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Analysis of key performance indicators for sustainable manufacturing in sugar industry using analytical hierarchy process

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Industries around the globe are facing challenges with respect the implementation of sustainable manufacturing in their respective firms. Sugar industries are pointed as a major consumer of natural raw materials, energy, and pollutants, resulting in a major concern, which demands an immediate attention as it contributes to global warming at large. Hence, assessing sustainability in this industry has become an essential. This paper makes an effort to recognize vital key performance indicators (KPIs) build on the concept of the triple bottom line of sustainability. KPI's are ranked using analytical hierarchy process (AHP). It has been anticipated that the projected KPIs provides aid to the sugar industry in achieving higher performance in sustainable manufacturing.

Keywords: Sustainable manufacturing, Sustainable development, Business sustainability, Sugar industry, Analytic hierarchy process, Key performance indicators

1 Introduction

Population explosion pooled with life style of industrialized countries generates escalating pressures on globe for developing countries. The numerous challenges of sustainable development such as degradation of environment, change of climate, shrinking non renewable resource are more and more being addressed in literature[1-4]. In tune many industries have undertaken different sustainability manufacturing measures for a several reasons to take care of harmful social, environmental and economic impressions of their operations. In this paper analytic hierarchy process (AHP) is used to analyze the key performance indicators (KPIs) for sustainable manufacturing in relation to sugar industry.

1.1 Sustainability and sustainability indicators

The department of commerce, United States express sustainable manufacturing as the conception of manufactured products employing process that reduce harmful environmental effects, preserve natural resources along with energy, also safe in the hands of workforce, consumers, the public and are viable economically[5]. As per Sustainable Development (SD) commission[6], "SD is development that meets the needs of the present, without compromising the ability of future generations to meet their own needs."

SD principle focus on reduction of materials utilized, emissions, waste generation, and energy utilization, through preserving, or enhancing the worth of products to society and organizations[2]. A technical form of this definition is "Sustainable manufacturing is a systems approach for the creation and distribution of products and services that decreases the use of natural resources; and produces less waste that in effect reduces greenhouse gases, *e.g.*, carbon footprint"[7]. SD is distinct and broadly recognized as key thought for a safer prospect[4]. SD by definition, is not only rigid with environmental aspect, other than it involves meeting economic and social aspects. Sustainable manufacturing should deal with the combination of all the three indicators economic, social, and environmental, recognized as the triple bottom line of sustainability[2]. The people, planet, profit (3Ps) and triple bottom line of sustainability, highlight that SD is not only deal with environmental concern, but it attempt three encircling aspects social, environmental and economic[2,4]. Hence, SD must be assessed relating three indicators that connect a community's social, environmental and economic[8]. Indicators assist in identifying position of something, the improvement made towards specific goal. Conventional indicators namely economic prosperity,

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water and health excellence, determine changes in part of the community independent of the other, on the contrary sustainability indicators reproduce the associations among the three aspects of sustainability and many more factors that affect them[8]. Performance measurement, metrics and key performance indicators are crucial as far as dimensions of lifecycle assessment are concerned[9]. An effective assessment of sustainability requires passing through, the simultaneous evaluation of all three aspects namely economic, environmental, and social performance[10]. The combined use of triple bottom line based indicators may assist understanding logistics performance system of the company along with global performance by taking into account key features and productivity[11]. As sustainability issues is gaining importance, corporate reports show detailed yardsticks of economic, environmental and social actions in their yearly reports, for the knowledge of stakeholders as sign of sustainability related actions. Nevertheless, these reporting tools may remain as trivial tools until a generalized system for reporting is developed and assist for comparison within sectors and companies[12]. Deficiency of a universal, as well as organized technique of measuring will be solved if indicators and indices of business sustainability are in place firmly[13]. The present work identifies vital KPIs in order to assess the sustainability of manufacturing appropriate for sugar industry which is established on triple bottom line of sustainability aspects. The KPIs are identified using AHP. It's assumed that the anticipated KPIs and the assessment model facilitate sugar industry in endeavor towards sustainable manufacturing.

1.2 Triple bottom line of sustainability

The triple bottom line of sustainability has three factors namely economic, social, and environmental.

