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SMART MCDM APPROACH IN SELECTING SUSTAINABLE PRODUCTION TECHNOLOGY

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ABSTRACT

In this present age of technology, the industrial sectors are adopting advanced technology to enhance production. One of the underlying challenges is the selection of sustainable technology subjected to conflicting and multidimensional criteria. This study applies the multi-criteria decision making method of SMART (Simple Multi-Attribute Rating Technique) to rank the alternatives of production technology. The decision making model considers the criteria of cost, operational efficacy, reliability, compatibility and environmental impact. The decision framework based on SMART is efficient in handling both quantitative and qualitative criteria. The ranking results of the proposed model ensure efficacy and accuracy in the context of sustainability driven production technology.

Keywords: SMART, Sustainability, Production Technology

INTRODUCTION

The industrial revolution across several ages has transformed the production systems. The present industrial ecosystem is dominated with the elements of sustainability to evolve a carbon free society. The existing stringent environmental regulations are redefining and reshaping the production scenario. The economic and environmental factors are serving as the two primary pillars of any production technology. Furthermore, the decision makers are also constrained with other factors of reliability, efficiency and customer satisfaction. The decision making on selection of production technology is complex due to the interactions between conflicting criteria with the coexistence of quantitative and qualitative factors. To handle such crisis, the researchers prefer multi-criteria decision making approaches. The classifications of MCDM approaches are ample in literature. However, this research work focus on the MCDM approach that handles both quantitative and qualitative criteria. One such MCDM approach is

Simple Multi-Attribute Rating Technique (SMART). This method is robust, simple and reliable when it comes to the selection of alternatives based on complex and conflicting criteria set.

As sustainability is gaining momentum since few decades, the eco related factors are inherited into industrial systems. In align with that, this research work attempts to evolve a decision making model based on SMART to identify the optimum sustainable driven production technology considering several factors of economic, environment, reliability, compatibility and efficacy. The remaining contents of this work are structured into the following segments. The review of works is briefed in section 2. The methodology of SMART is sketched in section 3. The decision making problem is well presented together with the application of SMART in section 4. The results are discussed in section 5 and the final section concludes the work with future directions.

REVIEW OF WORKS

This section presents a brief review of applications of SMART method and the applications of MCDM approaches in choosing optimal production technology of various entities. The research gaps are identified and the notable contributions of this study are also discussed.

The MCDM methods of different kinds are applied in making robust decisions on optimal production technologies. To mention a few, Ertay [6] in plastic mold production, Emrani et al [5] in nitrogen production plants, Lenin et al [11] in post-harvest technology for smallholder cocoa production, Kheybari et al [10] and Castanho et al [2] in biofuel production technology selection, Cristea et al [4] in lighting technology selection, Xiaojun et [17] in green food production base, Hacklin et al [7] in Technology partner selection, Hung et al [8] in electricity production technology. These MCDM methods are capable of handling either quantitative or qualitative criteria, but not both. This is the point of origin of the method SMART. The method of SMART is grounded on the principles of multi utility theory. The simple approach od this method is applied in invariably across several domains, to mention a few, Taylor and Love [16] in renewable deployment decisions, Oktavianti et al [13] in employee promotions, Borissova and Keremedchiev [1] in evaluation of student's performances, Sihombing et al

[15] in determining outstanding employees, Prasetya [14] in selecting real time well monitoring project, Idmayanti et al [9] in evaluation of projects, Mohamed et al [12] in 5G industry evaluation. This method is also applied to discuss the aspects of multi-capital sustainability in supply chain [3]. However, this method is not discussed in the selection of sustainable centric production technology.

These identified few research gaps has motivated the author to extend the application of SMART method in determining the ideal sustainable driven production technology. This research work is a step towards the development of sustainable industry.

METHODOLOGY

This section presents the stepwise procedure of the proposed decision making method.

Let us consider m alternatives and n criteria of the forms $A = \{a_1, ..., a_m\}$ and $C = \{c_1, ..., c_n\}$. The decision matrix X = $[x_{ij}]$ represents the degrees of apprutenance between the alternatives and the criteria. The criterion weights are denited using w_j.

Step 1: Problem definition and data representation

The problem is well defined with alternatives and criteria pertinent to the decision making problem. The criteria are classified as benefit and cost based on the influences of each criterion.

Step 2: Normalization of the Decision Matrix

The values in the decision matrix are normalized using Min–Max linear scaling and the newly obtained values belong to the range [0,1].

