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Selecting Sustainable Project Portfolio By A Electre Method

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Abstract

Evaluating a sustainable project which encompasses both conventional and sustainability dimensions, stands as a crucial component of a company's strategic pursuit of a competitive edge. To solve this problem, one of the commonly used method, ELECTRE, is used. Once decision-makers, criteria, and the project set have been identified, the analysis focuses on assessing the factors that influence the evaluation process, aiming to pinpoint the most optimal sustainable project. Furthermore, the study incorporates nine criteria for appraising sustainable projects, encompassing both quantitative and qualitative considerations. Ultimately, a numerical illustration is provided to illustrate the practicability of the proposed method.

Keyword: sustainable project; criteria; electre; mcdm

1. Introduction

In recent decades, the implementation of new projects has been a driving force behind the competitive advantages attained by organizations within their respective markets (Ma et al., 2020). However, despite the widespread adoption of new project initiatives, instances of project failure or instability persist across various industries (Allen et al., 2014). According to a report from the Project Management Institute (PMI) in 2016, in the United States, for every $1 billion invested in projects, an alarming $122 million goes to waste due to subpar project performance. Furthermore, a recent study conducted by Bloch and colleagues (2012) involving over 5,400 IT projects, in collaboration with McKinsey and the University of Oxford, revealed that approximately half of IT projects with budgets exceeding $15 million run an average of 45% over budget, with 17% reaching a point where they jeopardize the very existence of the company (Costantino et al., 2015). Consequently, the adoption of a more strategic approach to project selection, coupled with ongoing monitoring, is imperative for companies aiming to sustain their competitiveness within their respective markets.

Project Portfolio Selection (PPS) refers to the ongoing and cyclical process of choosing and financing a collection of projects that align with an organization's defined goals and objectives (Mohagheghi et al., 2019). Project portfolio management encompasses crucial objectives such as identifying, ranking, prioritizing, selecting, and authorizing projects or programs (Mohagheghi et al., 2019). Over time, PPS studies have evolved significantly. Initially, these studies primarily concentrated on the financial aspects of projects. Subsequently, frameworks emerged that placed greater importance on strategic criteria in managing PPS. More recently, attention has dispersed towards various other criteria such as sustainable development, strategic alliances, investment risks, and organizational readiness (Khalili-Damghani & Sadi-Nezhad, 2013). As public awareness concerning environmental protection and social issues continues to grow, organizations are now required to focus not only on their economic activities but also on their environmental and social responsibilities with utmost seriousness (Fallahpour et al., 2020). Therefore, PPS should consider not only economic dimension but also social and environmental aspects. The selection process involves evaluating various criteria across different project alternatives to pinpoint the most suitable project aligned with desired goals (Alyamani & Long, 2020). Ranking these crucial sustainable project characteristics assists project managers and decision-makers in prioritizing essential areas during the evaluation of various project alternatives and in effectively allocating resources (Alyamani & Long, 2020). Therefore, it is multiple criteria decision-making issue. To solve this problem, the study provided the ELECTRE I method to select the optimal solution.

The selection process entails the consideration of a wide array of factors, encompassing both qualitative and quantitative aspects. Researchers have devoted significant efforts to exploring sustainable factors for the purpose of selecting a sustainable project portfolio. In their study, Ma et al. (2020) employed fuzzy TOPSIS to undertake project portfolio selection within a threefold framework: economic, environmental, and social sustainability. Mohagheghi et al. (2019) introduced the Moras method, operating in an environment of interval type 2-fuzzy numbers, to facilitate the selection of sustainable infrastructure projects. Kaveh et al. (2013) adopted a hybrid fuzzy rule-based multi-criteria framework to make selections for a sustainable project portfolio, taking into account six essential sustainable factors, which include Strategic Alliance, Economic Impact, Social Impact, Environmental Impact, Investment Risk, Organizational Readiness, and Financial Analysis. This study employs nine distinct sustainable criteria to evaluate the sustainable project portfolio including environment impacts, noise pollution, job creation, social impacts, natural resources, economic impacts, NPV, initial cost, growth.

