A Sustainability-Based Multi-Criteria Decision Approach for Information Systems Project Selection

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Abstract: An effective approach for evaluating and selecting information systems (IS) projects in project management from a sustainability perspective is highly desirable in contemporary organisations with sustainable objectives. Such an approach, however, is absent from the literature. This paper presents a multi-criteria analysis approach for effectively evaluating and selecting IS projects for project management in organisations based on their sustainability performance under environmental, economic, and social dimensions. Such an approach considers the subjective and uncertain nature of the IS project selection process using linguistic variables approximated by fuzzy numbers and effectively aggregates the subjective assessments for determining the overall sustainable performance of individual IS projects across all the selection criteria and their associated sub-criteria. The proposed multi-criteria decision-making approach provides organisations with a proactive mechanism for effectively evaluating and selecting IS projects from a sustainability perspective. An IS project selection problem is presented to demonstrate the effectiveness of the approach.

Keywords: multi-criteria decision analysis, fuzzy theory, project selection, sustainability performance, information systems, project management

1. Introduction

Sustainability is becoming increasingly important to every organisation due to the rapidly growing world population, the increasing industrial production activities which heavily rely on the consumption of non-renewable resources and the rapid development of emerging economies (Silvius and Schipper, 2014). Organisations worldwide are under growing pressure to meet government environmental regulations and compliance standards, to mitigate the environmental impact of their operations, and to address the environmental concerns of various stakeholders while simultaneously increasing their profitability and improving their competitiveness (Huemann and Silvius, 2017).

Project-based organisations undertake projects to achieve their business objectives (Project Management Institute, 2013). To effectively achieve the organisational sustainability objective in a dynamic environment, the evaluation and selection of appropriate projects for development needs with the consideration of sustainability are critical to the organisation (Sanchez, 2015).

Much research has been done on sustainability and project management, but few studies focus on the intersection of these two topics (Marcelino-Sadaba, Gonzalez-Jaen and Perez-Ezcurdia, 2015; Huemann and Silvius, 2017). The existing studies that integrate these two themes focus on the evaluation of the environmental impact of projects, particularly construction and engineering projects (Huemann and Silvius, 2017). Limited research has been conducted on evaluating the sustainability performance of information systems (IS) projects in organisations. This creates an enormous gap in research as to how to incorporate the sustainability assessment in the process of evaluating and selecting IS projects.

Evaluating and selecting IS projects are important processes in modern organisations (Marnewick, 2017; Zou, Duan and Deng, 2019). This is because industrial production, service provisioning, and business administration are all heavily dependent on the smooth operations of IS which are expensive to develop, complex to use, and difficult to maintain (Deng and Wibowo, 2008). The availability of numerous IS projects, the increasing complexities of these projects, and the pressure to make timely decisions in a dynamic environment further complicate the IS project evaluation and selection process (Yeh et al., 2010; Dutra, Ribeiro and DeCarvalho, 2014).

Evaluating the performance of IS projects is complex and challenging. It often involves multiple evaluation criteria and subjective and imprecise assessments. Much research has been done on the development of

appropriate multi-criteria approaches for evaluating the performance of traditional IS projects. Deng and Wibowo (2008), for example, develop an intelligent decision support system for facilitating the adoption of the most appropriate multi-criteria analysis approach in solving the IS project evaluation and selection problem. Yeh et al. (2010) propose a fuzzy multi-criteria group decision-making approach for solving the IS projects selection problem. Lee and Kim (2001) present an integrated multi-criteria approach using Delphi, an analytic network process concept and zero-one goal programming for solving the IS project selection problem. Wei, Liang and Wang (2007) approach the IS project selection problem by proposing a comprehensive framework comprising three main phases—the strategic objective analysis phase, the system analysis phase, and the group decision-making phase. Dutra, Ribeiro and DeCarvalho (2014) propose an economic-probabilistic model for solving the IS project evaluation and selection problem.

