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The development of a project typology and selection tool to improve decision-making in sustainable projects

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THE DEVELOPMENT OF A PROJECT TYPOLOGY AND SELECTION TOOL TO IMPROVE DECISION-MAKING IN SUSTAINABLE PROJECTS

by

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ABSTRACT

Decision-making in sustainable projects is a complex and challenging process, especially during the initiating and planning phases of project development, due to influence from several external factors, as well as the uncertain environments surrounding their creation. It is essential to improve the decision-making process in sustainable projects during these two phases by relying on strong decision-making tools. The first contribution in this work identifies gaps in the literature of how institutionalization can impact sustainable projects through the effects of institutional isomorphisms from institutional theory. This helps decision makers better understand the relationship between institutionalization and sustainable projects. The second contribution is a sustainable project typology based on the affects that the coercive, normative, and mimetic institutional pressures have on common key sustainable project characteristics. The typology can improve decision-making by providing realistic predictions about the project early in the planning phase. The third contribution further develops this typology into a project selection tool that can be used in the initiating phase. It applies the Fuzzy Analytic Hierarchy Process (FAHP) to rank the key project characteristics based on importance as selection criteria by utilizing the literature as the voice of expert opinion. Because using the literature as a source of expert opinion can present its own set of challenges, the fourth contribution considers how the choice of selection tool inputs can impact project selection. Accordingly, Subject Matter Experts (SMEs) are utilized as an alternative source of expert opinion in an effort to validate the previously generated results and compare how these selection criteria are prioritized in literature and practice.

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1. INTRODUCTION

1.1. BACKGROUND AND MOTIVATION

The use of fossil fuels as source of energy has generally been considered extremely attractive is the past, especially from the economic perspective. In recent years however, these sources presented a wide range of issues such as environmental pollution, low efficiency, unsustainability, and geographical dependency in addition to being one of the major causes of global warming (Qin et al., 2012). Moreover, it is argued that the Green House Gases (GHGs) resulting from the use of these conventional sources can cause a wide range of health issues over time (Almasoud & Gandayh, 2015; Fleury-Bahi et al., 2015). As a result, global efforts to combat these adverse effects of conventional energy sources has led to a massive focus on sustainability and sustainable development in a large number of fields.

As one of the crucial fields promoting sustainability, project management has showed an increased focus on sustainable development in the past 10 years in both practice and research (Silvius et al., 2017). Part of the project management research is focused on developing project typologies. In these typologies, projects are classified into a set of ideal types based on the relationship between these types and specific project characteristics. The variation between these ideal types is not determined by a single characteristic but multiple characteristics within these project types (Niknazar & Bourgault, 2017). The degree to which a project fits any of the ideal types, should provide an indication of the outcome of the project (Alyamani & Long, 2018). Some of the commonly used key project characteristics in project typologies include level of change (Shenhar & Dvir, 1996), project uncertainty (Shenhar & Dvir, 1996, 2007), the level of technological information transfer between the provider of the technology and the recipient of the technology (Stock & Tatikonda, 2000), and the skill and experience required in different types of projects to insure project success (Shenhar & Dvir, 1996; Stock & Tatikonda, 2000). Accordingly, project typologies are considered by project managers and decision makers as important tools that can improve the decision-making process by providing relatively realistic predictions early in the planning phase regarding the characteristics used in these typologies and thus, allowing them to be better prepared and improve their decision making when undertaking these projects (Alyamani et al., 2020). Nonetheless, it is important to note that all typologies present "ideal" project types that are rarely found in real projects and so, these typologies are only used to provide indicators based on the degree a project fits any of the ideal types presented in the typology.

It is a well-established fact in the project management literature that all projects are subject to influence from a wide range of external factors that can potentially impact the different characteristics of projects and subsequently influencing the overall projects (Alyamani & Long, 2018; Gudienė et al., 2013; Musa et al., 2015). Consequently, it is crucial to understand how these different external factors can uniquely influence projects. One of the most ignored external influences on projects, or more specifically sustainable projects, in the project management literature is institutionalization. Institutional theory provides an insight into the forces that provide the legitimacy and survival of organizations and organizational practices in an institutional environment.