1.2.1 Economical factors

Economic sustainability comprises generating economic value out of whatever decisions are undertaken. It indicates that decisions are taken in the most reasonable and monetarily most excellent manner while considering other aspects of sustainability. Comparatively fewer indicators were used for economic analysis in manufacturing industries[14].

1.2.2 Social factors

Social aspect of sustainability is found on the perception that a decision made by the industry ought to uphold the societal betterment. In broad-spectrum, generations of future must have similar or better quality of life than the present generation practice. Social sustainability means that organizations support diversity, offer reasonable opportunities, support the local community, make sure the quality of life and offer self governing process also answerable governance[15]. Certainly, company's employ Corporate Social Responsibility (CSR) as a means to improve their social repute [16].

1.2.3 Environmental factors

In a precisely sustainable environment, an eco system would retain postulations, biodiversity and the whole functionality over an extensive time period. Preferably decisions that are taken, must promote stability within the natural systems along optimistic growth. Environmental sustainability addresses the use of resources, energy and footprint industries depart as a result of their process and operations[17]. Environmental sustainability is frequently associated with reduction of waste, pollution, energy, emissions, as well as the utilization of hazardous/toxic/harmful resources, a reduction in the occurrence of accidents due to environmental[17].

1.3 Overview of analytic hierarchy process

AHP is a multi attribute decision support system, proposed by T.L. Satty in 1977, and employs a multilevel hierarchical objective, criteria, sub-criteria and alternative. Method adopts calculations and ranks the alternative through pair-wise comparison approach[18,19]. AHP process compares criteria/alternatives in a pair-wise approach. For this it employs a basic scale of absolute numbers that has been established in practice and confirms to physical and decision problem experiments. The scale fundamentally confines each individual choice relating to qualitative and quantitative attributes better than other scales employed for the rationale[18,19]. It changes individual choices into ratio scale that are being pooled to form linear additive weight. The consequential output may be used for evaluating and ranking the alternatives, thus, facilitating decision taker in making a decision.

1.4 Sugar industry and sustainability

The cultivation as well as manufacturing of sugar creates impact on environment leading to loss of natural habitats, widespread use of water, profound application of agro chemicals, polluted effluents

discharge also pollution of air. This leads to the deprivation of air, water, soil, and wildlife, in the downstream of ecosystems[20]. Sustainability does not mean increased profits or productivity; in fact focuses on measures required to diminish environmental effects, will often offer monetary rewards to farmers as well as to mills. This offers a chance to bring together environmental plus social requirements keeping in mind the long-standing growth of the sugar industry.

2 Methodology

The methodology has following steps:

a. The initial KPIs were identified for sustainable manufacturing through literature review and deliberations with academic experts.
b. The initial KPIs were authenticated with industry experts basically managers of the sugar industry where study is carried out.
c. Finally using AHP methodology the sustainably manufacturing KPIs were ranked.

2.1 Initial KPIs identification

Initially 30 key performance Indicators were identified through literature review and deliberations with academic experts under three factors (economical, social and environmental) respectively as shown in the Table 1.

2.2 Validations of initial KPIs

A scale ranging from 1-5 (where, 1-is not at all important, 2- slightly important, 3- important, 4 - fairly important, 5- very important) was adapted to rate the indicators according to the importance given in that particular plant. The mangers of the industry were approached to get the response. The mean of the responses is calculated from the ratings given by managers. The Table 2 depicts the mean of indicators. Means ranging from 4.00 to 5.00 is considered to finalize the key performance indicators. The finalized KPIs are listed in Table 3.

2.3 Construction of the hierarchy model

This stage is sorted into four hierarchy decision process levels as shown in Fig.1. The four level hierarchy model is illustrated as:

Table 2 — Mean values of indicators.