Compute $x_j^{\min} = \min{}_i x_{ij}$ and $x_j^{\max} = \max{}_i x_{ij}$. Then define

- If c_j is a benefit:

$$n_{ij} = \frac{x_{ij} - x_j^{\min}}{x_j^{\max} - x_j^{\min}}.$$

- If $c_j$is a cost:

$$n_{ij} = \frac{x_j^{\max} - x_{ij}}{x_j^{\max} - x_j^{\min}}.$$

Step 3: Computation of Criterion Weights

The criterion weights are predetermined based on the opinion experts. The raw scores that are initially ascertained are converted using Eq. 1

$w_j = \frac{r_j}{\sum_{k=1}^{n} r_k}, j = 1, \dots, n,$ ----------------------------- (1)

Such that $\sum_{j=1}^{n} w_j = 1.$

Step 4: Construction of single – attribute value function

The linear value function say v_j is used primarily in constructing value functions. Let us initially fix the reference points say $x_j^{\text{bad}}$and x_j^{good} respectively for cost and benefit criteria.

$$v_j(x) = \begin{cases} 0, & x \le x_j^{\text{worst}}, \\ \dfrac{x - x_j^{\text{worst}}}{x_j^{\text{good}} - x_j^{\text{bad}}}, & x_j^{\text{bad}} < x < x_j^{\text{best}}, \\ 1, & x \ge x_j^{\text{good}}, \end{cases}$$

Step 5: Calculate weighted additive score

The overall additive aggregate value for each alternative a_i is computed using eq.2

$$V(a_i) = \sum_{j=1}^{n} w_j \, v_j(a_i) \,, i = 1, \dots, m.$$

Step 6: Ranking of the Alternatives

The alternatives are ranked based on the score values. The alternative with highest score is given priority.

For better understanding, the above steps are presented diagrammatically in Fig. 1.

Fig. 1 SMART MCDM Architecture

RANKING OF SUSTAINABILITY DRIVEN PRODUCTION TECHNOLOGY

Let us consider a decision making problem of sustainability driven production technology. Presently, the industrial sectors are shifting towards environmental centred. These industries embrace sustainable oriented technology to align with environmental standards. Let us assume there are five alternate sustainable production technologies say SPT1, SPT2, SPT3, SPT4 and SPT5. The criteria ascertained in ranking of the alternatives are presented in the Fig. 2.

Fig. 2 Criteria of Sustainability Driven Production Technology

Let us consider a decision making matrix with score values from 0-100 as in Table 1.

Table 1 Initial Decision Making Matrix

	Economic Feasibility	Environmental Sustainability	Technical Performance	Social Impact	Operational Flexibility
ST1	75	68	72	70	65
ST2	82	74	78	76	72
ST3	65	85	70	80	68
ST4	70	90	75	85	70
ST5	88	72	85	78	82

The criterion Economic Feasibility is considered to be cost criteria and other criteria are considered to be benefit.

The normalized matrix is obtained using Step 2 as in Table 2.

Table 2 Normalized Matrix

	Economic Feasibility	Environmental Sustainability	Technical Performance	Social Impact	Operational Flexibility
ST1	0.565217	0	0.133333	0	0
ST2	-0.73913	0.272727	0.533333	0.4	0.411765
ST3	-1.82609	0.772727	0	0.666667	0.176471
ST4	-3.04348	1	0.333333	1	0.294118
ST5	-3.82609	0.181818	1	0.533333	1

The criterion weights are determined using step 3 and presented in Table 3

Table 3 Criterion Weights

Criteria	**Economic Feasibility**	**Environmental Sustainability**	**Technical Performance**	**Social Impact**	**Operational Flexibility**
Raw Scores	80	85	78	82	75
Final Criterion Weights	0.2	0.2125	0.195	0.205	0.1875

The single-attribute values of each of the alternatives are determined using step 4. Other than the maximum (best) and minimum (worst) values, the values of $x_j^{\text{good}}, x_j^{\text{bad}}$ are ascertained and discoursed in Table 4 .

Table 4 Significant Values of Alternatives

	ST1	**ST2**	**ST3**	**ST4**	**ST5**
x_j^{best}	88	90	85	85	82
x_j^{good}	70	85	78	80	72
x_j^{bad}	82	72	72	76	70
x_j^{worst}	65	68	70	70	65

The final values of Vj are determined as follows as in Table 5.