The core idea of institutional theory is that organizations are not just rationally designed, but are also shaped by the culture in which they exist (Bresnen, 2016). Thus, institutional theory has moved research away from rationalistic explanations of how organizations should operate towards the idea that organizations are embedded in a larger cultural environment that influences how these organizations behave, which is why the theory is sometimes thought of as a cultural theory (Frumkin & Galaskiewicz, 2004). The theory suggests that external social norms, values, and beliefs create standards of legitimacy to organizations which in turn, influence their management decisions and practices (Rivera, 2004). DiMaggio and Powell (1983) described three institutional isomorphisms or institutional pressures by which these institutional environments can influence organizations as coercive, normative, and memetic. Conforming to these institutional isomorphisms creates legitimacy for organizations and organizational practices within the institutional environment they exist in.

From a project management prospective, the influence of these institutional pressures on projects in general or, more specifically, sustainable projects can also be explored thorough the modern theory of project management, which identifies projects as temporary organizations (Alyamani et al., 2020; Miterev et al., 2017; Van Donk & Molloy, 2008). Institutional isomorphisms can thus be used to explain how the institutional environment can impact decisions regarding the development of sustainable activities and sustainable projects (Glover et al., 2014). Accordingly, these institutional pressures create environments where projects are not just driven by efficiency and economic gain, but instead are also driven by the institutional environment in an effort to gain legitimacy. This follows a narrative presented in the institutional theory literature stating that not all management decisions are made based on economic benefits, but instead on what is viewed as favorable or acceptable in an institutional environment in an effort to improve the legitimacy of the project (Rivera, 2004).

Even though, as mentioned previously in this section, the project management literature has shown an increased in research related to sustainability and sustainable development in addition to the development of project typologies, there has been little research that is dedicated to developing sustainable project typologies that can help project managers and decision makers in the sustainable development field make better decisions early in the planning phase of these projects (Alyamani & Long, 2018). More notably, there has been a lack of research on the impact of institutionalization on sustainable projects and how the coercive, normative, and memetic institutional pressures can impact such projects (Svejvig & Andersen, 2015). Addressing these gaps in the literature can potentially improve the decision-making process in sustainable projects and thus, improve their success rate.

However, even though developing a sustainable project typology would help improve the decision-making process in the planning phase of the project, one major drawback to such typology is that it only focuses on evaluating the project characteristics or criteria in the planning phase once the project is selected. It would not address the decision making that occurs during the preceding initiating phase. The initiating phase includes evaluating different sustainable project alternatives to select the appropriate project that meets the desired goals (Shah, 2012). Selecting the right project to develop based on established criteria or characteristics is an essential step to a achieve the desired goals form the project.

Decision makers often find themselves in situations where they are presented with a number of sustainable development proposals where they are ideally required to select the best sustainable project to develop that would best meet the desired goals. Realistically speaking, not every project proposal can be selected for development. There are many factors that play a role in project selection including the viability of the presented project alternatives in addition to the availability of resources (Amiri, 2010; Nguyen & Tran, 2017). One extremely useful approach to sustainable project selection is utilizing a list of key selection criteria which are then used to determine the best possible project alternative. Establishing a ranking for these selection criteria can help project managers and decision makers further improve the project selection process by prioritizing the more important areas which can in turn help differentiate between the different sustainable project alternatives.

One of the most popular approaches to sustainable project selection based on established selection criteria is the utilization of Multi-Criteria Decision Making (MCDM) methodologies that are used to score or rank a determined number of alternatives based on multiple evaluation or selection criteria (Qureshi et al., 2018; Wang et al., 2019). The Analytic Hierarchy Process (AHP), first introduced by Saaty (1980), is one of the most commonly used and established MCDM techniques used in project selection. It is used to make optimal selection decisions in cases where multiple selection criteria are used by assigning priority weights to these criteria through a pairwise comparison process (Ligus, 2017). One of its major advantages is that it provides a relatively simple approach to multi-criteria decision-making. However, a major downside to the classical AHP approach is that it does not account for the uncertainty and ambiguity that is usually associated with experts' judgments when performing the pairwise comparison between the different criteria (Kahraman et al., 2004).

To overcome this issue, a combination of fuzzy set theory and AHP known as the Fuzzy Analytic Hierarchy Process (FAHP) was created to deal with such uncertain and subjective expert judgments. It is used to covert ambiguous linguistic ratings provided by experts into specific numeric intervals which are then used to determine the criteria priority weights of importance. Applying FAHP to rank the previously mentioned project criteria of level of change, uncertainty, skill and experience, and technology information transfer in addition to project cost as a fifth criterion will help further develop the sustainable project typology into a project selection tool that can improve the project selection process in the preceding initiating phase.

