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The Application of Fuzzy Analytic Hierarchy Process in Sustainable Project Selection

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Abstract: The project selection process is a crucial step in sustainable development. Effective sustainable development depends on the ability to select the appropriate sustainable project to implement to ensure that the desired goals are met. Some of the most common characteristics or criteria used in evaluating sustainable projects include novelty, uncertainty, skill and experience, technology information transfer, and project cost. Prioritizing these criteria based on relative importance helps project managers and decision makers identify elements that require additional attention, better allocate resources, as well as improve the selection process when evaluating different sustainable project alternatives. The aim of this research is to use the fuzzy analytic hierarchy process (FAHP) methodology in which fuzzy numbers are utilized to realistically represent human judgment to rank the different project criteria based on relative importance and impact on sustainable projects. The results from the FAHP show that the most important criterion to consider in sustainable project selection is project cost, followed by novelty and uncertainty as the second and third most important criteria, respectively. The two least important criteria out of the total of five examined in this research were the skill and experience and technology information transfer, respectively. These results will help project managers and decision makers identify selection criteria with higher weights of importance. Given that the selection criteria chosen for this research are not limited to the evaluation of a specific type of sustainable projects or a specific location, they can be used to evaluate different types of sustainable projects in different environments and locations.

Keywords: fuzzy analytic hierarchy process; project selection; sustainable projects; multi-criteria decision making

1. Introduction

The use of fossil fuels as a source of energy has been linked to a wide range of issues such as geographical dependency, limited resources, and low efficiency [1]. Conventional energy sources are also known to be one of the major causes of environmental pollution and global warming by emitting a wide variety of greenhouse gases (GHGs) [2]. GHG emissions can also pose a major risk to public health as well as the perceived quality of life [3]. Global efforts in promoting sustainability by The World Commission on Environmental and Development report in 1987 have led to an increased awareness of the adverse effects of using fossil fuels and the benefits of sustainability [4]. That increase in awareness has led to an increase in sustainability and sustainable-development-related research in a variety of fields.

Effective sustainable development depends on the ability to select appropriate sustainable development projects to ensure that the desired results are achieved. The viability of different project proposals, as well as limited resources available, must be considered carefully based on established criteria [5]. The selection process also includes considering many different criteria of the different

project alternatives in an effort to determine the best possible project that can meet the desired goals. By ranking these key sustainable project characteristics or criteria, it helps project managers and decision makers focus on more important areas when evaluating the different project alternatives in addition to resource allocation.

The project selection process considers several different project factors or criteria as well as project goals and objectives [6]. This process usually takes place in a highly uncertain and complex environment. These uncertainties may be the result of unquantifiable measures or subjective judgments of experts about the relative importance of the different criteria used in the decision-making process [7]. The analytical hierarchy process (AHP) is one of the most commonly used techniques for project selection and assigns weights to different project factors used in the selection process. However, despite a recognition of the presence of uncertainty and ambiguity, AHP does not count for the ambiguity and uncertainty associated with project selection in an effective way [8]. To solve this problem, a combination of fuzzy numbers and AHP, known as the fuzzy analytic hierarchy process (FAHP), is used to account for the uncertainty and ambiguity in expert judgments [9].

The use of FAHP in sustainable project selection has mostly focused on evaluating different sustainable technology alternatives, with an emphasis on the technical aspects of these technologies, not necessarily the projects as a whole. This research improves the selection process of sustainable projects by developing a selection tool that considers the often-neglected criteria in the FAHP literature of novelty, uncertainty, team skill and experience, and technology information transfer, as they are described by Alyamani et al. [10], in addition to project cost. Accordingly, fuzzy AHP is used in this selection tool to rank these five selection criteria based on importance in the context of sustainable projects using input data from sustainable project experts. This tool will help project managers and decision makers focus on the selection criteria with higher weights of importance when evaluating different sustainable project alternatives. In addition, given that the selection criteria chosen for this research are not limited to the evaluation of a specific type of sustainable projects or a specific location, they can be used to evaluate different types of sustainable projects in different environments and locations.

This research is organized into five sections as follows: After the introduction section, Section 2 provides a literature review of relevant literature as well as major gaps found. Section 3 includes an explanation of the FAHP methodology and how it is implemented in this research to generate the results. Section 4 includes a discussion of the ranking results obtained from implementing the FAHP methodology and their relation to some of the existing literature. The final section (Section 5) of this research presents the conclusion, limitations, and future work.

2. Literature Review

Fuzzy AHP has been used in the literature by researchers in many different fields including project selection by assigning weights to selected project characteristics or criteria based on importance [11]. Bilgen and Şen [12] used a fuzzy AHP to develop a selection tool for six sigma projects. Their selection tool used resources, benefits, and effects as the major characteristics for their FAHP project selection tool. Enea and Piazza [6] used fuzzy AHP to develop a project selection tool based on the following characteristics: risk, cost, impact, and duration. Nguyen and Tran [13] studied the use of fuzzy AHP in construction projects for site selection, contractor selection, construction methods, risk assessment, and other areas related to construction projects. Other examples exist in the literature utilizing the fuzzy AHP methodology in project selection [14–16].

Fuzzy AHP has been used as part of sustainability and sustainable development research in recent years [11] across a broad spectrum of examples. Sabaghi et al. [17] used fuzzy AHP to evaluate product and process sustainability. FAHP was used in their research to assign weights to determine the importance of different economic, social, and environmental indicators in product development. Lespier et al. [7] used fuzzy AHP to quantify and rank key environmental impact criteria in maritime transportation systems (MTS) in an effort to help decision makers improve environmental sustainability

in Maritime shipping. Ligus [8] utilized FAHP to evaluate sustainability in the development of different energy technologies based on determined economic, social, and environmental criteria. Li et al. [9] developed a fuzzy AHP based tool to evaluate the carbon performance of public projects by ranking different carbon emission criteria related to the design, construction, and operation phases of these projects. Other examples of using FAHP to rank the different economic, social, and environmental impacts of sustainable technologies also exist [18,19]. Malik et al. [20] provide a ranking for the following five sustainable project characteristics: technology, economic impact, environmental impact, planning time, and policy to aid in the selection between alternative sustainable projects in Oman. However, since the standard AHP methodology was used to rank these characteristics, the uncertainty in experts' subjective judgments was not considered.

Although previous research demonstrates the use of FAHP to evaluate sustainability and sustainable project development, the focus has mainly been on the selection between different sustainable technology alternatives not necessarily the projects as a whole with an emphasis on the technical aspects of these technologies such as technology efficiency, reliability, scalability, and many other technical aspects in addition to the economic, social, and environmental impacts of these technologies [11]. Even though these technical factors and the impacts of these technologies are important to consider when selecting from different sustainable project alternatives, it is also important to consider the characteristics of these projects as a whole in the selection process not just the sustainable technologies used and their impact. More specifically, there seems to be little research in the FAHP literature that combines project cost and the more neglected, but crucial, project selection criteria of novelty, uncertainty, skill and experience, and technology information transfer and ranking them based on importance in the context of sustainable projects. These criteria can be used to evaluate sustainable projects as a whole regardless of the type of sustainable technology used and location of these projects.