The above studies show that the development of a multi-criteria approach for evaluating the performance of IS projects is of great practical benefit. Existing studies, however, are not satisfactory due to the inadequacy of handling the subjectiveness and imprecision inherent in the evaluation process and the computational effort required (Duan, Deng and Corbitt, 2010). Furthermore, these approaches have not specifically considered the sustainability performance assessment of the IS projects. Thus, the development of an approach capable of addressing the above shortcomings is desirable.

This paper presents a multi-criteria analysis approach for effectively evaluating the sustainability performance of IS projects in organisations. Such an approach considers the subjectiveness and uncertainty in the IS project selection process using linguistic variables approximated by fuzzy numbers and effectively aggregates the subjective assessments for determining the overall sustainable performance of individual IS projects across all the selection criteria and their associated sub-criteria. As a result, the most appropriate IS project which meets the sustainability requirements of the organisation can be ranked and selected.

In what follows, Section 2 presents an overview of the IS project sustainability evaluation problem, leading to the identification of the sustainability criteria and their associated sub-criteria. Section 3 presents a multi-criteria analysis approach for evaluating the sustainability performance of IS projects. Section 4 gives an example for demonstrating the applicability of the approach. Section 5 discusses the contribution of this research, followed by the conclusion in Section 6.

2. Sustainability Performance Evaluation of IS Projects

Sustainability is concerned with development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987). The concept of sustainability is widely accepted as one based on the integration of economic, environmental, and social goals, known as the triple-bottom-line (Huemann and Silvius, 2017).

Many companies have adopted sustainability through their mission statement and strategy. IS projects are the vehicles for implementing such principles in an organisation (Marnewick 2017; Zou, Duan and Deng, 2019). To effectively achieve the organisational sustainability objectives in a dynamic environment, the balance and incorporation of the three sustainability dimensions into the IS project evaluation and selection process ensures adherence to the sustainability principles of the organisation.

Much research has been done to identify the factors and criteria for evaluating the sustainability performance of IS projects in project management from different perspectives (Huemann and Silvius, 2017; Marnewick, 2017). These studies, however, evaluate the sustainability performance of the IS projects without adequately considering the triple-bottom-line (Martens and Carvalho, 2017). For example, Chen, Boudreau and Watson (2008) assess the sustainability performance of IS projects from the environmental perspective using criteria including eco-efficiency, eco-equity and eco-effectiveness. Watson, Boudreau and Chen (2010) evaluate the IS projects sustainability performance from the environmental perspective for a comprehensive energy informatics framework. These studies concentrate on evaluating the sustainability performance of IS projects from environmental perspectives. The rationale of these studies is that well-designed IS projects can effectively reduce the negative impact of the organisational operations on the environment and remove potential health hazards that otherwise would have resulted from implementing the chosen IS projects (Silvius and Schipper, 2014). Such studies provide insights on evaluating the sustainability performance of IS projects

from the environmental perspective. However, they fail to consider the social and economic performance of IS projects in the sustainability assessment.

The economic dimension is also considered a critical evaluation criterion in the IS project selection process because IS projects bring several economic benefits to the organisation and society, including reduced operational costs, improved productivity, employment, and the generation of wealth (Marnewick, 2017). This leads to the development of specific economic models based on various financial criteria including the return on investment, net present value, discounted cash flow, and opportunity cost for the evaluation and selection of IS projects (Aarseth et al., 2017; Huemann and Silvius, 2017).

The social dimension of sustainability is under-examined in the IS project management literature. This aspect, however, needs to be properly incorporated into the sustainability assessment (Checkland, 2000; Valdes-Vasquez and Klotz, 2012; Martens and Carvalho, 2017; Sarker et al., 2019). Valdes-Vasquez and Klotz (2012), for example, argue that a truly sustainable project must include social considerations about the end users, as well as considerations of the impacts of the project in the community with regards to the safety, health, and education of people involved. Modern organisations are striving to be outstanding corporate citizens, due partly to increasing societal pressure. Usually, organisations have to consider their social responsibilities seriously when adopting an IS project (Sarker et al., 2019). This is because the initiatives taken by an organisation to improve the performance of its activities will help increase the organisation's image and reputation.