The first outranking method, known as ELECTRE I, was pioneered by Roy (Roy, 1968). One notable advantage of outranking methods, such as the ELECTRE series, is their capacity to consider ordinal scales without necessitating the conversion of original scales into abstract forms with arbitrarily imposed ranges (Hatami-Marbini & Tavana, 2011). Additionally, these methods preserve the original verbal meaning of the criteria. ELECTRE I serves the purpose of constructing partial priorities and is primarily aimed at selecting a set of the most favorable alternatives (Qu et al., 2020). In contrast, the tasks of ELECTRE II, III, and IV involve establishing the order of alternatives from the best to the worst, effectively ranking them (Qu et al., 2020). ELECTRE I represents one of the earliest multicriteria evaluation methods, and, when used alongside other advanced methods, it aids in the selection of a preferred alternative that accommodates both synchronization across multiple evaluation criteria and discrepancies under various preferred criteria (Chinnasamy et al., 2022). The foundational principles of ELECTRE I are rooted in the creation of a diverse and often contradictory set of criteria, encompassing both quantitative and qualitative implications. These implications are not solely tied to numerical ordinal scales but are also associated with imprecise, uncertain, and poorly determined data (Nghiem & Chu, 2021). Consequently, this study employs the ELECTRE I method to select the most suitable sustainable project portfolio.

Numerous ELECTRE methods and their applications have been thoroughly investigated, and an extensive review of these methods can be found in Govindan and Jepsen (2016). Sharma et al. (2021) introduced a novel approach by combining fuzzy AHP and the ELECTRE method to define and rank the six primary indicators for green manufacturing. Nghiem and Chu (2021) contributed to the field by presenting a modified ELECTRE I method tailored for selecting sustainable conceptual designs. In another innovative approach, Akram et al. (2020) merged the ELECTRE method with Pythagorean fuzzy numbers to facilitate the selection of a solid waste management plant. Uddin et al. (2019) explored the integration of AHP and ELECTRE in evaluating barriers to green supply chain management, particularly in the leather industry. These diverse applications highlight the versatility and adaptability of ELECTRE methods in addressing a wide range of decision-making and evaluation challenges.

2. Literature Review

Numerous ELECTRE methods and their applications have been thoroughly investigated, and an extensive review of these methods can be found in Govindan and Jepsen (2016). Sharma et al. (2021) introduced a novel approach by combining fuzzy AHP and the ELECTRE method to define and rank the six primary indicators for green manufacturing. Nghiem and Chu (2021) contributed to the field by presenting a modified ELECTRE I method tailored for selecting sustainable conceptual designs. In another innovative approach, Akram et al. (2020) merged the ELECTRE method with Pythagorean fuzzy numbers to facilitate the selection of a solid waste management plant. Uddin et al. (2019) explored the integration of AHP and ELECTRE in evaluating barriers to green supply chain management, particularly in the leather industry.

These diverse applications highlight the versatility and adaptability of ELECTRE methods in addressing a wide range of decision-making and evaluation challenges.

3. Material and Method

Assume that a committee of k decision makers (i.e. Dt, t=1~k) is responsible for the evaluation of m alternatives (i.e. Ai, i=1~m) under n criteria (Cj, j=1~n), and criteria can be classified to benefit (B), larger better, and cost (C), smaller better. Assume that   denotes the performance rating of alternative Ai evaluated by decision makers versus criterion Cj.

Step 1. Normalization of decision matrix

$$r_{ij} = \frac{p_{ij}}{\sqrt{\sum_{i=1}^{m} p_{ij}^2}} \ , \ p_{ij} \in B \tag{1}$$

$$r_{ij} = 1 - \frac{p_{ij}}{\sqrt{\sum_{i=1}^{m} p_{ij}^2}} \ , \ p_{ij} \in C \tag{2}$$

Step 2. Obtain weights of criteria

$$w_j^{'} = \sum_{i=1}^{m} \frac{p_{ij}}{m} \ , \ w_j^{'} \text{ denotes the average of } p_{ij}, \ i = 1 \sim m \ . \tag{3}$$

$$w_j = \frac{w_j^{'}}{\sum_{j=1}^{n} w_j^{'}} \ , \ w_j \text{ denotes the weight of the } j\text{th criterion and } \sum_{j=1}^{n} w_j = 1 \ . \tag{4}$$

Step 3. Weighting the normalized decision matrix

$$v_{ij} = r_{ij} \times w_j, \ i = 1 \sim m, \ j = 1 \sim n \tag{5}$$

$v_{ij} \in V$ and V is a $m \times n$ matrix.

