficiency score of the DMU is maximized. An efficiency score of 1 indicates that the particular DMU is efficient. Any score less than 1 indicates that the DMU is inefficient and has scope for improvement.

4.1 Benchmarking using Data Envelopment Analysis (DEA)

The primal solution of the DEA is converted into a dual problem in order to obtain the benchmarks. DEA identifies a corresponding efficient DMU for every inefficient DMU and this can be utilized as benchmark for improvement.
The dual function is as follows:

Minimize E
s.t. $\sum_{j=1}^{m} \lambda y_{ki} \geq y_{kp} \forall j, \sum_{j=1}^{m} \lambda x_{ki} \leq E x_{kp} \forall k$ **and** $\lambda \geq 0 \ \forall i$
Where:
E = Efficiency score
λi = Dual variable

The dual function identifies a test DMU as inefficient if a composite DMU is seen to utilize less input that the test DMU while maintaining the same output level. Thus, the variables that form the composite DMU is set as benchmark by the DEA for the test DMU.

4.2 Efficiency Score

DEA finds the relative efficiency of the organisation based on the multiple inputs and output parameters. The relative efficiency score (E) of the organisation is shown in Table 3. The table indicates that firm 1, 2, 3, 5, 11 and 17 are relatively efficient in terms of sustainability where as there is scope of improvements for the rest of the firms.

Table 3: Relative Efficiency Score (E)

Firm	Relative EfficiencyScore
1	100%
2	100%
3	100%
4	38%
5	100%
6	27%
7	21%
8	60%
9	34%
10	46%
11	100%
12	13%
13	19%
14	82%
15	92%
16	6%
17	100%
18	29%
19	15%
20	37%
21	4%
22	5%
23	2%
24	5%
25	10%
Mean	**45.7%**

4.3 Improvements Possible

The weights are not assigned to each input and output variables in advance. The DEA assigns ideal weights of each input and output parameter to maximize relative efficiency score based on the linear program it establishes the relative efficiencies and the weighs improvements possible at each of the parameters are obtained. The results are tabulated in Table 4 indicates, for inefficient DMUs, the ideal combination of inputs and outputs possible.

For instance, for DMU-4 which is Smithfield Foods Inc., the total waste generated can be reduced from 1.3 to 0.49% with Capital reduction from $9894 to $995.78 Mn; Pollution generated from Air and Water can be reduced from 18 to 3.93%; COGS from $419.883 to $159.33 Mn; Training expenses from $132.47 to $43.99 Mn and average Inventory from $2153.25 to $205.46 Mn. The amount of recycling the waste should rise from 90 to 131.8metric tons; greenhouse gases reduction should increase from 5.7ppm to 43.33 and sales from $14438.4 to $158322.09 Mn. These improvements are to be done in order to reach the 100% efficiency for sustainability. Similar improvements are possible forother inefficient firms like DMU-6, DMU-7 and DMU-8 and so on in the observed model.