The need to work toward sustainability by introducing the environmental, social, and economic dimensions into project management is clear, as discussed above. Based on this line of reasoning, four relevant criteria for evaluating the sustainability performance of IS projects can be identified, including Economic sustainability (C_1), Environmental sustainability (C_2), Social sustainability (C_3) and IS project capability (C_4). Figure 1 shows the hierarchical structure of the IS projects sustainability performance evaluation problem.
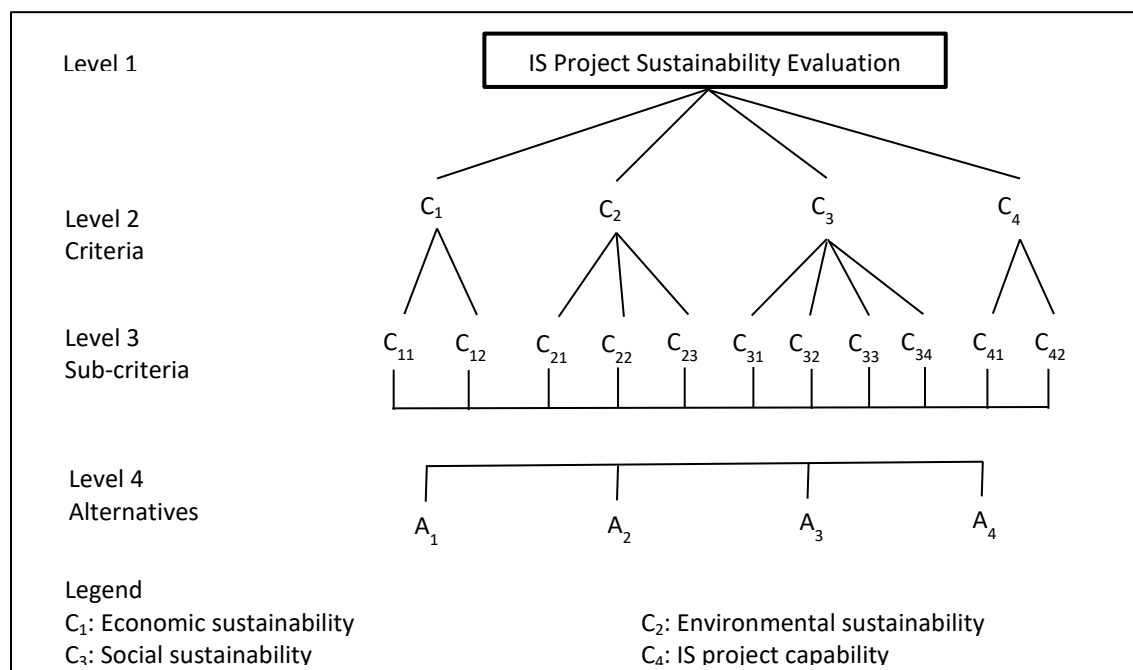

Figure 1: The hierarchical structure of IS projects sustainability performance evaluation

Economic sustainability (C_1) focuses on maximising profit, reducing costs, growing revenue and improving quality, which are considered to be some of the traditional business imperatives (Silvius and Schipper, 2014; Marnewick, 2017). This is measured by the direct financial benefits (C_{11}) and the indirect benefits (C_{12}) (Marnewick, 2017). The measure of direct financial benefits (C_{11}) is related to the profitability gained through the effective adoption of IS projects. The indirect benefits (C_{12}) refer to the potential business opportunities explored due to the implementation of IS projects.

Environmental sustainability (C_2) is concerned with the physical environment that people inhabit (Silvius and Schipper, 2014; Sanchez, 2015). This is assessed by procurement (C_{21}), energy (C_{22}), and waste (C_{23}) (Sanchez, 2015). Procurement (C_{21}) is related to the selection of suppliers and the sourcing of project materials to help deliver the project more sustainably. Energy (C_{22}) focuses on IS project-specific policies regarding energy consumption. This includes the energy consumption of individual team members and the equipment used during the project. Waste (C_{23}) concerns with the way that waste is dealt with during the implementation of IS projects in the organisation.