Research Question

This research aims to fill the gap in the literature discussed above and answer the following research question specifically:

- Among the five chosen sustainable project selection criteria in this research, which one of them is the most important to consider when selecting between different sustainable project alternatives?

Given that novelty, uncertainty, team skill and experience, technology information transfer, and project cost are considered universal key criteria used to evaluate sustainable projects [10,21], the results from this research will provide project managers and decision makers presented with multiple sustainable project alternatives with a globally applicable selection tool capable of identifying the most important selection criteria when presented with multiple sustainable project alternatives.

3. Methodology

Project selection is an increasingly complicated process. This is due to the many interrelated variables that are used to evaluate these projects. Each of these variables has potential consequences to the project that must be determined to ensure the success of the project. In addition, the uncertainties surrounding both measuring these variables and determining their consequences on the project can be significant. These uncertainties sometimes stem from information that is difficult to quantify, or from subjective opinions of decision makers [7]. Such uncertainties make the project selection process highly subjective and at risk of inaccurate information and judgments. This results in a lack of consensus on the relative importance of the different criteria used to evaluate projects in the selection process [6].

3.1. Fuzzy AHP and Fuzzy Logic

Multi-criteria decision-making (MCDM) techniques are extremely beneficial for project selection problems when considering different selection criteria. These techniques use mathematical models and simulations to aid in the project selection process. AHP, introduced by Saaty [22], is one of the most

common and established MCDM techniques in project selection [15]. However, for these techniques to yield meaningful results, they need crisp and specific input data, which are usually difficult to obtain in project selection situations due to the subjective and uncertain nature of experts' judgments. Fuzzy AHP was developed to handle such uncertain and subjective input data more effectively than conventional MCDM techniques [7]. Fuzzy AHP applies the fuzzy set theory to allow researchers and decision makers to convert uncertain and vague linguistic input information from experts, such as the phrase "A lot more important", for example, to specific decisions intervals that are a lot more convenient to deal with by decision makers [15,23]. As project selection becomes increasingly global, this is a critical dimension to evaluate effectively.

The concept of fuzzy numbers used in the FAHP represents a range of possible values for a specific variable or rating. This means that a single ambiguous linguistic rating will be translated into a fuzzy number consisting of a range of numbers [24]. In fuzzy theory, it is more convenient to use triangular fuzzy numbers (TFNs) because of their computational simplicity and usefulness in representing information in a fuzzy environment [25]. TFNs are represented as three numbers (l, m, u) where the variables l, m, and u indicate the lowest possible value, the modal or most likely value, and the upper or highest possible value, respectively [7]. The mathematical representation of a fuzzy number A with a membership function $\mu_A(x)$ is depicted in Equation (1), as shown in Shukla et al. [24] and Hsieh et al. [26].

$$\mu_A(x) = \begin{cases} 0 & x < l; \\ \frac{x-l}{m-l} & l \leq x \leq m; \\ \frac{u-x}{u-m} & m \leq x \leq u; \\ 0 & x > u. \end{cases} \tag{1}$$

The geometric representation of the fuzzy number A from Equation (1) is shown in Figure 1, adapted from Lespier et al. [7] and Sun [27].
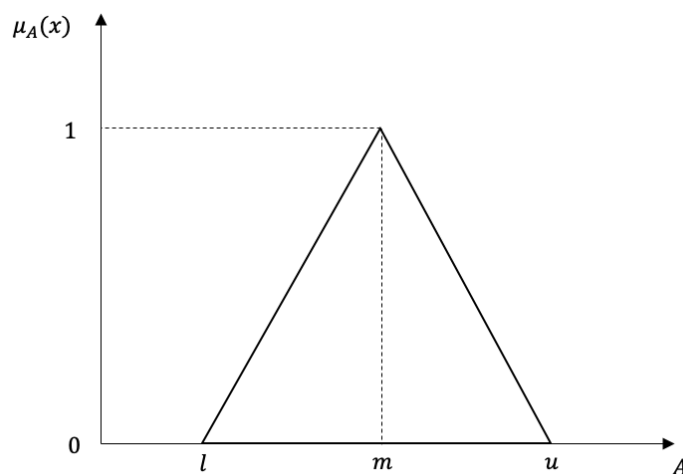

Figure 1. A triangular fuzzy number (TFN), A [7,27].

3.2. FAHP Selection Criteria

Alyamani and Long [21] and Alyamani et al. [10] identified four common key project characteristics that are used to evaluate sustainable projects in different institutional environments. This research extends their work by utilizing the characteristics they identified in addition to project cost as a fifth characteristic. The five characteristics are then used as selection criteria in evaluating multiple sustainable project alternatives. Using these characteristics as selection criteria develops a selection tool that can be used to evaluate projects in different environments regardless of location. Consequently, this research aims to rank novelty, uncertainty, skill and experience, technology information transfer,

and project cost from the context of sustainability as part of project selection in different environments and locations.

Novelty describes the degree to which a project differs from what is considered standard and established in terms of sustainable practices, processes, and technologies. In other words, this refers to the originality of the project and the maturity of the selected sustainable practices and technologies [28]. Undertaking a novel project that is utilizing completely new sustainable technologies or practices presents its own set of challenges and requires a certain level of resources and capabilities to ensure the successful implementation of such projects as opposed to more mature sustainable projects using standard and established sustainable practices and technologies [10,29].

Project uncertainty is generally defined in the literature as negative events for which both the consequence and probability of occurrence is unknown [30,31]. Different projects have different levels and sources of uncertainty [10]. In any case, however, these different sources of uncertainty, whether it be technological, financial, environmental, political, or any other source, should be outlined and addressed with appropriate mitigation plans to reduce their potential impact on the project should they occur.

The skill and experience criterion describes the level of skill and experience a project team is required to possess to be able to complete the project tasks effectively and efficiently, thus ensuring the successful completion of the project [10]. This criterion essentially addresses matching workforce capabilities with the project requirements [32]. Some sustainable projects require a highly skilled and experienced project team to be able to successfully complete the project, while other sustainable projects require relatively lower levels of skill and experience. The availability of the required workforce capabilities within the location of the evaluated project alternatives is an important component of this criterion. Project tasks can range from being trivial and standard all the way to complex and unusual. Consequently, choosing a project team with the appropriate know-how and sufficient level of experience to undertake these tasks and implement the chosen sustainable technology or practice is crucial in achieving project success and ensuring that project goals are met.