Table 4: Improvements Possible

DMU	Input Variables							Output Variables				
	Total Waste Generated	Pollution Generated (Air)	Pollution Generated (Water)	Equity	COGS	Avg. Inventory	Training Expenses	Recycling	GHG Reduction	Safer workplace	Sales	Inventory turnover Ratio
DMU1	0 to 0	0 to 0	0 to 0	488.66 to 488.66	21.85 to 21.85	131.61 to 131.61	5.75 to 5.75	100 to 100	33.2 to 33.2	0 to 0	101351.1 to 101351.1	16.6 to 16.6
DMU2	2 to 2	1.8 to 1.8	2 to 2	1010.71 to 1010.71	4.94 to 4.94	33.72 to 33.72	7.14 to 7.14	98 to 98	47 to 47	20 to 20	357870 to 357870	14.64 to 14.64
DMU3	1 to 1	4 to 4	3 to 3	12.88 to 12.88	10.04 to 10.04	3.47 to 3.47	2.53 to 2.53	100 to 100	52 to 52	0 to 0	4134.7 to 4134.7	2.89 to 2.89
DMU4	1.3 to 0.49	10 to 1.51	8 to 2.42	9894 to 995.78	419.883 to 159.33	2153.25 to 205.46	132.47 to 43.99	90 to 131.8	5.7 to 43.33	8 to 8	14438.4 to 158322.09	19.5 to 19.5
DMU5	6.3 to 6.3	3.2 to 3.2	0 to 0	12975 to 12975	10126.6 to 10126.6	2025.4 to 2025.4	576.60 to 576.60	100 to 100	8.16 to 8.16	1.57 to 1.57	26912 to 2912	4.97 to 4.97
DMU6	2 to 0.54	4.68 to 0.71	4 to 0.94	80220 to 540.51	147.74 to 39.57	4004 to 80.88	131.31 to 12.12	72 to 72	7.54 to 26.94	6 to 6	35058 to 134014.35	3.69 to 11.09
DMU7	20 to 1.913	15 to 3.11	26 to 3.12	2851 to 592.071	2293 to 15.89	1227.5 to 28.04	210.72 to 5.45	96 to 96	15 to 46.99	12 to 12	129.69 to 209145.91	1.76 to 9.59
DMU8	11 to 4.94	11 to 6.57	42 to 8.6	1712.64 to 1022.16	6113 to 74.76	1558 to 87.11	63.55 to 10.14	50 to 123.98	10 to 55.84	23 to 23	80.09 to 359397.28	3.9 to 15.17
DMU9	40 to 2.13	10 to 1.74	5 to 1.69	80570 to 1763.95	18657 to 714.80	6659.5 to 170.61	137.65 to 46.49	60 to 89.77	9 to 40.26	17 to 17	88365.58 to 304068.97	2.8 to 12.74
DMU10	22 to 3.48	33 to 3.02	7 to 3.18	43907 to 2204.73	6461 to 469.36	2532 to 146.13	82.6 to 37.67	57 to 16	11.12 to 75.40	32 to 32	91.78 to 572513.73	0.06 to 23.59
DMU11	1 to 1	7 to 7	12 to 12	2001.99 to 2001.99	781.11 to 781.11	397.68 to 397.68	212.05 to 212.05	98 to 98	16.9 to 16.9	27.54 to 27.54	5641.05 to 5641.05	4.13 to 4.13
DMU12	16 to 1.68	20 to 2.58	30 to 2.64	4195 to 542.95	407 to 13.49	3968 to 25.13	886.4 to 4.83	77 to 82.02	40 to 40	11 to 11	4087.56 to 191834.95	1.01 to 8.63
DMU13	18 to 1.50	11 to 1.27	7 to 1.29	84301 to 1088.37	12366 to 342.01	24722 to 89.59	129.3 to 23.9	63 to 66.78	13.42 to 30.69	13 to 13	1898.24 to 232558.03	5 to 9.64
DMU14	23 to 2.69	14 to 9.65	9 to 7.35	330 to 269.72	267 to 26.65	398 to 28.52	68.80 to 7.83	70 to 26.79	30.1 to 133.37	3.7 to 3.7	114.69 to 86773.88	11.23 to 11.23
DMU15	15 to 7.12	17 to 10.84	16 to 14.77	558.64 to 515.61	253.21 to 148.34	679.53 to 127.99	19.8 to 9.74	80 to 101.97	18 to 41.35	16 to 16	26.27 to 177284.69	3.73 to 8.23
DMU16	21 to 1.26	23 to 1.25	34 to 1.33	27096 to 754.61	11208 to 9.55	2552 to 57.75	101.33 to 6.07	66 to 91.75	40 to 40	12.19 to 12.19	18023 to 246993.54	3.96 to 13.71
DMU17	8 to 8	13 to 13	18 to 18	21.6 to 21.6	190.58 to 190.58	145.45 to 145.45	8.12 to 8.12	70 to 70	23.68 to 23.68	8 to 8	751.64 to 751.64	1.31 to 1.31
DMU18	31 to 1.14	19 to 3.64	28 to 2.83	720.55 to 162.46	765.65 to 9.21	184.09 to 7.98	11.14 to 3.21	99 to 99	3.4 to 50.89	3 to 3	1151.67 to 57166.05	4.15 to 4.63
DMU19	37 to 2.6	16 to 2.34	36 to 2.6	31915 to 2515.76	15831 to 60.17	2513 to 367.52	335.06 to 23.42	57 to 373.35	15 to 142.75	26 to 26	258.73 to 714500.53	6.29 to 59.86
DMU20	17 to 2.17	12 to 3.44	11 to 4.08	1086.38 to 400.76	20279.9 to 32.21	4725.91 to 35.43	173.95 to 4.51	69 to 69	32 to 32.45	9 to 9	39.45 to 140790.66	4.29 to 6.50
DMU21	21 to 0.61	30 to 1.29	30 to 1.08	10659.59 to 456.64	6755.29 to 15.04	1817.92 to 77.8	128.22 to 5.03	88 to 95.85	39 to 39	1.23 to 3.78	14207.4 to 123093.51	3.72 to 12.36
DMU22	19 to 0.61	12 to 0.55	15 to 0.61	13715.11 to 558.02	9720.68 to 12.67	3516.74 to 77.55	179.68 to 5.12	81 to 81	20 to 31.03	6.14 to 6.14	21575.31 to 160950.89	2.76 to 12.94