Social sustainability (C_3) refers to the communities in which organisations operate, as well as the employees of an organisation, which means organisations should take cognisance of the communities in which they operate and of their employees (Checkland, 2000; Marnewick, 2017). This is measured by labour practices in the workplace (C_{31}), human rights (C_{32}), public acceptability (C_{33}), and corporate reputation (C_{34}) (Marnewick, 2017). The measure of labour practices in the workplace (C_{31}) is related to health and safety, training and education, values and ethics, and organisational learning in the workplace. Human rights (C_{32}) reflects the non-discrimination and freedom of association culture within the organisation. Public acceptability (C_{33}) refers to the general attitude toward the IS projects of the organisation. Corporate reputation (C_{34}) concerns the stakeholders' satisfaction levels regarding the IS projects in the organisation.

The IS project capability (C_4) is related to features and functionalities of the IS project (Deng and Wibowo 2008; Yeh et al., 2010). This is measured by the IS project system functionality (C_{41}) and the system flexibility (C_{42}) (Yeh et al., 2010). The IS project system functionality (C_{41}) is related to the unique features and functions of the IS project that help achieve its claimed business objectives. The system flexibility (C_{42}) refers to the ability of the system to respond to potential internal or external changes affecting its value delivery in a timely and cost-effective manner.

With the sustainability criteria and sub-criteria identified above, all available IS projects have to be comprehensively evaluated to determine their overall performance across all the sustainability evaluation criteria so that the most appropriate IS projects can be selected. To effectively solve this problem, the next section presents a fuzzy multi-criteria approach for evaluating the sustainability performance of IS projects.

3.   A Multi-Criteria Analysis Approach

Multi-criteria analysis approaches are proven to be effective in tackling problems involving evaluating and selecting alternatives from a finite number of options with multiple and often conflicting criteria (Duan, Deng and Corbitt, 2010; Chen and Hwang, 2012). The multi-dimensional nature of the IS projects sustainability evaluation process justifies the use of the multi-criteria analysis methodology.

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a popular multi-criteria analysis approach for solving various multi-criteria analysis problems in fields such as politics, economics, social science and management science (Chen and Hwang, 2012). The underlying rationale of this approach is that the most preferred alternative should have the shortest distance from the positive ideal solution and at the same time have the longest distance from the negative ideal solution. The popularity of TOPSIS in addressing various practical problems is due to its simplicity and comprehensibility in concept and efficiency in calculation (Deng, Yeh and Willis, 2000).

Subjectiveness and imprecision are always present in e-market evaluation and selection due to the presence of (a) incomplete information (b) conflicting evidence, (c) ambiguous information, and (d) subjective information (Yeh et al., 2010; Chen and Hwang, 2012). To solve the IS projects sustainability evaluation and selection problem, this section extends the TOPSIS approach to effectively model the subjectiveness and imprecision inherent in the human decision-making process using linguistic variables approximated by fuzzy numbers.

A typical IS projects sustainability evaluation problem can be characterised by (a) the available IS projects for evaluation and selection, denoted as alternatives A_i *(i=1, 2, …, n)* and (b) the multiple sustainability evaluation and selection criteria C_j *(j = 1, 2, …, m)* and their associated sub-criteria C_{jk} *(k = 1, 2, …, p_j)* as shown in Figure 1. The IS projects sustainability evaluation process involves (a) assessing the performance ratings of each IS project with respect to the sustainability criteria and sub-criteria as x_{ij} *(i = 1, 2, …, n, j = 1, 2, …, m)*, (b) determining the relative importance of the sustainability criteria as criteria weights *W = (w_1, w_2, ..., w_j)* and

their associated sub-criteria as sub-criteria weights $W_j = (w_{j1}, w_{j2}, ..., w_{jk})$, and (c) aggregating the performance ratings and sustainability criteria weights to determine the overall performance of individual IS projects on which the selection decision can be made.