Step 4. Determine concordance and discordance sets

$$C_{ij} = \left\{ k, v_{ik} \geq v_{jk} \right\}, \ v_{ij}, v_{jk} \in V \tag{6}$$

$$D_{ij} = \left\{ k, v_{ik} < v_{jk} \right\}, \ v_{ij}, v_{jk} \in V \tag{7}$$

Step 5. Produce concordance and discordance matrixes

$$C = \left[c_{ij} \right]_{m \times n} \ , \ c_{ij} = \frac{\sum_{k \in c_{ij}} w_k}{\sum_{k=1}^{n} w_k} \tag{8}$$

$$D = \left[d_{ij} \right]_{m \times n} \ , \ d_{ij} = \frac{\max_{k \in D_{ij}} \left\{ \left| v_{ik} - v_{jk} \right| \right\}}{\max_{k \in J} \left\{ \left| v_{ik} - v_{jk} \right| \right\}}, J = \left\{ 1, 2, \ldots.., n \right\} \tag{9}$$

Step 6. Obtain concordance and discordance dominant matrixes

The concordance dominant matrix is determined by

$$F = \left[f_{ij} \right]_{m \times n} \tag{10}$$

$f_{ij} = 1$, $if\ c_{ij} \geq \overline{c}$, and $f_{ij} = 0$, $if\ c_{ij} < \overline{c}$ and $\overline{c} = \sum_{\substack{i=1 \\ i \neq j}}^{m} \sum_{\substack{j=1 \\ j \neq i}}^{m} \frac{c_{ij}}{m(m-1)}$.

The disconcordance dominant matrix is determined by

$$G = \left[g_{ij} \right]_{mxn} \tag{11}$$

$g_{ij} = 1$, $d_{ij} \leq \overline{d}$, $and\ g_{ij} = 0$, $if\ d_{ij} > \overline{d}$ and $\overline{d} = \sum_{\substack{i=1 \\ i \neq j}}^{m} \sum_{\substack{j=1 \\ j \neq i}}^{m} \frac{d_{ij}}{m(m-1)}$.

Step 7. Produce global matrix

The global matrix can be produced by multiplication between the elements in *F* and *G*

$$E = \left[e_{ij} \right]_{m \times n},\ e_{ij} = f_{ij} \times g_{ij} \tag{12}$$

Matrix *E* gives the order of selection of each alternative when e_{ij} = 1, it defines that A_i outranks A_j and ; thus outranking relations between alternatives are determined.

1. Numerical example

Nine criteria of sustainable project portfolio selection are considered in the study. These criteria are qualitative and quantitative which can be classified to benefit (B) such as job creation, social impacts, natural resources, economic impacts, NPV, growth as well as cost (C) such as initial cost, environment impacts, noise pollution. Assume that a manufacturing company must select a sustainable product to develop new product. After preliminary screening, six products A_i, *i*=1~6, are chosen for further evaluation. The selection process of the best sustainable product is done by a committee of three decision makers D_t, *t*=1~3, the aim of which is to select the most sustainable product among six alternatives by the proposed method as follows.

Step 1. Normalization of decision matrix

Assume that the performance rating of alternative versus qualitative criteria are conducted by aggregating the opinions from the three decision makers by using the scale from 1 - 9 (1= very poor, 2 = poor, 3 = medium poor, 4 = slightly poor, 5 = fair, 6 = slightly good, 7 = medium good, 8 = good, 9 = very good). Besides, the data of quantitative criteria has been collected as shown in Table 1. The normalization of decision matrix is established by Eqs. (1)-(2) as present in Table 2.

Step 2. Obtain weights of criteria

The weights of criteria can be obtained by Eqs. (3)-(4) as shown in Table 1.

Step 3. Weighting the Normalized Decision Matrix

The weighted normalized matrix can be obtained by Eq. (5) as displayed in Table 3.