Sl no	Indicators	Mean
1	Profitability	4.8
2	Minimizing toxic waste	4.7
3	Air emission	4.6
4	Water utilization	4.6
5	Contributing to local economy	4.5
6	Reduction of overall cost	4.4
7	Inventory, Labor, Material costs reduction	4.3
8	Complying with the law	4.3
9	Training & education	4.3
10	Energy consumption cost	4.2
11	Land utilization	4.2
12	Occupational health & safety	4.1
13	Labour relationship	4.0
14	Protecting biodiversity	4.0
15	Creating jobs	3.9
16	Non-product output	3.9
17	Addressing community issues	3.7
18	Noise pollution	3.5
19	Respecting human rights	3.5
20	Employee involvement in determining environmental goals	3.0
21	Minimizing use of natural resources	2.9
22	Use of solar energy	2.9
23	Treating suppliers fairly	2.9
24	Traffic jams	2.8
25	Accident rate	2.8
26	Paying tax responsibly	2.0
27	Ensuring product safety	1.8
28	Product innovativeness	1.5
29	Raw material substitution	1.0
30	Possibilities of product being recyclable, reusable	1.0

Table 1 — Initial Key performance indicators.

Economical Factors (ECF)	Social Factors (SOF)	Environmental Factors (ENF)
✓ Profitability	✓ Accident rate	✓ Noise pollution
✓ Reduction of overall cost	✓ Labor relationship	✓ Air emission
✓ Raw material substitution	✓ Occupational health and safety	✓ Non-product output
✓ Possibilities of product being recyclable, reusable	✓ Training and education	✓ Water utilization
✓ Inventory, Labor, Material costs reduction	✓ Complying with law	✓ Land utilization
✓ Energy consumption cost	✓ Respecting human rights	✓ Minimizing toxic waste
✓ Product innovativeness	✓ Ensuring products safety	✓ Use of solar energy
✓ Paying tax responsibly	✓ Treating suppliers fairly	✓ Minimizing use of natural resources
✓ Contributing to local economy	✓ Addressing community issues	✓ Protecting biodiversity
✓ Creating jobs	✓ Traffic jams	✓ Employee involvement in determining
		✓ environmental goal

Level I: the objective/goal
Level II: this level symbolizes the factors of triple bottom line of sustainability.
Level III: this level contains hierarchy of specific KPIs
Level IV: priorities of vital KPIs are established at this level.

The 14 KPIs identified as shown in Table 3 from above steps were used in the preparation of questionnaire for pair wise comparison. Participating managers are requested to provide the weight for pair-wise comparison from Saaty's method on a nine point scale, in which, weight 1 means equal preference between two indicators and both contribute equally to the factor. Similarly 3 means moderate, 5 means strong, 7 means very strong, 9 means extreme importance, intensities of 2, 4, 6, and 8 may be used for intermediate intensities.

The pair wise comparisons were ascertained between factors and within the indicators of the factors of KPIs. The pair wise comparison matrix for the three factors of triple bottom line is depicted in Table 4. The steadiness of pair wise is examined through consistency ratio (CR). If CR value is less than 0.1 makes the consistency tests to be acceptable. If not the comparison needs to repeated.

Table 3 — Finalized KPIs.

Sl no	Code	Indicators	Mean
1	ECF1	Profitability	4.8
2	ECF2	Contributing to local economy	4.5
3	ECF3	Reduction of overall cost	4.4
4	ECF4	Inventory, Labor, Material costs reduction	4.3
5	ECF5	Energy consumption cost	4.2
6	ENF1	Minimizing toxic waste	4.7
7	ENF2	Air emission	4.6
8	ENF3	Water utilization	4.6
9	ENF4	Land utilization	4.2
10	ENF5	Protecting biodiversity	4.0
11	SOF1	Training & education	4.3
12	SOF2	Complying with the law	4.3
13	SOF3	Occupational health & safety	4.1
14	SOF4	Labour relationship	4.0

3 Results and Discussion

Inferences from Table 5, shows the economic factor is the top priority, followed by environmental and social factors. The ranking of indicators is depicted in Table 6, based on AHPs approach of global weight. Global weights are obtained by multiplying the relative weight of factors with the relative weights of each particular indicator[21]. Among all 14 indicators there are 5 economic indicators and gained first 4 ranks that point out that still sugar