To model the subjectiveness and imprecision of the IS projects sustainability evaluation and selection process, linguistic variables approximated by triangular fuzzy numbers are used to represent the decision-maker's subjective assessments of the sustainability criteria weightings and alternative performance ratings. Triangular fuzzy numbers are usually denoted as *(a, b, c)* in which *b* represents the most possible assessment value, and *a* and *c* represent the lower and upper bounds or the fuzziness of the assessment (Deng, Yeh and Willis, 2000).

Table 1 shows the approximate distribution of the linguistic variables Performance and Importance (Duan, Deng and Corbitt, 2010) for measuring the alternative performance rating and criteria weightings respectively in the IS projects evaluation and selection process.

Table 1: Linguistic variables and their corresponding triangular fuzzy numbers

Performance		Importance	
Linguistic Variable	**Fuzzy Numbers**	**Linguistic Variable**	**Fuzzy Numbers**
Very Poor (VP)	(0.0, 0.0, 0.3)	Very Low (VL)	(0.0, 0.0, 0.3)
Poor (P)	(0.1, 0.3, 0.5)	Low (L)	(0.1, 0.3, 0.5)
Fair (F)	(0.3, 0.5, 0.7)	Medium (M)	(0.3, 0.5, 0.7)
Good (G)	(0.5, 0.7, 0.9)	High (H)	(0.5, 0.7, 0.9)
Very Good (VG)	(0.7, 1.0, 1.0)	Very High (VH)	(0.7, 1.0, 1.0)

Using the linguistic variable Performance as defined in Table 1, the fuzzy decision matrix for the IS projects sustainability evaluation and selection problem can be determined as

$$X = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1m} \\ x_{21} & x_{22} & \cdots & x_{2m} \\ \cdots & \cdots & \cdots & \cdots \\ x_{n1} & x_{n2} & \cdots & x_{nm} \end{bmatrix} \quad (1)$$

Where x_{ij} represents the decision-maker's assessment of the sustainability performance rating of alternative A_i with respect to the sustainability criteria C_j, which is to be given by the decision-maker using linguistic variables or aggregated from a lower-level decision matrix for its associated sub-criteria.

If sub-criteria C_{jk} exist for C_j, a lower-level fuzzy decision matrix can be determined in (2), where y_{jk} is the decision-maker's assessment of the performance rating of alternative A_i with respect to sub-criteria C_{jk} of the criteria C_j.

$$Y_{C_j} = \begin{bmatrix} y_{11} & y_{21} & \cdots & y_{n1} \\ y_{12} & y_{22} & \cdots & y_{n2} \\ \cdots & \cdots & \cdots & \cdots \\ y_{1p_j} & y_{2p_j} & \cdots & y_{np_j} \end{bmatrix} \quad (2)$$

The weighting vectors for the sustainability evaluation criteria C_j and sub-criteria C_{jk} can then be given in (3) and (4) by the decision-maker using the linguistic variable Importance defined in Table 1.

$$W = (w_1, w_2, ..., w_j) \qquad (3)$$
$$W_j = (w_{j1}, w_{j2}, ..., w_{jk}) \qquad (4)$$

With the formulation of the lower-level fuzzy decision matrix for the sustainability criteria C_j in (2), and the weight vector in (4) for its associated sub-criteria C_{jk}, the decision vector *(x1j, x2j, ..., xnj)* across all the alternatives with respect to criteria C_j in (1) can be determined by

$$(x_{1j}, x_{2j}, ..., x_{nj}) = \frac{W_j Y_{Cj}}{\sum_{k=1}^{p_j} w_{jk}} \qquad (5)$$