Technology information transfer, originally presented by Stock and Tatikonda [32], describes the amount of sustainable technology information being exchanged between the supplier of the sustainable technology and the project team implementing that technology. In other words, it describes the amount of interaction required between a supplier of a technology and the recipient of that technology to ensure the successful integration and implementation of said technology in the project. Selecting the appropriate technology and making sure it is correctly implemented in the project is one of the major steps towards achieving project goals. The level of information sharing between the two parties can vary significantly from project to project depending on the type of technology implemented. Stock and Tatikonda [32] explain that the level of information sharing between the supplier of the technology and the project team can range from a simple "arms-length" purchase requiring trivial information sharing, all the way to a "co-development" type of technology information sharing where both the supplier of the technology and the project team work closely together on the details of the design and specifications to ensure successful integration of the technology in the project [10].

Project cost essentially describes the total cost of the project including the initial investment cost and subsequent annual project costs. This criterion was added because it is considered one of the major driving factors in sustainable development and sustainable project selection [11]. One of the major challenges facing sustainable energy projects is competing with conventional energy sources in financial cost. However, the reduction in sustainable development costs in recent years in addition to the consideration of the indirect costs associated with conventional energy sources has somewhat balanced the scales between sustainable and conventional energy sources from the economic perspective [20]. Nonetheless, the costs associated with sustainable energy development in the international stage remain one of the major driving forces in sustainable energy project development.

A summary of the criteria explained above and their notations as used in this research are presented in Table 1.

Table 1. Key sustainable project selection criteria used in fuzzy analytic hierarchy process (FAHP).

Notation	Project Selection Criteria
C1	Project Cost
C2	Novelty
C3	Uncertainty
C4	Skill and Experience
C5	Technology Information Transfer

Based on these criteria, a typical hierarchy model of the sustainable project selection process is created, as shown in Figure 2, which consists of three levels: the goal of evaluating sustainable project alternatives, the criteria used to evaluate these alternatives as presented in Table 1, and the sustainable project alternatives to be evaluated using these criteria. As such, the prioritization of weights for the presented criteria using fuzzy analytic hierarchy process (FAHP) will aid in the selection process when presented with different sustainable project alternatives.
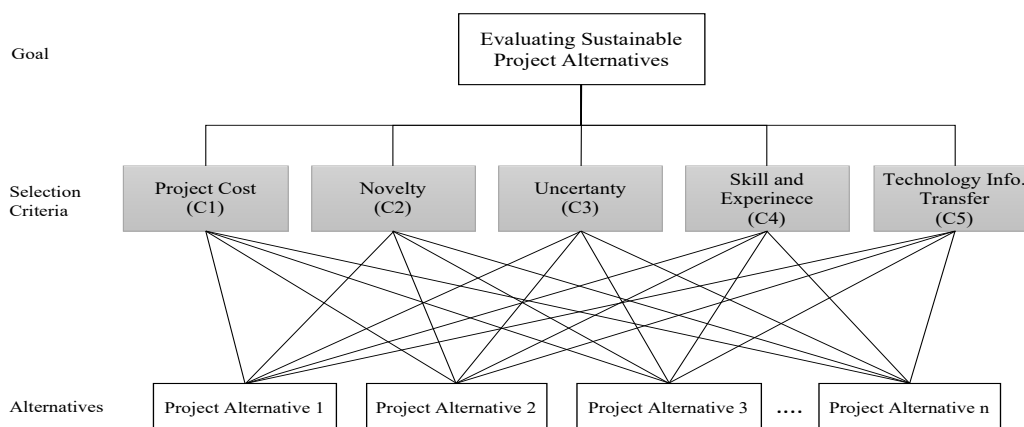

Figure 2. The hierarchy model for sustainable project selection.

3.3. The Application of FAHP for Weight Calculation

After defining the five sustainable project criteria, as shown in the previous subsection, the first step in determining the priority weights of these criteria is collecting the opinions of experts in sustainability and sustainable development regarding the relative importance of these criteria in sustainable project selection. In this research, a number of literature publications related to sustainable project selection and sustainable development as well as some prominent project management literature covering the chosen criteria were selected and evaluated, as part of the literature review for this research, to serve as the voice of experts in determining preferences among the five different criteria shown in Table 1. These studies were closely reviewed in an effort to determine the relative importance of these criteria and preference patterns, as presented by the authors of these publications. The list of the chosen literature publications is shown in Table 2.

Table 2. Selected expert literature used for the evaluation of criteria.

Expert	Source(s)
E1	Malik et al. [20]
E2	Alyamani et al. [10]
E3	Sabaghi et al. [17]
E4	Shenhar and Dvir [29], Stock and Tatikonda [32]
E5	Chen et al. [33]
E6	Wang et al. [28]
E7	Işik and Aladağ [34]
E8	Hatefi and Tamošaitienė [16]
E9	Luthra et al. [35]
E10	Solangi et al. [36]

The second step in determining the priority weights of the five sustainable project criteria is utilizing the expert opinions from the literature in Table 2 based on the linguistic variables and triangular fuzzy numbers (TFNs), shown in Table 3, as presented by Ballı and Korukoğlu [25]. In this step, expert opinions are gathered from the literature and translated into the linguistic variables. After creating the pairwise comparison matrix representing the opinions of each of the ten experts shown in Table 1 using the linguistic variables, these ten matrices are then combined to form the combined pairwise comparison matrix shown in Table 4.

Table 3. Linguistic variables and triangular fuzzy number scale.

Linguistic Variable	Triangular Fuzzy Numbers (TFN)	Reciprocal TFNs
Equally Important (E)	(1, 1, 1)	(1, 1, 1)
Weakly Important (W)	(1, 3, 5)	(1/5, 1/3, 1)
Fairly Important (F)	(3, 5, 7)	(1/7, 1/5, 1/3)
Strongly Important (S)	(5, 7. 9)	(1/9, 1/7, 1/5)
Absolutely Important (A)	(7, 9, 11)	(1/11, 1/9, 1/7)

Source: adapted from Ballı and Korukoğlu [25].

Table 4. Pairwise comparison matrix using linguistic variables.

Criteria	Expert	C1	C2	C3	C4	C5
	E1	E	F	S	A	A
	E2	E	S^{-1}	S^{-1}	F	S
	E3	E	S	F	F	A
	E4	E	S^{-1}	S^{-1}	F	W
C1	E5	E	S	F	F	A
	E6	E	A	F	A	F
	E7	E	F	A	F	S
	E8	E	F	W^{-1}	S	W^{-1}
	E9	E	F	A	S	F
	E10	E	W	F	S	A