There are two main sources of input data that are commonly used in the literature to collect expert judgments regarding the relative importance of the sustainable project selection criteria. Researchers can utilize the existing sustainable development literature as one reliable source of expert opinion (Pérez et al., 2019). One major advantage to using the literature as a source of expert opinion is that it is readily available for most researchers and relatively inexpensive. However, a major downside to this approach is that it may add an additional level of uncertainty stemming from the interpretations of the existing literature by the researchers collecting the data which is not accounted for in the FAHP process. This issue can be solved using the other main source of input data through the direct collection of opinions for subject matter experts (SMEs) using a standard FAHP pairwise comparison survey. In addition, collecting data from both the literature and SMEs can provide a unique opportunity to compare the results from both sources as a way to validate the results. Also, any variation in ranking of the selection project selection criteria between the literature and practice.

1.2. RESEARCH OBJECTIVES AND CONTRIBUTION

The aim of this dissertation is to develop a sustainable project typology that explores the impact of coercive, normative, and memetic institutional isomorphic influences on sustainable projects to help improve the decision making process in the planning phase of sustainable projects, and further develop this typology into a project selection tool using the identified project criteria from the typology to help improve the sustainable project selection process in the preceding project initiating phase.

Publication 1: A systematic literature review is conducted by combining the integrated literature review and the State-of-the-Art Matrix (SAM) analysis methodologies in an effort to determine how the coercive, normative, and memetic institutional isomorphisms can impact sustainable projects and thus, be used to develop a sustainable project typology. The literature review focused on examining the literature from the fields of institutional isomorphisms, project management/typology, and sustainability in an effort to answer that question. This research can provide project managers and decision-makers with a better understanding of the issues surrounding current research related to the relationship between sustainable projects and the institutional environment.

Publication 2: The knowledge gained from the literature review done in the first publication is used to develop a sustainable project typology that classifies sustainable projects into three types based on the coercive, normative, and memetic institutional isomorphisms impacting these projects. The typology examines the influence of the three institutional pressures on the expected level of change, level of uncertainty, required project team skills and experience levels, and the level of technology information exchange in sustainable projects. This research can help define the relationship between institutional isomorphisms and sustainable projects and thus, demonstrate one way institutional isomorphisms can be used to develop a sustainable project typology.

Publication 3: This research further develops the typology from the previous publication into a sustainable project selection tool using the Fuzzy Analytic Hierarchy Process (FAHP) technique to rank novelty, uncertainty, skill and experience, technology information transfer, and project cost as selection criteria based on importance. The research utilizes existing sustainable project selection literature as the voice of expert opinion regarding the relative importance of these criteria. This selection tool should help project managers and decision makers make better decisions in sustainable project selection during the initiating phase.

Publication 4: This research utilizes subject matter experts (SMEs) as an alternative source of expert opinion when applying the FAHP technique to rank the project cost, project maturity, project uncertainty, skill and experience, and technology information transfer selection criteria based on importance. The results from this publication are then used to validate the earlier results from the previous publication by comparing how these sustainable project selection criteria are ranked in both the literature and practice. Doing so would also provide an opportunity to identify any variation in opinion between the two perspectives regarding the importance of these criteria in sustainable project selection.

PAPER

I. INTEGRATING SUSTAINABLE PROJECT TYPOLOGY AND ISOMORPHIC INFLUENCES: AN INTEGRATED LITERATURE REVIEW

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ABSTRACT

Prior research demonstrates that projects are affected by external factors (e.g. the environment in which the projects exist), and sustainable projects are no exception. Understanding the effects of these external factors may help project managers be better informed in decision making in the earlier planning phase. This research uses an integrative literature review to determine how the coercive, normative, and mimetic external influences of institutional theory can best be used to develop a sustainable project typology. The literature is grouped by topic using a State-of-the-Art Matrix Analysis (SAM). Key research questions that emerged include how these institutional influences affect the expected level of change, level of uncertainty, project team skills and experience levels, and the level of technology information exchange. Results of this research will provide the

engineering manager with a better understanding of issues surrounding the influence of institutional theory on sustainable project decision making.

Keywords: Sustainable Projects, Project Typology, Integrated Literature Review, State of the Art Matrix Analysis.