With the IS projects sustainability evaluation and selection problem described as above, the overall objective for solving the IS projects sustainability evaluation and selection problem is to rank all the alternative IS projects by giving each of them an overall performance rating with respect to all sustainability criteria and their associated sub-criteria. The process of determining the overall performance of each alternative IS project across all the sustainability criteria and their associated sub-criteria starts with calculating the overall weighted performance matrix of all the alternatives with respect to multiple sustainability evaluation and selection criteria by multiplying the criteria weights w_j and the alternative performance rating x_{ij}, shown as follows:

$$Z = \begin{bmatrix} w_1 x_{11} & w_2 x_{12} \cdots w_m x_{1m} \\ w_1 x_{21} & w_2 x_{22} \cdots w_m x_{2m} \\ \cdots & \cdots \quad \cdots \quad \cdots \\ w_1 x_{n1} & w_2 x_{n2} \cdots w_m x_{nm} \end{bmatrix} \qquad (6)$$

To avoid the complex and unreliable process of comparing fuzzy utilities often required in fuzzy multi-criteria analysis (Yeh et al., 2010), the defuzzification method determined by (7) based on the geometric centre of a fuzzy number, is applied to the weighted fuzzy performance matrix in (6) (Chen and Hwang, 2012).

$$r_{ij} = \frac{\int_{S_{ij}} x \mu_{w_j x_{ij}}(x) \, dx}{\int_{S_{ij}} \mu_{w_j x_{ij}}(x) \, dx} \qquad (7)$$

S_{ij} in (7) is the support of fuzzy number $w_j x_{ij}$ in (6). For a triangular fuzzy number (*a, b, c*), (7) is simplified as (8)

$$r_{ij} = \frac{a + b + c}{3} \qquad (8)$$

A weighted performance matrix in a crisp value format can then be obtained as

$$R = \begin{bmatrix} r_{11} & r_{12} \cdots & r_{1m} \\ r_{21} & r_{22} \cdots r_{2m} \\ \cdots & \cdots \quad \cdots \quad \cdots \\ r_{n1} & r_{n2} \cdots r_{nm} \end{bmatrix} \qquad (9)$$

To rank the alternatives based on (9), the TOPSIS method is applied. To facilitate the use of the TOPSIS method, the concept of the positive-ideal and the negative-ideal solution is used. The positive-ideal solution A^+ and the negative-ideal solution A^-, which represent the best possible and worst possible results among the alternatives respectively across all sustainability criteria, can be determined by

$$A^+ = (\, r_1^+,\, r_2^+,\, ...,\, r_m^+\,),\, A^- = (\, r_1^-,\, r_2^-,\, ...,\, r_m^-\,) \qquad (10)$$

Where
$$r_j^+ = max\, (\, r_{1j},\, r_{2j},\, ...,\, r_{nj}\,),\,\, r_j^- = min\, (\, r_{1j},\, r_{2j},\, ...,\, r_{nj}\,) \qquad (11)$$

From (10) to (11), the distance between alternative A_i and the positive-ideal solution and between alternative A_i and the negative-ideal solution can be calculated respectively by

$$d_i^+ = \sqrt{\sum_{j=1}^{m}(r_j^+ - r_{ij})^2}\,; \qquad d_i^- = \sqrt{\sum_{j=1}^{m}(r_{ij} - r_j^-)^2} \qquad (12)$$

A preferred alternative should have the shortest distance from the positive ideal solution and the longest distance from the negative ideal solution. As a result, an overall performance index for alternative A_i across all criteria can be determined by

$$P_i = \frac{d_i^-}{d_i^+ + d_i^-} \qquad i = 1, 2, ..., n \qquad (13)$$

The larger the performance index, the more preferred the alternative.