Table 4. *Cont.*

Criteria	Expert	C1	C2	C3	C4	C5
	E1	F^{-1}	E	E	S	A
	E2	S	E	W	S	A
	E3	S^{-1}	E	F^{-1}	F^{-1}	W
	E4	S	E	W	A	S
C2	E5	S^{-1}	E	F^{-1}	S^{-1}	W
	E6	A^{-1}	E	S^{-1}	W	S^{-1}
	E7	F^{-1}	E	S	E	F
	E8	F^{-1}	E	S^{-1}	F	S^{-1}
	E9	F^{-1}	E	S	F	W^{-1}
	E10	W^{-1}	E	F	S	S
	E1	S^{-1}	E^{-1}	E	F	S
	E2	S	W^{-1}	E	S	S
	E3	F^{-1}	F	E	W	S
	E4	S	W^{-1}	E	A	S
C3	E5	F^{-1}	F	E	F^{-1}	F
	E6	F^{-1}	S	E	S	W^{-1}
	E7	A^{-1}	S^{-1}	E	S^{-1}	F^{-1}
	E8	W	S	E	A	E
	E9	A^{-1}	S^{-1}	E	F^{-1}	S^{-1}
	E10	F^{-1}	F^{-1}	E	F	S
	E1	A^{-1}	S^{-1}	F^{-1}	E	W
	E2	F^{-1}	S^{-1}	S^{-1}	E	W
	E3	F^{-1}	F	W^{-1}	E	S
	E4	F^{-1}	A^{-1}	A^{-1}	E	F^{-1}
C4	E5	F^{-1}	S	F	E	S
	E6	A^{-1}	W^{-1}	S^{-1}	E	S^{-1}
	E7	F^{-1}	E^{-1}	S	E	F
	E8	S^{-1}	F^{-1}	A^{-1}	E	A^{-1}
	E9	S^{-1}	F^{-1}	F	E	F^{-1}
	E10	S^{-1}	S^{-1}	F^{-1}	E	W
	E1	A^{-1}	A^{-1}	S^{-1}	W^{-1}	E
	E2	S^{-1}	A^{-1}	S^{-1}	W^{-1}	E
	E3	A^{-1}	W^{-1}	S^{-1}	S^{-1}	E
	E4	W^{-1}	S^{-1}	S^{-1}	F	E
C5	E5	A^{-1}	W^{-1}	F^{-1}	S^{-1}	E
	E6	F^{-1}	S	W	S	E
	E7	S^{-1}	F^{-1}	F	F^{-1}	E
	E8	W	S	E^{-1}	A	E
	E9	F^{-1}	W	S	F	E
	E10	A^{-1}	S^{-1}	S^{-1}	W^{-1}	E

These linguistic variables in the combined matrix are then further translated into the corresponding triangular fuzzy numbers (TFNs) and reciprocal TFNs based on the scale shown in Table 3, resulting in the combined TFN pairwise comparison matrix, shown in Table 5.

Table 5. Pairwise comparison matrix using TFNs.

Criteria	Expert	C1	C2	C3	C4	C5
C1	E1	(1, 1, 1)	(3, 5, 7)	(5, 7. 9)	(7, 9, 11)	(7, 9, 11)
	E2	(1, 1, 1)	(1/9, 1/7, 1/5)	(1/11, 1/9, 1/7)	(3, 5, 7)	(5, 7. 9)
	E3	(1, 1, 1)	(5, 7. 9)	(3, 5, 7)	(3, 5, 7)	(7, 9, 11)
	E4	(1, 1, 1)	(1/9, 1/7, 1/5)	(1/9, 1/7, 1/5)	(3, 5, 7)	(1, 3, 5)
	E5	(1, 1, 1)	(5, 7. 9)	(3, 5, 7)	(3, 5, 7)	(7, 9, 11)
	E6	(1, 1, 1)	(7, 9, 11)	(3, 5, 7)	(7, 9, 11)	(3, 5, 7)
	E7	(1, 1, 1)	(3, 5, 7)	(7, 9, 11)	(3, 5, 7)	(5, 7. 9)
	E8	(1, 1, 1)	(3, 5, 7)	(1/5, 1/3, 1)	(5, 7. 9)	(1/5, 1/3, 1)
	E9	(1, 1, 1)	(3, 5, 7)	(7, 9, 11)	(5, 7. 9)	(3, 5, 7)
	E10	(1, 1, 1)	(1, 3, 5)	(3, 5, 7)	(5, 7. 9)	(7, 9, 11)
C2	E1	(1/7, 1/5, 1/3)	(1, 1, 1)	(1, 1, 1)	(5, 7. 9)	(7, 9, 11)
	E2	(5, 7. 9)	(1, 1, 1)	(1, 3, 5)	(5, 7. 9)	(7, 9, 11)
	E3	(1/9, 1/7, 1/5)	(1, 1, 1)	(1/7, 1/5, 1/3)	(1/7, 1/5, 1/3)	(1, 3, 5)
	E4	(5, 7. 9)	(1, 1, 1)	(1, 3, 5)	(7, 9, 11)	(5, 7. 9)
	E5	(1/9, 1/7, 1/5)	(1, 1, 1)	(1/7, 1/5, 1/3)	(1/9, 1/7, 1/5)	(1, 3, 5)
	E6	(1/11, 1/9, 1/7)	(1, 1, 1)	(1/9, 1/7, 1/5)	(1, 3, 5)	(1/9, 1/7, 1/5)
	E7	(1/7, 1/5, 1/3)	(1, 1, 1)	(5, 7. 9)	(1, 1, 1)	(3, 5, 7)
	E8	(1/7, 1/5, 1/3)	(1, 1, 1)	(1/9, 1/7, 1/5)	(3, 5, 7)	(1/9, 1/7, 1/5)
	E9	(1/7, 1/5, 1/3)	(1, 1, 1)	(5, 7. 9)	(3, 5, 7)	(1/5, 1/3, 1)
	E10	(1/5, 1/3, 1)	(1, 1, 1)	(3, 5, 7)	(5, 7. 9)	(5, 7. 9)
C3	E1	(1/9, 1/7, 1/5)	(1, 1, 1)	(1, 1, 1)	(3, 5, 7)	(5, 7. 9)
	E2	(5, 7. 9)	(1/5, 1/3, 1)	(1, 1, 1)	(5, 7. 9)	(5, 7. 9)
	E3	(1/7, 1/5, 1/3)	(3, 5, 7)	(1, 1, 1)	(1, 3, 5)	(5, 7. 9)
	E4	(5, 7. 9)	(1/5, 1/3, 1)	(1, 1, 1)	(7, 9, 11)	(5, 7. 9)
	E5	(1/7, 1/5, 1/3)	(3, 5, 7)	(1, 1, 1)	(1/7, 1/5, 1/3)	(3, 5, 7)
	E6	(1/7, 1/5, 1/3)	(5, 7. 9)	(1, 1, 1)	(5, 7. 9)	(1/5, 1/3, 1)
	E7	(1/11, 1/9, 1/7)	(1/9, 1/7, 1/5)	(1, 1, 1)	(1/9, 1/7, 1/5)	(1/7, 1/5, 1/3)
	E8	(1, 3, 5)	(5, 7. 9)	(1, 1, 1)	(7, 9, 11)	(1, 1, 1)
	E9	(1/11, 1/9, 1/7)	(1/9, 1/7, 1/5)	(1, 1, 1)	(1/7, 1/5, 1/3)	(1/9, 1/7, 1/5)
	E10	(1/7, 1/5, 1/3)	(1/7, 1/5, 1/3)	(1, 1, 1)	(3, 5, 7)	(5, 7. 9)
C4	E1	(1/11, 1/9, 1/7)	(1/9, 1/7, 1/5)	(1/7, 1/5, 1/3)	(1, 1, 1)	(1, 3, 5)
	E2	(1/7, 1/5, 1/3)	(1/9, 1/7, 1/5)	(1/9, 1/7, 1/5)	(1, 1, 1)	(1, 3, 5)
	E3	(1/7, 1/5, 1/3)	(3, 5, 7)	(1/5, 1/3, 1)	(1, 1, 1)	(5, 7. 9)
	E4	(1/7, 1/5, 1/3)	(1/11, 1/9, 1/7)	(1/11, 1/9, 1/7)	(1, 1, 1)	(1/7, 1/5, 1/3)
	E5	(1/7, 1/5, 1/3)	(5, 7. 9)	(3, 5, 7)	(1, 1, 1)	(5, 7. 9)
	E6	(1/11, 1/9, 1/7)	(1/5, 1/3, 1)	(1/9, 1/7, 1/5)	(1, 1, 1)	(1/9, 1/7, 1/5)
	E7	(1/7, 1/5, 1/3)	(1, 1, 1)	(5, 7. 9)	(1, 1, 1)	(3, 5, 7)