DMU23	15 to 0.35	15 to 0.31	15 to 0.35	66241 to 396.92	16529 to 10.64	2749.5 to 64.77	570.13 to 3.83	62 to 62	17 to 23.14	1.1 to 3.53	262.32 to 108515.098	6.01 to 10
DMU24	5 to 0.22	20 to 0.56	25 to 0.73	10981 to 492.53	28785 to 45.87	2835 to 109.95	284.01 to 12.74	85 to 85	8 to 29.44	2.46 to 2.46	635.25 to 97343.95	10.15 to 12.96
DMU25	32 to 2.34	28 to 1.96	20 to 1.98	84477 to 1742.62	12036 to 583.68	1506 to 149.16	653.46 to 40.02	70 to 102.77	7.67 to 47.01	19.9 to 19.9	860.50 to 355982.48	5.83 to 14.78

Table 5: Lambda values indicating benchmarking

DMU	Input oriented CRS Efficiency	Sum of lamdas	Returns to scale	Optimal lamdas with benchmark DMU		
DMU1	1.00	1.00	Constant	1.00 : DMU-1		
DMU2	1.00	1.00	Constant	1.00 : DMU-2		
DMU3	1.00	1.00	Constant	1.00 : DMU-3		
DMU4	0.37	1.33	Decreasing	0.99 : DMU-1	0.16 : DMU-2	0.18 : DMU-11
DMU5	1.00	1.00	Constant	1.00 : DMU-5		
DMU6	0.26	0.73	Increasing	0.44 : DMU-1	0.25 : DMU-2	0.04 : DMU-11
DMU7	0.21	0.99	Increasing	0.58 : DMU-2	0.36 : DMU-3	0.05 : DMU-17
DMU8	0.60	1.40	Decreasing	1.03 : DMU-2	0.37 : DMU-17	
DMU9	0.34	0.91	Increasing	0.84 : DMU-2	0.07 : DMU-5	
DMU10	0.46	1.64	Decreasing	1.59 : DMU-2	0.05 : DMU-5	
DMU11	1.00	1.00	Constant	1.00 : DMU-11		
DMU12	0.13	0.84	Increasing	0.53 : DMU-2	0.27 : DMU-3	0.04 : DMU-17
DMU13	0.18	0.68	Increasing	0.65 : DMU-2	0.03 : DMU-5	
DMU14	0.82	2.63	Decreasing	0.11 : DMU-1	0.19 : DMU-2	2.33 : DMU-3
DMU15	0.92	1.25	Decreasing	0.49 : DMU-2	0.76 : DMU-17	
DMU16	0.06	0.92	Increasing	0.28 : DMU-1	0.61 : DMU-2	0.04 : DMU-3
DMU17	1.00	1.00	Constant	1.00 : DMU-17		
DMU18	0.28	0.99	Increasing	0.15 : DMU-2	0.84 : DMU-3	
DMU19	0.14	2.76	Decreasing	1.46 : DMU-1	1.30 : DMU-2	
DMU20	0.37	0.74	Increasing	0.39 : DMU-2	0.20 : DMU-3	0.15 : DMU-17
DMU21	0.04	0.97	Increasing	0.54 : DMU-1	0.19 : DMU-2	0.24 : DMU-3
DMU22	0.04	0.82	Increasing	0.51 : DMU-1	0.31 : DMU-2	
DMU23	0.02	0.63	Increasing	0.45 : DMU-1	0.18 : DMU-2	
DMU24	0.04	0.84	Increasing	0.70 : DMU-1	0.07 : DMU-2	0.07 : DMU-11
DMU25	0.09	1.05	Decreasing	0.99 : DMU-2	0.06 : DMU-5	

4.4 Graphical Representation

The following is the graphical representation of the optimal lambda values of inefficient firms with respect to the benchmarked DMUs whose efficiency = 1.In the graph,

- The DMUs on curve depicts the firms with efficiency equals to 1 which are optimum and are benchmark for the inefficient firms.
- The DMUs inside the curve depicts the firms whose efficiency is less than or more than 1 making them firms with improvements needed.