The sustainability based multi-criteria decision approach presented above can be summarised as follows:

1. Step 1: Obtain the fuzzy decision matrix assessed by the decision-maker, as expressed in (1).
2. Step 2: Obtain the fuzzy performance rating of alternatives with respect to criteria and sub-criteria assessed by the decision-maker, as expressed in (2).
3. Step 3: Obtain the fuzzy weighting vector assessed by the decision-maker, as expressed in (3) and (4).
4. Step 4: Determine the weighted fuzzy performance matrix by multiplying the overall fuzzy decision matrix and the overall fuzzy weighting vector, as expressed in (6).
5. Step 5: Transfer the weighted fuzzy performance matrix into a crisp value format, as expressed in (9).
6. Step 6: Determine the positive-ideal solution and the negative-ideal solution using (10) and (11).
7. Step 7: Calculate the distance between each alternative to the positive-ideal solution and the negative-ideal solution using (12).
8. Step 8: Determine the overall preference value for each alternative using (13).
9. Step 9: Rank the alternatives in descending order of their preference value.

4. An Example

To demonstrate the applicability and effectiveness of the sustainability-based multi-criteria selection approach presented in the previous sections, an IS project selection problem at a high-tech manufacturing company is presented. This company plans to implement an IS project to improve operational efficiency. There are four alternatives (A_1, A_2, A_3, A_4) from which the company needs to select the most appropriate one. Meanwhile, this high-tech manufacturing company is trying to incorporate sustainability principles into its operation due to pressure from the government and trading partners. Sustainable development is incorporated in the mission statement and strategic objectives of the organisation. As a result, the organisation wants to ensure that such principles are followed when evaluating and selecting IS projects.

To start with the IS projects sustainability evaluation and selection process, the performance of each IS project with respect to the sustainability evaluation and selection sub-criteria of each criterion is determined by

making a subjective assessment using the linguistic variables as presented in Table 1. Tables 2 shows the assessment results of four alternative IS projects with respect to each sub-criterion.

Table 2: Assessment results for each sub-criterion

Sub-Criterion	A_1	A_2	A_3	A_4
C_{11}	VG	F	P	F
C_{12}	P	G	VG	P
C_{21}	F	VG	P	P
C_{22}	F	G	G	G
C_{23}	VG	F	F	F
C_{31}	G	P	G	P
C_{32}	G	VP	VG	VG
C_{33}	P	F	G	VG
C_{34}	G	F	VG	G
C_{41}	P	G	P	F
C_{42}	VG	P	F	G

The relative importance of the IS projects sustainability evaluation criteria and its associated sub-criteria is determined by the decision-maker using the linguistic variable Importance shown as in Table 1. Table 3 shows the sustainability criteria and their associated sub-criteria weights for the IS projects evaluation and selection.

Table 3: Criteria/sub-criteria weights for IS projects sustainability performance evaluation

Criterion	Linguistic Weights	Fuzzy Number
C_1	H	(0.5, 0.7, 0.9)
C_{11}	VH	(0.7, 1.0, 1.0)
C_{12}	L	(0.1, 0.3, 0.5)
C_2	M	(0.3, 0.5, 0.7)
C_{21}	H	(0.5, 0.7, 0.9)
C_{22}	M	(0.3, 0.5, 0.7)
C_{23}	VH	(0.7, 1.0, 1.0)
C_3	VH	(0.7, 1.0, 1.0)
C_{31}	M	(0.3, 0.5, 0.7)
C_{32}	VH	(0.7, 1.0, 1.0)
C_{33}	H	(0.5, 0.7, 0.9)
C_{34}	M	(0.3, 0.5, 0.7)
C_4	H	(0.5, 0.7, 0.9)
C_{41}	M	(0.3, 0.5, 0.7)
C_{42}	H	(0.5, 0.7, 0.9)

To construct the fuzzy performance matrix for all the alternatives with respect to multiple sustainability evaluation and selection criteria as in equation (1), a lower-level fuzzy performance matrix of all the alternatives with respect to sub-criteria determined from Table 2 is aggregated with respect to criterion weights in Table 3 using equation (5). Table 4 shows the aggregated fuzzy performance matrix of alternatives with respect to the IS projects sustainability evaluation and selection criteria.