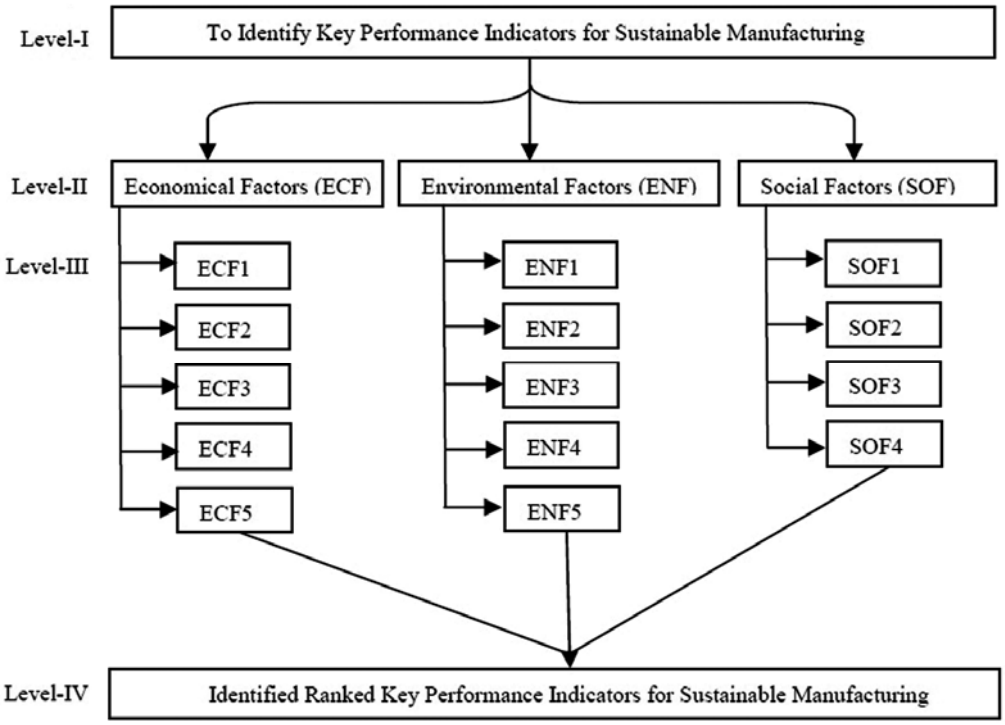

Fig. 1 — Hierarchy model of identified essential KPIs of sustainability.

Table 4 — Pair-wise comparison matrix.

	ECF	SOF	ENF
ECF	1	4	4
SOF	0.25	1	0.5
ENF	0.25	2.00	1

Table 5 — AHP weights.

Factors	Weights
Economic	0.661
Social	0.131
Environmental	0.208

Table 6 — Local and global weights of factors with specific indicators.

Factors	Relative weights by AHP	Indicator number	Indicators	Relative weights by AHP	Global weights by AHP	Rank of indicator
Economic	0.661	ECF1	Profitability	0.438	0.290	1
		ECF2	Contributing to local economy	0.047	0.031	12
		ECF3	Reduction of overall cost	0.226	0.149	2
		ECF4	Inventory, Labor, Material costs reduction	0.158	0.104	3
		ECF5	Energy consumption cost	0.130	0.086	4
Social	0.131	SOF1	Training & education	0.085	0.011	14
		SOF2	Complying with the law	0.419	0.055	7
		SOF3	Occupational health & safety	0.316	0.041	9
		SOF4	Labour relationship	0.180	0.024	13
Environmental	0.208	ENF1	Minimizing toxic waste	0.182	0.038	10
		ENF2	Air emission	0.382	0.079	5
		ENF3	Water utilization	0.221	0.046	8
		ENF4	Land utilization	0.182	0.038	11
		ENF5	Protecting biodiversity	0.340	0.071	6

industries are giving maximum importance for economic factors of decision making process followed by environmental and social factors.

4 Conclusions

A result obtained from data analysis leads to significant inferences, implementation of sustainable manufacturing in sugar industries is critical and demands dexterity commencing from bottom-line work force to the top management. Analysis of key performance indicators for sustainable manufacturing is difficult due to its several characters. This paper has made an attempt to benchmark frame work to ease complicated rudiments to trim down as key performance indicators. By this, difficulties of KPIs identification towards environmental improvement by the managers' has become little easier. The work uncovered that Indian sugar industries are yet fight to prioritize environmental performance over economic and social performance.

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