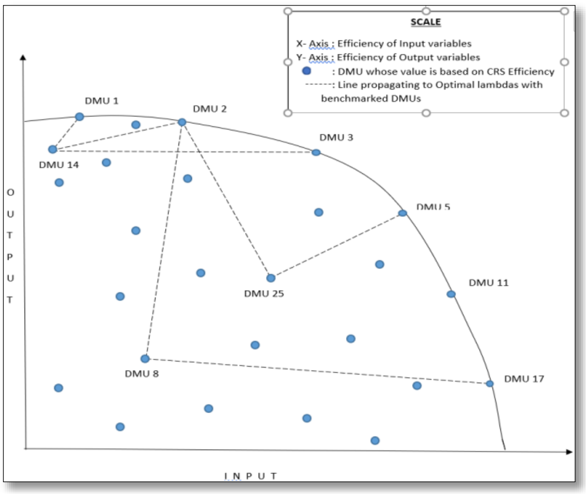


Fig. 2 ***– Graphical Representation of the Benchmarking of DMU's***

5. Fuzzy Model

Fuzzy logic system is a multi-valued logical model based on a crisp input which transforms non-linear functions of arbitrary complexity. It is later converted as a fuzzy output with addition of rules into the system. Finally, the resultant is transformed into a crisp output using simulation technique. We are using the logic and the design of the system is based on the single input and single output type. The descriptors are discussed below:

Input:

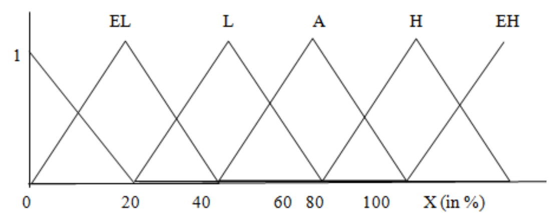
Let efficiency percentage for each DMUs be the input which is 0% to 100%.Then, the descriptor is given as-

Output:

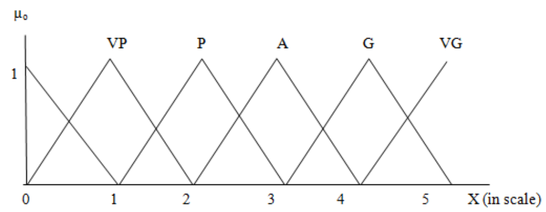
The sustainability index will be an output on a scale of 1 to 5.

Then, the descriptor is given as-

Using the above input variable and descriptor, the triangular membership function is depicted as follows:μ_i



Similarly, using the above input variable and descriptor, the triangular membership function is depicted as follows:



Post the graphical depiction of input and output triangular membership functions, the following rule set is calculated using the formula of equation of a line with one point and a gradient:

$(y - y_1)/(y_1-y_2) = (x-x_1)/(x_1-x_2)$

5.1 Rule set for input variable:

$\mu_{EL}(x) = (0, 0), (20,1)$ $\mu_{EL}(x) = x/20;\ 0 \leq x \leq 20$

$\mu_{EL}(x) = (40,0), (20,1)$ $\mu_{EL}(x) = 40 - x/20;\ 20 \leq x \leq 40$

$\mu_{L}(x) = (20,0), (40,1)$ $\mu_{L}(x) = x - 20/20;\ 20 \leq x \leq 40$

$\mu_{L}(x) = (60,0), (40,1)$ $\mu_{L}(x) = 60 - x/20;\ 40 \leq x \leq 60$

$\mu_{A}(x) = (40,0), (60,1)$ $\mu_{A}(x) = x - 40/20; 40 \leq x \leq 60$

$\mu_{A}(x) = (80,0), (60,1)$ $\mu_{A}(x) = 80 - x/20; 60 \leq x \leq 80$

$\mu_{H}(x) = (60,0), (80,1)$ $\mu_{H}(x) = x - 60/20; 60 \leq x \leq 80$

$\mu_{H}(x) = (100,0), (80,1)$ $\mu_{H}(x) = 100 - x/20;\ 80 \leq x \leq 100$

$\mu_{EH}(x) = (80,0), (100,1)$ $\mu_{EH}(x) = x - 80/20;\ 80 \leq x \leq 100$

5.2 Rule set for output variable:

$\mu_{VP}(y) = (0,0), (1,1)$ $\mu_{VP}(y) = y;\ 0 \leq y \leq 1$

$\mu_{VP}(y) = (2,0), (1,1)$ $\mu_{VP}(y) = 2 - y; 1 \leq y \leq 2$

$\mu_{P}(y) = (1,0), (2,1)$ $\mu_{P}(y) = y - 1; 1 \leq y \leq 2$

$\mu_{P}(y) = (3,0), (2,1)$ $\mu_{P}(y) = 3 - y; 2 \leq y \leq 3$

$\mu_{A}(y) = (2,0), (3,1)$ $\mu_{A}(y) = y - 2; 2 \leq y \leq 3$

$\mu_{A}(y) = (4,0), (3,1)$ $\mu_{A}(y) = 4 - y; 3 \leq y \leq 4$

$\mu_{G}(y) = (3,0), (4,1)$ $\mu_{G}(y) = y - 3; 3 \leq y \leq 4$

$\mu_{G}(y) = (5,0), (4,1)$ $\mu_{G}(y) = 5 - y; 4 \leq y \leq 5$

$\mu_{VG}(y) = (4,0), (5,1)$ $\mu_{VG}(y) = y - 4; 4 \leq y \leq 5$

5.3 Case Simulation:

To prove the applicability of the model, the below case simulation is done:

Consider the **relative efficiency score of DMU9 = 34%** i.e. x=34%

Since 34% lies between 20 to 40 % range as per the input descriptor, the following rule set is considered-

$\mu_{EL}(x) = 40 - x/20$; $20 \leq x \leq 40$

$\mu_{L}(x) = x - 20/20$; $20 \leq x \leq 40$

Substituting the values -

$\mu_{EL}(x) = 40 - 34/20 = 6/20 = 0.3$

$\mu_{L}(x) = 34 - 20/20 = 14/20 = 0.7$

By maximum rule, we got the fuzzy input value as -

$\mu_L(x) = 14/20 = 0.7$

Now, for L position the sustainability index scale value is calculated as per the corresponding output descriptor as follows –

$0.7 = \mu_P$

Which give the rule sets-

$0.7 = y - 1$ and $0.7 = 3 - y$

y=1.7 y=2.3

To get the crisp output, the average of the above fuzzy output variables is calculated i.e. y=2 (Mean of the range of y values obtained)

Hence, the sustainability index for DMU9 with relative efficiency score 34% lies at scale value 2 which makes the firm stand at poor scale in terms of sustainability.

6. Conclusion

Sustainability has become a major factor that is driving industries globally on a note that organizations cannot think of a sustained future without adapting sustainability as a way of work. 'Supply chain' should be a KRA for sustainability because of the numerous stakeholders and voluminous processes involved in supply chain management. Food Industry, being the fastest growing industry in the country has been suspected to various efforts in curbing the environmental and social impact and technology is becoming an enabler in this regard. Despite all these efforts, MSMEs become the victims of inefficiencies and inadequacies that is inbuilt in their business processes due to various constrains that comes along with their operations and existence. The major pullback from implementing sustainability in the supply chain is due to the lack of standard sustainability performance measurement system and lack of technological know-how.

This paper has proposedtwo unique sequential methods to be followed by MSMEs to address the inherent issue of MSMEs towards adapting sustainability. These novel methodologies include the following:-

1) A quantifiable approach is discussed for MSMEs to do competitive-benchmarking using DEA Solver in an attempt to decipher the best sustainability practices in the industry along the context of FSCM.

2) A unique sustainability index for Supply Chain is proposed using which companies can choose a practical and feasible best-practice and set the performance measure as their sustainability benchmark. The '**Supply Chain - Sustainability Index'** that is proposed in the paper is one of its kind and is the first attempt in research field to establish a quantifiable and practical system of sustainability index pertaining to Supply Chain, a much-ignored field of study in the literature in the same context. By proposing these methods, the researchers intend to drive the idea of sustainability deep in MSMEs which will eventually help these organizations build for themselves a Lean and Green Supply Chain.

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