Table 5. *Cont.*

Criteria	Expert	C1	C2	C3	C4	C5
	E8	(1/9, 1/7, 1/5)	(1/7, 1/5, 1/3)	(1/11, 1/9, 1/7)	(1, 1, 1)	(1/11, 1/9, 1/7)
	E9	(1/9, 1/7, 1/5)	(1/7, 1/5, 1/3)	(3, 5, 7)	(1, 1, 1)	(1/7, 1/5, 1/3)
	E10	(1/9, 1/7, 1/5)	(1/9, 1/7, 1/5)	(1/7, 1/5, 1/3)	(1, 1, 1)	(1, 3, 5)
	E1	(1/11, 1/9, 1/7)	(1/11, 1/9, 1/7)	(1/9, 1/7, 1/5)	(1/5, 1/3, 1)	(1, 1, 1)
	E2	(1/9, 1/7, 1/5)	(1/11, 1/9, 1/7)	(1/9, 1/7, 1/5)	(1/5, 1/3, 1)	(1, 1, 1)
	E3	(1/11, 1/9, 1/7)	(1/5, 1/3, 1)	(1/9, 1/7, 1/5)	(1/9, 1/7, 1/5)	(1, 1, 1)
	E4	(1/5, 1/3, 1)	(1/9, 1/7, 1/5)	(1/9, 1/7, 1/5)	(3, 5, 7)	(1, 1, 1)
C5	E5	(1/11, 1/9, 1/7)	(1/5, 1/3, 1)	(1/7, 1/5, 1/3)	(1/9, 1/7, 1/5)	(1, 1, 1)
	E6	(1/7, 1/5, 1/3)	(5, 7. 9)	(1, 3, 5)	(5, 7. 9)	(1, 1, 1)
	E7	(1/9, 1/7, 1/5)	(1/7, 1/5, 1/3)	(3, 5, 7)	(1/7, 1/5, 1/3)	(1, 1, 1)
	E8	(1, 3, 5)	(5, 7. 9)	(1, 1, 1)	(7, 9, 11)	(1, 1, 1)
	E9	(1/7, 1/5, 1/3)	(1, 3, 5)	(5, 7. 9)	(3, 5, 7)	(1, 1, 1)
	E10	(1/11, 1/9, 1/7)	(1/9, 1/7, 1/5)	(1/9, 1/7, 1/5)	(1/5, 1/3, 1)	(1, 1, 1)

Once the TFN pairwise comparison matrix is created, as shown above, it can be used to calculate the weight of importance for the five criteria. This calculation is performed in three main steps. The first step is to combine the fuzzy pairwise comparison from all ten experts for each of the five criteria. This can be done by calculating the geometric mean of the experts' opinions. To calculate the fuzzy geometric mean, the geometric mean method introduced by Buckley [37] is used leading to the fuzzy geometric mean pairwise comparison matrix shown in Table 6.

Table 6. Fuzzy geometric mean pairwise comparison matrix.

Criteria	C1	C2	C3	C4	C5
C1	(1, 1, 1)	(1.676, 2.647, 3.657)	(1.446, 2.125, 3.071)	(4.143, 6.221, 8.262)	(3.187, 4.904, 7.020)
C2	(0.273, 0.378, 0.597)	(1, 1, 1)	(0.672, 1.061, 1.513)	(1.621, 2.410, 3.249)	(1.247, 2.034, 3.045)
C3	(0.315, 0.459, 0.678)	(0.661, 0.943, 1.487)	(1, 1, 1)	(1.380, 2.104, 2.970)	(1.404, 1.951, 2.780)
C4	(0.121, 0.161, 0.241)	(0.308, 0.415, 0.617)	(0.337, 0.475, 0.725)	(1, 1, 1)	(0.659, 1.154, 1.719)
C5	(0.142, 0.204, 0.314)	(0.328, 0.492, 0.802)	(0.360, 0.512, 0.712)	(0.582, 0.866, 1.517)	(1, 1, 1)

The second step in calculating the criteria weights of importance is determining the fuzzy relative importance weight or the fuzzy synthetic extent of each of the five criteria. To do that, the extent analysis method introduced by Chang [38] is applied in this research, as shown in Equations (2–5). Let $G = \{g_1, g_2, g_3, \ldots, g_n\}$ be a goal set. Each criterion is taken and the extent analysis for each goal g_i is performed, respectively [25,39]. Accordingly, the m extent value for each criterion is obtained as follows: $M_{g_i}^1, M_{g_i}^2, M_{g_i}^3, \ldots, M_{g_i}^m$, where g_i ($i = 1, 2, 3, \ldots, n$) is the goal set and $M_{g_i}^j$ ($j = 1, 2, 3, \ldots, m$) are all TFNs. The value of the fuzzy synthetic extent (S_i) with respect to the ith criterion is defined as shown in Equation (2).

$$S_i = \sum_{j=1}^{m} M_{g_i}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} \tag{2}$$

In order to calculate $\sum_{j=1}^{m} M_{g_i}^j$, a fuzzy addition operation of the m extent is used for a certain matrix, as shown in Equation (3). This can be done following the addition of the fuzzy number process shown in Sun [27].

$$\sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \tag{3}$$

where the variables l, m, and u indicate the lowest possible value, the modal or most likely value, and the upper or highest possible value, respectively, as explained earlier in this research. The next logical operation is to calculate $\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j$ by performing another fuzzy addition operation of $M_{g_i}^j$ ($j = 1, 2, 3, \ldots, m$), as shown in Equation (4).

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right) \tag{4}$$

Finally, $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1}$ is determined by calculating the inverse of the vector above as shown in Equation (5).