Table 5 Single-attribute values of the Alternatives

Alternative	**Economic Feasibility**	**Environmental Sustainability**	**Technical Performance**	**Social Impact**	**Operational Flexibility**
ST1	1.00	0.00	0.25	0.00	0.00
ST2	1.00	0.35	1.00	0.60	1.00
ST3	0.00	1.00	0.00	1.00	0.43
ST4	1.00	1.00	0.63	1.00	0.71
ST5	1.00	0.24	1.00	0.80	1.00

Using step 5, the final weighted additive scores are determined as in Table 6.

Table 6 Final weighted additive scores with unequal weights

Alternatives	**Economic Feasibility**	**Environmental Sustainability**	**Technical Performance**	**Social Impact**	**Operational Flexibility**
ST1	0.2	0	0.04875	0	0
ST2	0.2	0.074375	0.195	0.123	0.1875
ST3	0	0.2125	0	0.205	0.080625
ST4	0.2	0.2125	0.12285	0.205	0.133125
ST5	0.2	0.051	0.195	0.164	0.1875

The alternatives are ranked based on the cumulative scores obtained as in Table 7.

Table 7 Aggregate Scores of the Alternatives with unequal weights

Alternatives	**Aggregate Scores**	**Rank**
ST1	0.25	5
ST2	0.78	3
ST3	0.50	4
ST4	0.87	1
ST5	0.80	2

RESULTS AND DISCUSSIONS

The ranking results presented in Table 7 elicit the prioritization of the sustainable production technology. To validate the results, the same problem is subjected with equal criterion weights.

The final weighted additive scores with equal criterion weights are determined as in Table 8

Table 8 Final weighted additive scores with equal weights

Alternatives	Economic Feasibility	Environmental Sustainability	Technical Performance	Social Impact	Operational Flexibility
ST1	0.2	0	0.05	0	0
ST2	0.2	0.07	0.2	0.12	0.2
ST3	0	0.2	0	0.2	0.086
ST4	0.2	0.2	0.126	0.2	0.142
ST5	0.2	0.048	0.2	0.16	0.2

The alternatives are ranked based on the cumulative scores obtained as in Table 9.

Table 9 Aggregate Scores of the Alternatives with equal weights

Alternatives	Aggregate Scores	Rank
ST1	0.25	5
ST2	0.79	3
ST3	0.49	4
ST4	0.87	1
ST5	0.81	2

From the Table 9 it is lucid that the ranking results are conserved however with different score values. A comparison of the score values is presented in Fig. 3

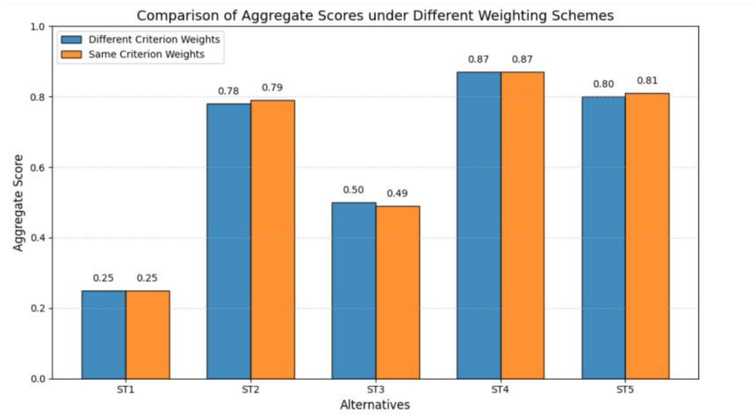

Fig. 3 Comparison of Aggregates Scores of Alternatives

From the fig. 3 the following inferences are obtained

- ST4 is the ideal alternative under both the cases signifying highest stability and rigidity.
- ST5 and ST2 occupy the next ranking positions only with marginal differences in score values.
- ST3 exhibits moderate performance but not dominant stability
- ST1 records lowest ranking position in both the cases denoting weaker performance.

The ranking results obtained in both the cases are same with negligible score value differences. This shows the ranking efficacy of SMART method both with equal and unequal criterion weights.

CONCLUSION

This research work presents the application of the SMART decision making approach to prioritize the sustainable production technology. The problem addressed in this study is discussed under two cases, one with unequal criterion weights and the other with equal criterion weights. This approach shall be further discoursed with the integration of other methods of criterion computation. The results obtained will certainly support the industrial decision makers in evolving a sustainable centric production scenario. On other hand the crisp scores used in this study shall be replaced with linguistic variable to handle uncertainty. Furthermore, the representations of fuzzy and its extended versions shall also be applied in the extended version of this proposed work.

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