1. INTRODUCTION

The use of traditional energy sources is accompanied with several issues such as pollution, dependency of geographical location, low efficiency, as well as the non-renewability of these resources (Qin, Grasman, Long, Lin, & Thomas, 2012). These traditional energy sources that use fossil fuels are known to be a major cause of global warming, as well as being generally harmful to human health and the environment through the Green House Gases (GHGs) emitted by these sources (Almasoud & Gandayh, 2015). Consequently, it is imperative that alternative sustainable energy sources are found and developed as a substitute for traditional sources. Fortunately, worldwide efforts to promote sustainability has led to increased awareness of the adverse effects of using traditional energy sources, leading to an increase in research devoted to sustainability in a wide variety of fields.

In the past 10 years, there has been a significant growth in the sustainable project management research, where project management played an important role in the implementation of sustainable development within organizations and societies (Silvius, Kampinga, Paniagua, & Mooi, 2017). To help project managers and decision makers in the decision-making process, part of this research was devoted to developing project typologies in which projects are classified into a set of ideal types. The degree to which a project fits any of the ideal types provides an indication of the outcome of the project (Niknazar & Bourgault, 2017). In these typologies, projects are classified based on many different project characteristics such as level of change, uncertainty level (Shenhar & Dvir, 1996), project team skills and experience levels, and the level of technology information exchange (Stock & Tatikonda, 2000). These characteristics, and many others, are subject to influence from a wide variety of external factors consequently impacting the overall project outcome (Gudienė, Banaitis, Banaitienė, & Lopes, 2013; Musa, Amirudin, Sofield, & Musa, 2015).

Institutionalization is one factor that can have a significant influence on projects, including projects related to sustainability. Institutional theory provides an insight into how groups and organizations seek legitimacy by conforming to different institutional influences, known as institutional isomorphisms, that stem from the norms and values of the institutional environment in which these groups and organizations exist (DiMaggio & Powell, 1983; Glover, Champion, Daniels, & Dainty, 2014). This suggests that managerial decisions, including project decisions, are not always based solely on the economic outcome of these decisions, but are also based on the rules, norms, and values in the existing institutional environment (Rivera, 2004). Although institutional theory mainly focuses on the organizational prospective in general, the modern theory of project management suggests that projects are temporary organizations that are affected by the same external factors as other organizations located in the same environment (Silvius et al., 2017; Svejvig & Andersen, 2015; Turner & Müller, 2003; Van Donk & Molloy, 2008). Moreover, (Bresnen, 2016)) suggests that institutionalization does indeed have an influence on project management. This paper explores the institutional theory, project management/typology, and sustainability literature to investigate how institutional isomorphisms affect sustainable projects, using an integrated literature review and the State-of-the-Art Matrix (SAM) method.

2. METHODOLOGY

This paper uses an integrated literature review and the SAM analysis to determine how external institutional isomorphisms from institutional theory can affect sustainable projects. Understanding the effects of these external influences is the first step in developing a sustainable project typology that categorizes these projects based on the institutional environment in which they exist. Research from the fields of institutional theory, project management/typology, and sustainability is examined and analyzed towards that goal. An integrated literature review is a methodology that is used to combine knowledge from different topics. This method is especially effective for new or emerging research where knowledge from different fields is combined to form a basis to the development of new conceptual models (Egbue & Long, 2012; Kohtala, 2015). Similarly, the SAM is a methodology that helps in analyzing literature by categorizing research into a matrix (Beruvides & Omachonu, 2001). It is used by researchers to systematically analyze data and identify gaps and trends in existing research (Egbue & Long, 2012). In this paper, SAM is used to systematically analyze research related to institutional isomorphisms, project management/typology, and sustainability.

The search for relevant literature was done using a variety of databases provided by the Missouri S&T library website including Sciencedirect, ABI/Inform, Scopus, and IEEE Xplore. The search was limited to peer-reviewed publications with no restrictions on the date of publication as to observe trends in research over the years. Keywords were used in the search process in different combinations in an effort to capture as much related literature as possible. These keywords included institutionalization, institutional isomorphisms, project typology, and sustainable/ sustainability. The found articles were then screened to determine inclusion or exclusion based on relevance to institutional isomorphisms, sustainable projects, and project typologies. The screening process included examining the abstract sections of the found papers to determine relevance. After all irrelevant publications were excluded, the remaining articles were fully examined to further determine the relevance. The reference sections of included articles were also examined in an effort to find more relevant literature.