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) \tag{5}$$

Equations (2)–(5) are now applied to the TFNs obtained in this research. To determine the fuzzy synthetic extent to the criteria chosen in this research, the $\sum_{j=1}^{m} M_{g_i}^j$ value is first calculated for each row of the matrix shown in Table 6. For example, for C1:

C1 = (1 + 1.676 + 1.446 + 4.143 + 3.187, 1 + 2.647 + 2.125 + 6.221 + 4.904, 1 + 3.657 + 3.071 + 8.262 + 7.020)

C1 = (11.452, 16.897, 23.010)

Accordingly, the $\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j$ value is calculated for each of the five criteria in Table 6 by applying Equation (4) as follows:

$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j = $ (11.452, 16.897, 23.010) $\oplus$ (4.813, 6.883, 9.404) $\oplus$ (4.760, 6.457, 8.915)
$\oplus$ (2.425, 3.205, 4.302) $\oplus$ (2.412, 3.074, 4.345)
$= (25.862, 36.516, 49.976)$

Based on that, the reciprocal value $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1}$ is calculated by applying Equation (5) as follows:

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^j \right]^{-1} = \left(\frac{1}{49.976}, \frac{1}{36.516}, \frac{1}{25.862} \right) = (0.020, 0.027, 0.039)$$

Finally, the value of the fuzzy synthetic extent (S_i) with respect to the ith criterion is calculated for each criterion, as shown in Equation (2). For example, the value of the fuzzy synthetic extent for the first criterion S_1 is calculated as follows:

$$S_1 = (11.452, 16.897, 23.010) \otimes (0.020, 0.027, 0.039) = (0.229, 0.436, 0.893)$$

The fuzzy synthetic extent or the fuzzy relative importance weights resulting from applying the same process to the remaining criteria is presented in Table 7.

Table 7. Fuzzy synthetic extent of sustainable project selection criteria.

Criteria	S_i Low	S_i Med	S_i Upper
C1	0.229	0.463	0.893
C2	0.096	0.188	0.364
C3	0.095	0.177	0.345
C4	0.049	0.088	0.166
C5	0.048	0.084	0.168

The third and final step in calculating the criteria weights of importance is the defuzzification of the fuzzy criteria weights shown in Table 7. To defuzzify these weights, the defuzzification method shown in Equation (6), as presented in Sun [27] and Lespier et al. [7], is used to obtain the best non-fuzzy priority (BNP) or crisp weights of the criteria.

$$BNP_{S_i} = \frac{\left[\left(u_{s_i} - l_{s_i}\right) + \left(m_{s_i} - l_{s_i}\right)\right]}{3} + l_{s_i} \qquad where \; i = 1, 2, \ldots, 5 \qquad (6)$$

As an example, applying Equation (6) to calculate the BNP for criterion 1 is done as follows:

$$BNP_{S_1} = \frac{\left[(0.893 - 0.229) + (0.463 - 0.229)\right]}{3} + 0.229 = 0.528$$

Accordingly, the crisp weights for the remaining criteria are calculated. Using these BNP values, the criteria can be ranked based on importance, where the criterion with the highest BNP is set as the most important, while the criterion with the lowest BNP is set as the least important, as shown in Table 8.

Table 8. Best non-fuzzy priority (BNP) or crisp criteria weights.

Criteria	BNP	Rank
C1—Project Cost	0.528	1
C2—Novelty	0.216	2
C3—Uncertainty	0.206	3
C4—Skill and Experience	0.101	4
C5—Technology Info. Transfer	0.100	5

4. Discussion of Results

Sustainable project selection is an important step in successful sustainable development. Selecting the appropriate sustainable project is a major step in ensuring the success of the project and, thus, achieving the desired sustainability and project goals. The sustainable project selection process depends on a wide variety of criteria. One of the major challenges facing decision makers in sustainable project selection is the strong dependence on the subjective judgments of experts in prioritizing the project selection criteria, as well as the uncertainties associated with these subjective judgments. To help overcome these challenges, a fuzzy multi-criteria decision-making methodology has been implemented in this research. FAHP has been used in this research to rank five key sustainable project selection criteria shown in Table 1 by calculating the relative weight of importance for each of these selection criteria.

The results show that the most important criterion to consider in sustainable project selection is project cost (C1) with an importance weight (BNP) of 0.528. This mainly includes different sources of cost for the project such as the project's initial investment cost, maintenance cost, labor cost, operating

costs, and any other cost associated with the project over its life cycle that can differ from one location or country to the other [28]. This result has been mostly consistent with what has been shown in the literature when considering the economic aspect of sustainable projects. As mentioned earlier in this research, project cost has been one of the major factors influencing sustainable development in the international stage due to concerns that renewable and sustainable energy projects cannot compete economically with conventional energy projects [20]. The different sources of project cost including the investment cost, operating and maintenance costs, and labor costs are also considered as variables in the measurement of project efficiency that can be used to evaluate sustainable projects, as shown by Švajlenka and Kozlovská [40].

The second and third most important criteria to consider in sustainable project selection in this research are novelty (C2) and uncertainty (C3) with BNPs of 0.216 and 0.206, respectively. Both of these criteria are also considered one of the most important in sustainable project selection. As mentioned earlier in this research, novelty mainly focuses on the originality and maturity of the sustainable technologies and practices used in these projects. It is also an indicator of how widespread a sustainable technology or practice is in the location or country these projects exist in and the improvement potential of these technologies and practices [28]. The novelty of the sustainable technologies and practices used in projects can also potentially help accelerate the opportunities for sustainability adoption in communities [33]. Uncertainty can include different sub criteria that can be on both a local or international scale such as financial uncertainty, technological uncertainty, environmental uncertainty, and political uncertainty each with a different impact on sustainable projects. Since most of the sustainable project selection literature focus on the technical aspect of sustainable technologies, there has been an emphasis on the technical uncertainties associated with these technologies. Nonetheless, other international or local sources of uncertainty are also important and should also be considered just as crucial in sustainable project selection, since they can potentially hinder the use of sustainable technologies and practices in a given location [35].

The two least important criteria out of the five considered in this research based on the selected experts' opinions are skill and experience (C4) and technology information transfer (C5) with BNPs of 0.101 and 0.100, respectively. These results show that both criteria have a relatively similar level of importance with skill and experience being just slightly more important than technology information transfer. However, these results cannot be interpreted as implying that these two criteria are not important and should not be considered in the selection of sustainable projects. They simply mean that the selected experts prioritize the other three criteria over skill and experience and technology information transfer when selecting between different sustainable project alternatives.

As explained earlier in this research, skill and experience refers to having the appropriate know-how to successfully undertake a selected sustainable project. Kahraman et al. [41], Amer and Daim [42], and Solangi et al. [36] all argue that having the appropriate human resources with the required skills and experience to build, operate, and maintain the sustainable project in the location or country in which these projects exist is a crucial factor to consider when selecting between different sustainable project alternatives to ensure the success of the project. Technology information transfer refers to the level of technology information sharing or communication between a supplier of a technology and the project team implementing that technology. The unavailability of the adequate technological information in a specific location or country as well as inadequate information sharing and communication may be considered as one of the greatest barriers to successful sustainable technology implementation and, ultimately, sustainable project success [35]. This information can include sustainable technology specifications, design, materials used, or any other technology information that is crucial to successful project implementation and, thus, achieving the overall goals of the project. For example, Švajlenka et al. [43] emphasized the importance of considering such information as environmental parameters in improving the decision-making process when evaluating the different project alternatives to examine whether or not these projects would meet the overall sustainable goals.