Table 4: Fuzzy decision matrix for IS projects sustainability performance evaluation

	C_1	C_2	C_3	C_4
A_1	(0.33, 0.84, 1.56)	(0.28, 0.73, 1.41)	(0.21, 0.60, 1.45)	(0.24, 0.71, 1.56)
A_2	(0.17, 0.55, 1.44)	(0.27, 0.70, 1.49)	(0.08, 0.28, 0.98)	(0.13, 0.47, 1.35)
A_3	(0.09, 0.46, 1.25)	(0.16, 0.48, 1.19)	(0.33, 0.87, 1.74)	(0.11, 0.42, 1.23)
A_4	(0.15, 0.45, 1.19)	(0.16, 0.48, 1.19)	(0.31, 0.81, 1.60)	(0.21, 0.62, 1.63)

The overall weighted IS projects sustainability performance matrix of all the alternatives with respect to IS projects sustainability evaluation and selection criteria is then calculated using Table 3 and Table 4, based on equation (6). The fuzzy numbers in the overall weighted performance matrix are further converted into comparable crisp numbers, following equation (8). The results are shown in Table 5.

Table 5: Weighted performance matrix in crisp numbers

	C_1	C_2	C_3	C_4
A_1	0.72	0.48	0.73	0.67
A_2	0.59	0.49	0.44	0.53
A_3	0.50	0.37	0.95	0.48
A_4	0.49	0.37	0.88	0.67

Following the approach illustrated in equation (9) to equation (13), an overall performance index for each IS project across all sustainability criteria can be calculated, as shown in Table 6.

Table 6: Performance index and ranking for IS projects sustainability performance evaluation

IS projects	Distance		Performance Index	Rank
	A+	A-	P_i	
A_1	0.22	0.43	0.66	1
A_2	0.54	0.16	0.23	4
A_3	0.31	0.51	0.62	3
A_4	0.27	0.48	0.64	2

It is clear that project A_1 is the preferred choice as it has the highest performance index.

5. Discussion

Evaluating the performance of alternative IS projects from a sustainability perspective is complex and challenging as it involves using multiple evaluation criteria that feature subjective and imprecise assessments. The above example has demonstrated the applicability of the proposed multi-criteria decision-making approach for evaluating and selecting IS projects from the sustainability perspective. Using the identified sustainability-based evaluation criteria and sub-criteria in Figure 1, the available IS projects can be comprehensively evaluated, and their overall performance across all evaluation criteria and sub-criteria can be determined. This leads to the selection of the most appropriate IS project from the sustainability perspective.

This study makes a significant theoretical and practical contribution to IS project sustainability performance evaluation research. IS projects perform an important role in the sustainability development of an organisation in modern society (Marnewick, 2017; Zou, Duan and Deng, 2019). Limited research, however, has been conducted on evaluating IS projects from the sustainability perspective in the process of selecting specific IS projects for development in organisations. Theoretically this research fills this gap by proposing an effective multi-criteria approach for assessing the sustainability performance of IS projects.

Practically, this research offers decision-makers an effective approach for evaluating and selecting IS projects for achieving organisational sustainability objectives. Such an approach effectively incorporates three sustainability dimensions into the IS project selection process, while considering specific characteristics of individual IS projects. Meanwhile, this approach reduces the cognitive demands of the evaluation process on the decision-maker while accounting for the subjectiveness and uncertainty inherent in the IS project selection process.

6. Conclusion

This paper has presented a multi-criteria analysis approach for effectively evaluating the sustainability performance of IS projects under conditions of uncertainty in an organisation. Using an example, the proposed multi-criteria analysis approach has demonstrated a number of advantages for dealing with the problem of evaluating the sustainability performance of alternative IS projects, including the capability to adequately handle multiple and usually conflicting sustainability criteria, and the ability to deal with the subjectiveness and imprecision inherent in the IS projects performance evaluation problem. The approach is found to be effective and efficient, due to the comprehensive underlying concepts and straightforward computation process.

A limitation of this research is that it only considered one decision-maker in the IS project performance evaluation process. Future research can be carried out to better deal with this issue through formulating such a decision problem as a group decision-making problem.

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