Based on the analysis, papers were grouped into three primary groups representing research related to institutional isomorphisms, project management/typology, and sustainability; and three secondary groups representing research related to the economic, social, and environmental aspects. The primary groups contain data that is used to understand the three primary fields of this research, and how they can be combined to reflect the effects of institutional isomorphisms on sustainable projects. The secondary groups reflect research that represent the bottom line of sustainable development, and is referred to by researchers as “the three pillars of sustainability” (Seay, 2015). Combining research from all six groups would present a holistic, but not comprehensive, first step in studying the effects of institutionalization on sustainable projects. An operational definition of the six research groups is provided as follows:

- **Institutional Isomorphisms**: this group focuses on research related to the concept of institutional isomorphisms and how they affect organizations, and potentially projects, in a variety of fields and social environments.
- **Project Management/Typology**: this group focuses on research related to project typology models, as well as project management research related the different characteristics used in these typologies, including the ones chosen in this paper.
- **Sustainability**: this group focuses on research related to the topics of sustainability and sustainable development in a variety of fields, including the development of renewable energy and sustainable processes.
- **Economic Aspects:** this group focuses on research related to the economic aspects of institutionalization, project management activities, or sustainability.
- **Social Aspects**: this group focuses on research related to the social aspects associated with the three primary groups.
- **Environmental Aspects**: this group focuses on research related to the environmental aspects associated with the primary groups, including the environmental impact of institutional isomorphisms, projects, and sustainability.

All included analyzed literature as well as the six research groups were then added to the SAM. The articles were listed chronologically on the vertical axis of the matrix, while the aforementioned research groups were listed horizontally. An “ X ” was placed below all topic discussed in the corresponding article resulting in a matrix that organized the literature by topic and year of publication (Table 1). Quantitative and qualitative analysis was then conducted to identify potential trends and gaps in the research.

Table 1. Summary of Literature by Topics.

#	Author	Year	Type	Institutional Isomorphisms	Project Management/ Typology	Sustainability	Economic Aspect	Social Aspect	Environmer Aspect
1	DiMaggio & Powell	1983	Journal	X				X	
2	Shenhar & Dvir	1996	Journal		X			X	X
3	Griffin & Page	1996	Journal		X				
4	Stock & Tatikonda	2000	Journal		X		X		
5	Turner & Muller	2003	Journal		X				
6	Delmas & Toffel	2004	Journal	X		X			X
7	Rivera	2004	Journal	X		X			X
8	Labuschagne & Brent	2005	Journal		X	X	X	X	X
9	Jung	2006	Journal			X			X
10	Mazouz et al.	2008	Journal		X		X	X	X
11	Olsen & Fenhann	2008	Journal			X		X	X
12	Van Donk & Molly	2008	Journal		X				
13	Wang et al.	2009	Journal		X		X		
14	Kujala et al.	2010	Journal		X				
15	Ball & Craig	2010	Journal	X		X		X	X
16	Long	2010	Journal		X				
17	Rangarajan et al.	2012	Journal		X	X	X	X	X
18	Wang & Mao	2012	Conference Proceeding		X				
19	Quin et al.	2012	Journal		X	X	X	X	X
20	Halawa et al.	2013	Journal		X		X		
21	Morimoto	2013	Journal		X			X	X
22	Ljung et al.	2013	Conference Proceeding		X				
23	Gudiene et al	2013	Conference Proceeding		X				
24	Glover et al.	2014	Journal	X		X	X	X	X
25	Clarke	2014	Journal		X		X		
26	Kovacic et al.	2014	Conference Proceeding		X				
27	Shin et al.	2015	Journal	X				X	
28	Mentis	2015	Journal		X		X	X	X
29	Seay	2015	Journal			X	X	X	X
30	Svejvig & Anderson	2015	Journal	X	X				
31	Bresnen	2016	Journal	X	X				
32	Parga-Dans et al.	2016	Journal	X		X		X	
33	Aarsrth et al.	2016	Journal		X	X	X	X	X
34	Zhang et al.	2016	Journal		X		X		X
35	Vigneshwari et al.	2016	Conference Proceeding			X	X		
36	Niknazar & Bourgault	2017	Journal		X				
37	Silvius et al.	2017	Journal		X	X			
	Total			**9**	**26**	**14**	**14**	**15**	**16**

3. RESULTS AND DISCUSSION

The search using the aforementioned keywords initially yielded forty-three articles. Examining the reference sections of these articles provided an additional six articles. After reviewing the articles to determine relevance, twelve papers were deemed irrelevant and thus were excluded, resulting in a total of thirty-seven articles (Table 1). The excluded articles included papers discussing irrelevant aspects of institutional theory with no mention of institutional isomorphisms, as well as articles discussing irrelevant aspects of project management. Ultimately, thirty-two peer-reviewed journal articles and five conference proceedings published between 1983 and 2017 were considered for this review.