The selection criteria chosen for this research are not limited to the evaluation of a specific type of sustainable projects or a specific location. Instead, these criteria are applicable to evaluate different types of sustainable projects in different environments and geographical locations [10]. Moreover, one of the major benefits of using FAHP to rank these criteria based on a number of diverse sources of expert opinions is that it is designed to minimize any uncertainty or biases that are associated with the subjective judgments of these experts when performing the pairwise comparison [44,45]. Accordingly, the results presented in this research reflect the consensus among these diverse expert sources regarding the relative importance of the selection criteria regardless of any subjective judgment or biases.

5. Conclusions

This research implements the fuzzy analytic hierarchy process (FAHP) methodology as a multi-criteria decision-making (MCDM) approach to develop a sustainable project selection tool that quantifies and ranks five key sustainable project criteria based on importance. This selection tool can be applied by any project manager or decision maker when evaluating different sustainable project alternatives for selection regardless of the type, environment, and location of these projects. The criteria chosen in this research are novelty, uncertainty, team skill and experience, technology information transfer, and project cost. Prioritizing these criteria based on relative importance helps project managers and decision makers identify more important project elements that require additional attention, better allocate resources, as well as improve the selection process when evaluating different sustainable project alternatives. This research utilizes the existing literature examined as part of the literature review process to represent the voice of experts on the relative importance of the selected criteria.

The results from the FAHP methodology in this research answers the research question introduced earlier by showing that project cost is the most important criterion to consider when evaluating different sustainable project alternatives with a best non-fuzzy priority (BNP) of 0.528. This indicates that sustainable development is still significantly driven by economic factors specific to location. The second and third most important criteria to consider in sustainable project selection based on the FAHP results are novelty and uncertainty with BNPs of 0.216 and 0.206, respectively. This indicates that the originality and maturity of the sustainable technologies and practices used in these projects, as well as the different sources of uncertainty surrounding such projects, are also strong driving factors in sustainable project selection. Finally, the FAHP results show that the two least important criteria out of the five considered in this research are skill and experience and technology information transfer with BNPs of 0.101 and 0.100, respectively. This represents possible good news for developing economies that should be considered as part of future research.

The limitations associated with this research include the small sample size of literature considered to act as the voice of experts in the pairwise comparison of the chosen criteria. A larger sample size in the future could yield more accurate results regarding the relative importance of the selected criteria. It is also important to note that these results are limited to the knowledge and experiences of the chosen experts. Another potential limitation of this research is the use of literature to act as the voice of experts. This could add another layer of uncertainty and subjective judgment that stems from the interpretations and opinions of the researchers utilizing the literature, which is not accounted for by the FAHP. Future research should focus on gathering input data from sustainable project researchers and practitioners in an effort to gather direct input and, thus, eliminating any need for interpretation by the researchers.

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References

1.   Qin, R.; Grasman, S.E.; Long, S.; Lin, Y.; Thomas, M. A framework of cost-effectiveness analysis for alternative energy strategies. *Eng. Manag. J.* **2012**, *24*, 18–35. [CrossRef]
2.   Almasoud, A.; Gandayh, H.M. Future of solar energy in Saudi Arabia. *J. King Saud Univ. Eng. Sci.* **2015**, *27*, 153–157. [CrossRef]
3.   Fleury-Bahi, G.; Préau, M.; Annabi-Attia, T.; Marcouyeux, A.; Wittenberg, I. Perceived health and quality of life: The effect of exposure to atmospheric pollution. *J. Risk Res.* **2015**, *18*, 127–138. [CrossRef]
4.   Labuschagne, C.; Brent, A.C. Sustainable project life cycle management: The need to integrate life cycles in the manufacturing sector. *Int. J. Proj. Manag.* **2005**, *23*, 159–168. [CrossRef]
5.   Amiri, M.P. Project selection for oil-fields development by using the AHP and fuzzy TOPSIS methods. *Expert Syst. Appl.* **2010**, *37*, 6218–6224. [CrossRef]
6.   Enea, M.; Piazza, T. Project selection by constrained fuzzy AHP. *Fuzzy Optim. Decis. Mak.* **2004**, *3*, 39–62. [CrossRef]
7.   Lespier, L.P.; Long, S.; Shoberg, T.; Corns, S. A model for the evaluation of environmental impact indicators for a sustainable maritime transportation systems. *Front. Eng. Manag.* **2019**, *6*, 368–383. [CrossRef]
8.   Ligus, M. Evaluation of economic, social and environmental effects of low-emission energy technologies development in Poland: A multi-criteria analysis with application of a fuzzy analytic hierarchy process (FAHP). *Energies* **2017**, *10*, 1550. [CrossRef]
9.   Li, L.; Fan, F.; Ma, L.; Tang, Z. Energy utilization evaluation of carbon performance in public projects by FAHP and cloud model. *Sustainability* **2016**, *8*, 630. [CrossRef]
10. Alyamani, R.; Long, S.; Nurunnabi, M. Exploring the Relationship between Sustainable Projects and Institutional Isomorphisms: A Project Typology. *Sustainability* **2020**, *12*, 3668. [CrossRef]
11. Kubler, S.; Robert, J.; Derigent, W.; Voisin, A.; Le Traon, Y. A state-of the-art survey & testbed of fuzzy AHP (FAHP) applications. *Expert Syst. Appl.* **2016**, *65*, 398–422.
12. Bilgen, B.; Şen, M. Project selection through fuzzy analytic hierarchy process and a case study on Six Sigma implementation in an automotive industry. *Prod. Plan. Control* **2012**, *23*, 2–25. [CrossRef]
13. Nguyen, L.D.; Tran, D.Q. *FAHP-Based Decision Making Framework for Construction Projects. Fuzzy Analytic Hierarchy Process*; CRC Press: Boca Raton, FL, USA, 2017; p. 327.
14. Chu, P.-Y.V.; Hsu, Y.-L.; Fehling, M. A decision support system for project portfolio selection. *Comput. Ind.* **1996**, *32*, 141–149. [CrossRef]
15. Huang, C.-C.; Chu, P.-Y.; Chiang, Y.-H. A fuzzy AHP application in government-sponsored R&D project selection. *Omega* **2008**, *36*, 1038–1052.
16. Hatefi, S.M.; Tamošaitienė, J. Construction projects assessment based on the sustainable development criteria by an integrated fuzzy AHP and improved GRA model. *Sustainability* **2018**, *10*, 991. [CrossRef]
17. Sabaghi, M.; Mascle, C.; Baptiste, P.; Rostamzadeh, R. Sustainability assessment using fuzzy-inference technique (SAFT): A methodology toward green products. *Expert Syst. Appl.* **2016**, *56*, 69–79. [CrossRef]
18. Durairaj, S.; Sathiya Sekar, K.; Ilangkumaran, M.; RamManohar, M.; Thyalan, B.; Yuvaraj, E.; Ramesh, S. Multi-Criteria Decision Model for Biodiesel Selection in an Electrical Power Generator Based on Fahp-Gra-Topsis. *Int. J. Res. Eng. Technol.* **2014**, *3*, 226–233.
19. Seddiki, M.; Bennadji, A. Multi-criteria evaluation of renewable energy alternatives for electricity generation in a residential building. *Renew. Sustain. Energy Rev.* **2019**, *110*, 101–117. [CrossRef]
20. Malik, A.; Al Badi, M.; Al Kahali, A.; Al Nabhani, Y.; Al Bahri, A.; Al Barhi, H. Evaluation of renewable energy projects using multi-criteria approach. In Proceedings of the IEEE Global Humanitarian Technology Conference (GHTC 2014), San Jose, CA, USA, 10–13 October 2014.
21. Alyamani, R.; Long, S. Integrating Sustainable Project Typology and Isomorphic Influences: An Integrated Literature Review. In Proceedings of the International Annual Conference of the American Society for Engineering Management, Coeur d'Alene, ID, USA, 17–20 October 2018; pp. 1–10.
22. Saaty, T.L. *The Analytic Hierarchy Process, Planning, Priority Setting, Resource Allocation*; McGraw-Hill: New York, NY, USA, 1980.