Step 4: Determine concordance and discordance sets

Concordance set and discordance set can be obtained by using Eqs. (6)-(7) as shown in Table 4.

Step 5. Produce concordance and discordance matrixes

By Eqs.(8)-(9), the concordance and discordance matrixes are built as shown in Tables 5 and 6.

Step 6. Obtain concordance and discordance dominant matrixes

The dominant matrixes of concordance and discordance can be obtained using Eqs. (10)-(11) as shown in Tables 7 and 8.

Step 7. Produce global matrix

The global matrix can be produced by Eq. (12) as displayed in Table 9.

Table 1. Performance Rating Of Alternative Versus Qualitative And Quantitative Criteria

	Environment impacts	**Noise pollution**	**Job Creation**	**Social impacts**	**Natural resources**	**Economic impacts**	**NPV**	**Initial cost**	**Growth**
	C	C	B	B	B	B	B	C	B
A_1	8	5	2	3	8	7	3	4.5	7
A_2	6	4	5	4	7	7	5	5	7.5
A_3	4	1	9	8	5	6	8	7	8
A_4	7	4	3	3	7	4	3	3.5	5
A_5	5	2	3	5	8	8	4	4	5
A_6	6	4	7	7	4	8	6	6	7.5
Ave	6.000	3.333	4.833	5.000	6.500	6.667	4.833	5.000	6.667
Weight	0.1229	0.0683	0.0990	0.1024	0.1331	0.1365	0.0990	0.1024	0.1365

Table 2. Normalization Of Decision Matrix

	Environment impacts	**Noise pollution**	**Job Creation**	**Social impacts**	**NPV**	**Economic impacts**	**Natural resources**	**Initial cost**	**Growth**
A_1	0.77	0.43	0.01	0.02	0.14	0.08	0.02	0.97	0.04
A_2	0.83	0.55	0.02	0.02	0.12	0.08	0.03	0.96	0.04
A_3	0.89	0.89	0.04	0.04	0.09	0.07	0.04	0.95	0.04
A_4	0.80	0.55	0.01	0.02	0.12	0.04	0.02	0.97	0.03

A_5	0.86	0.77	0.01	0.03	0.14	0.09	0.02	0.97	0.03
A_6	0.83	0.55	0.03	0.04	0.07	0.09	0.03	0.95	0.04

Table 3. Weighted Normalized Matrix

	Environment impacts	**Noise pollution**	**Job Creation**	**Social impacts**	**NPV**	**Economic impacts**	**Natural resources**	**Initial cost**	**Growth**
A_1	0.095	0.030	0.001	0.002	0.018	0.011	0.002	0.099	0.005
A_2	0.102	0.037	0.002	0.002	0.016	0.011	0.003	0.098	0.006
A_3	0.109	0.061	0.004	0.005	0.011	0.009	0.004	0.097	0.006
A_4	0.098	0.037	0.001	0.002	0.016	0.006	0.002	0.100	0.004
A_5	0.105	0.053	0.001	0.003	0.018	0.012	0.002	0.099	0.004
A_6	0.102	0.037	0.003	0.004	0.009	0.012	0.003	0.098	0.006

Table 4. Concordance Set And Discordance Set

	Concordance	**Discordance**		**Concordance**	**Discordance**
12	5.6.8	1.2.3.4.7.9	41	1.2.3.4.7.8	5.6.9
13	5.6.8	1.2.3.4.7.9	42	2.5.8	1.3.4.6.7.9
14	4.5.6.7.9	1.2.3.8	43	5.8	1.2.3.4.6.7.9
15	5.9	1.2.3.4.6.7.8	45	3.8.9	1.2.4.5.6.7
16	5.8	1.2.3.4.6.7.9	46	2.5.8	1.3.4.7.9
21	1.2.3.4.7.9	5.8	51	1.2.3.4.6.7.9	5.9
23	5.6.8	1.2.3.4.7.9	52	1.2.3.4.7.6.9	3.7.9
24	1.2.3.4.5.6.7.9	8	53	5.6.8	1.2.3.4.5.7.9
25	3.7.9	1.2.4.5.6.8	54	1.2.3.4.5.6.7.9	8
26	1.2.5.8.9	3.4.6.7	56	1.2.5.6.8	3.4.7.9
31	1.2.3.4.7.9	5.6.8	61	1.2.3.4.6.7.9	5.8
32	1.2.3.4.7.9	5.6.8	62	1.2.3.4.6.7.9	5.8
34	1.2.3.4.6.7.9	5.8	63	6.8	1.2.3.4.5.7.9
35	1.2.3.4.7.9	5.6.8	64	1.2.3.4.6.7.9	5.8
36	1.2.3.4.5.7.9	6.8	65	3.4.6.7.9	1.2.5.8