Table 2 provides a summary of the topic coverage in the literature by expressing the percent of the overall literature considered that discussed a specific topic. The summary shows that project management/typology is the most discussed topic in the literature with 70% coverage. This suggests that the project management/typology topic is a more robust field which has been extensively researched compared to the other fields considered in this study. On the other hand, institutional isomorphisms represent only 24% of the literature, which indicates that institutional isomorphisms is a less explored field that has yet to be fully studied. The relatively similar percent coverage of sustainability and the economic, social, and environmental aspects is expected since, as mentioned previously, the three aspects are considered the basis of sustainability and thus, are often associated with it. Identifying the link between institutional isomorphisms and sustainable project typologies provide an opportunity to expand the research in both fields.

Table 2. Summary of Topic Coverage in Literature.

Topic Discussed	Number	Percentage
Institutional isomorphisms	9	24%
Project Management/Typology	26	70%
Sustainability	14	38%
Economic Aspects	14	38%
Social Aspects	15	41%
Environmental Aspects	16	43%

Further analysis by considering the literature timeline (Figure 1) also shows the research trends in each of the six research groups (Figure 2). The trends show an increase in research related to all six research groups at different levels over time. Project management/typology shows the most increase in recent years followed the economic aspects. Institutional isomorphisms research shows an incremental, but steady, increase since they were first introduced in 1983. The amount of sustainability literature found also showed incremental increase over time. It is worth noting that although the economic, social, and environmental aspects are considered the basis of sustainability, the amount of research in these aspects mostly exceeded the amount of sustainability research found. One reason for that is the fact that these aspects are not exclusively related to sustainability. For example, projects often use economic, social, and environmental factors to assess the success of projects.

3.1. PROJECT MANAGEMENT/TYPOLOGY LITERATURE

As part of the project management literature, project typologies are created as tools to aid decision makers and managers in the decision-making process early in the planning phase. Niknazar and Bourgault (2017) defined project typology as interrelated sets of ideal

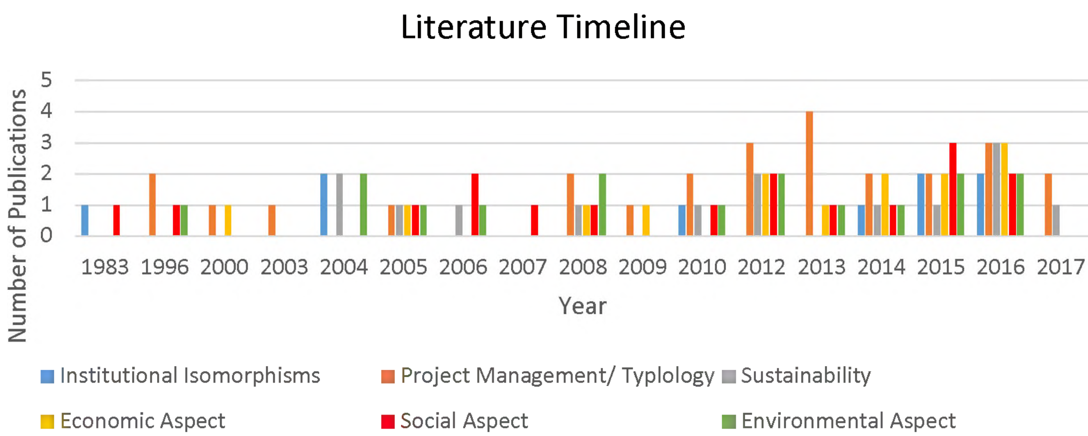

Figure 1. Literature Timeline Graph.