23. Kaur, P.; Chakrabortyb, S. A new approach to vendor selection problem with impact factor as an indirect measure of quality. *J. Mod. Math. Stat.* **2007**, *1*, 8–14.

24. Shukla, R.K.; Garg, D.; Agarwal, A. An integrated approach of Fuzzy AHP and Fuzzy TOPSIS in modeling supply chain coordination. *Prod. Manuf. Res.* **2014**, *2*, 415–437. [CrossRef]

25. Ballı, S.; Korukoğlu, S. Operating system selection using fuzzy AHP and TOPSIS methods. *Math. Comput. Appl.* **2009**, *14*, 119–130. [CrossRef]

26. Hsieh, T.-Y.; Lu, S.-T.; Tzeng, G.-H. Fuzzy MCDM approach for planning and design tenders selection in public office buildings. *Int. J. Proj. Manag.* **2004**, *22*, 573–584. [CrossRef]

27. Sun, C.-C. A performance evaluation model by integrating fuzzy AHP and fuzzy TOPSIS methods. *Expert Syst. Appl.* **2010**, *37*, 7745–7754. [CrossRef]

28. Wang, B.; Song, J.; Ren, J.; Li, K.; Duan, H. Selecting sustainable energy conversion technologies for agricultural residues: A fuzzy AHP-VIKOR based prioritization from life cycle perspective. *Resour. Conserv. Recycl.* **2019**, *142*, 78–87. [CrossRef]

29. Shenhar, A.J.; Dvir, D. Toward a typological theory of project management. *Res. Policy* **1996**, *25*, 607–632. [CrossRef]

30. Clarke, H. Evaluating infrastructure projects under risk and uncertainty: A checklist of issues. *Aust. Econ. Rev.* **2014**, *47*, 147–156. [CrossRef]

31. Toma, S.-V.; Chiriţă, M.; Şarpe, D. Risk and uncertainty. *Procedia Econ. Financ.* **2012**, *3*, 975–980. [CrossRef]

32. Stock, G.N.; Tatikonda, M.V. A typology of project-level technology transfer processes. *J. Oper. Manag.* **2000**, *18*, 719–737. [CrossRef]

33. Chen, H.H.; Kang, H.-Y.; Lee, A.H. Strategic selection of suitable projects for hybrid solar-wind power generation systems. *Renew. Sustain. Energy Rev.* **2010**, *14*, 413–421. [CrossRef]

34. Işik, Z.; Aladağ, H. A fuzzy AHP model to assess sustainable performance of the construction industry from urban regeneration perspective. *J. Civ. Eng. Manag.* **2017**, *23*, 499–509. [CrossRef]

35. Luthra, S.; Kumar, S.; Garg, D.; Haleem, A. Barriers to renewable/sustainable energy technologies adoption: Indian perspective. *Renew. Sustain. Energy Rev.* **2015**, *41*, 762–776. [CrossRef]

36. Solangi, Y.A.; Tan, Q.; Mirjat, N.H.; Valasai, G.D.; Khan, M.W.A.; Ikram, M. An integrated Delphi-AHP and fuzzy TOPSIS approach toward ranking and selection of renewable energy resources in Pakistan. *Processes* **2019**, *7*, 118. [CrossRef]

37. Buckley, J.J. Fuzzy hierarchical analysis. *Fuzzy Sets Syst.* **1985**, *17*, 233–247. [CrossRef]

38. Chang, D.-Y. Applications of the extent analysis method on fuzzy AHP. *Eur. J. Oper. Res.* **1996**, *95*, 649–655. [CrossRef]

39. Kahraman, C.; Cebeci, U.; Ruan, D. Multi-attribute comparison of catering service companies using fuzzy AHP: The case of Turkey. *Int. J. Prod. Econ.* **2004**, *87*, 171–184. [CrossRef]

40. Švajlenka, J.; Kozlovská, M. Evaluation of the efficiency and sustainability of timber-based construction. *J. Clean. Prod.* **2020**, *259*, 120835. [CrossRef]

41. Kahraman, C.; Kaya, İ.; Cebi, S. A comparative analysis for multiattribute selection among renewable energy alternatives using fuzzy axiomatic design and fuzzy analytic hierarchy process. *Energy* **2009**, *34*, 1603–1616. [CrossRef]

42. Amer, M.; Daim, T.U. Selection of renewable energy technologies for a developing county: A case of Pakistan. *Energy Sustain. Dev.* **2011**, *15*, 420–435. [CrossRef]

43. Švajlenka, J.; Kozlovská, M.; Pošiváková, T. Analysis of selected building constructions used in industrial construction in terms of sustainability benefits. *Sustainability* **2018**, *10*, 4394. [CrossRef]

44. Fu, H.-H.; Chen, Y.-Y.; Wang, G.-J. Using a Fuzzy Analytic Hierarchy Process to Formulate an Effectual Tea Assessment System. *Sustainability* **2020**, *12*, 6131. [CrossRef]

45. Tsai, H.-C.; Lee, A.-S.; Lee, H.-N.; Chen, C.-N.; Liu, Y.-C. An Application of the Fuzzy Delphi Method and Fuzzy AHP on the Discussion of Training Indicators for the Regional Competition, Taiwan National Skills Competition, in the Trade of Joinery. *Sustainability* **2020**, *12*, 4290. [CrossRef]