Table 5. Concordance Matrix

	A_1	A_2	A_3	A_4	A_5	A_6
A_1	-	0.372	0.372	0.608	0.270	0.235
A_2	0.628	-	0.372	0.898	0.334	0.563
A_3	0.628	0.628	-	0.765	0.628	0.761
A_4	0.594	0.304	0.235	-	0.338	0.304
A_5	0.730	0.666	0.372	0.898	-	0.563
A_6	0.765	0.765	0.372	0.765	0.573	-

Table 6. Discordance Matrix

	A_1	A_2	A_3	A_4	A_5	A_6
A_1	-	0.05	0.031	0.102	0.023	0.041
A_2	0.051	-	0.023	0.258	0.051	0.079
A_3	0.064	0.016	-	0.132	0.292	0.034
A_4	0.195	0.411	0.132	-	0.035	0.886
A_5	0.065	0.122	0.292	0.025	-	0.122
A_6	0.129	0.114	0.023	0.286	0.102	-

Table 7. Concordance Dominant Matrix

	A_1	A_2	A_3	A_4	A_5	A_6
A_1	-	0	0	1	0	0
A_2	1	-	0	1	0	1
A_3	1	1	-	1	1	1
A_4	1	0	0	-	0	0
A_5	1	1	0	1	-	1
A_6	1	1	0	1	1	-

Table 8. Disconcordance Dominant Matrix

	A_1	A_2	A_3	A_4	A_5	A_6
A_1	-	1	1	1	1	1
A_2	1	-	1	0	1	1
A_3	1	1	-	1	0	1
A_4	0	0	1	-	1	0
A_5	1	1	0	1	-	1
A_6	1	1	1	0	1	-

Table 9. Global Matrix

	A_1	A_2	A_3	A_4	A_5	A_6
A_1	-	0	0	1	0	0
A_2	1	-	0	0	0	1

A_3	1	1	-	1	0	1
A_4	0	0	0	-	0	0
A_5	1	1	0	1	-	1
A_6	1	1	0	0	1	-

5. Discussion

According to Table 9, the ranking order of six projects is the projects 3 and 5 are the best sustainable projects which dominate other ones. Therefore, the company should choose projects 3 and 5 to develop with highest priority.

6. Conclusion, Implication, and Recommendation

Evaluating a sustainable portfolio project, which considers both traditional and sustainability aspects, is a crucial element of a company's long-term success strategy in today's fiercely competitive landscape for sustainable development. This study encompasses nine criteria, encompassing qualitative factors like job creation, social impacts, natural resource considerations, and economic effects, alongside quantitative criteria such as initial costs, environmental impact, noise pollution, net present value (NPV), and growth potential, all of which are employed to assess the viability of sustainable projects. These criteria can be categorized into cost and benefit dimensions. To address this challenge, our work introduces the ELECTRE I method, a nine-step approach. It starts by identifying the decision-makers (DMs), criteria, and product set. Subsequently, the influence factors governing the selection of sustainable products are analyzed using the ELECTRE I method, culminating in the selection of the best sustainable product.

This method has versatile applications, extending to various selection problems like determining optimal locations for hospitals, hotels, banks, and supplier selection, and product assessment. Our future research will explore two key aspects: firstly, the integration of AHP and ELECTRE to address ambiguity and vagueness in decision-making, primarily driven by human preferences, and secondly, the incorporation of real-world data and information relevant to the case study.

7. References

Article Journal

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9. Appendix (if any)

This section should be placed at the end of the manuscript after the reference list.