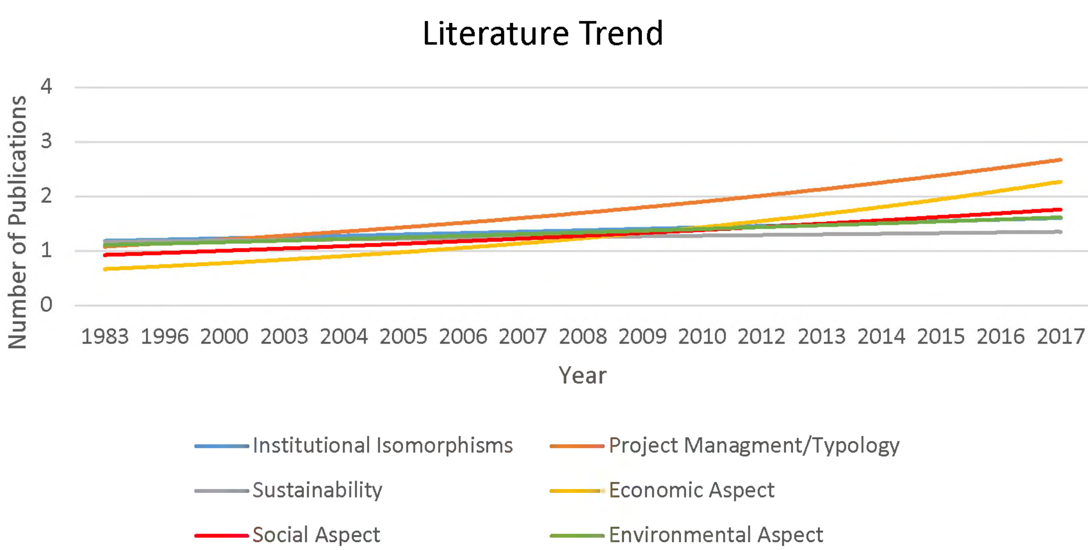

Figure 2. Research Trend Graph.

project types that are based on a specific concept that explain a dependent outcome. The degree to which a project fits any of the ideal types is believed to determine the outcome. They also added that the degree of fit of a project to the typology doesn't depend on one attribute but on the relationship between several attributes.

There have been several project typologies that use several different characteristics or attributes to classify projects each created with its own purpose. For example, Griffin and Page (1996) developed a project typology based on a project's "newness to the firm" and "newness to the market" in an effort to determine success at both the project level and program level. Shenhar and Dvir (1996) also created a project typology based on two factors: system scope and technological uncertainty in an effort to help managers determine the most effective management style. They later further developed their typology to include novelty, technology, complexity, and pace (Shenhar & Dvir, 2007). Another example is a typology created by Mazouz, Facal, and Viola (2008) for public-private partnership (PPP) projects. They presented a typology based on a project's ability to generate other projects and its proximity to the target in an effort to determine the management challenges, risks, and issues with PPP projects. Their typology was further developed by Rangarajan, Long, Ziemer, and Lewis (2012) to include sustainable projects by adding "quality of life" as a third factor in an effort to consider the sustainability of such projects. Several other typologies exist that also consider different factors to classify projects (Kujala, Artto, Aaltonen, & Turkulainen, 2010; Stock & Tatikonda, 2000).

Several key project characteristics can be identified by exploring the project management/typology literature. The level of change is one characteristic that is commonly used in classifying projects (Shenhar & Dvir, 1996). Project uncertainty, or more specifically technological uncertainty, is another characteristic used to classify projects (Shenhar & Dvir, 1996; Stock & Tatikonda, 2000). Stock and Tatikonda (2000) explored the level of technology information transfer between the provider of the technology and the recipient of that technology, as well as emphasized on the prior experience and skill levels required based on the different levels of uncertainty. Mentis (2015) also discussed project uncertainty and how it differs from the concept of risk. He also presented several examples of both internal and external project uncertainties.

3.2. INSTITUTIONAL ISOMORPHISMS LITERATURE

DiMaggio and Powell (1983) first introduced the concept of institutional isomorphisms in an effort to explain the external institutional influences on organizations. They defined three types of isomorphic influences: coercive, normative, and memetic. Coercive influences reflect those influences that are exerted from a possession of power such as rules and regulations enforced by the government (Kondra & Hurst, 2009). Normative influences describe those influences that are exerted by professionalization and academic institutions to adapt new processes, rules, or legitimate practices (Glover et al., 2014). Memetic influences reflect influences that are exerted on organizations to be viewed as legitimate and show competitiveness by mimicking other successful organizations within the same industry (Kondra & Hurst, 2009).

Since they were first introduced, institutional isomorphisms have been used by researchers to describe the impact of institutionalization on a variety of organizations and industries. For example, Shin, Lee, and Kim (2015) used institutional isomorphisms to identify the factors that create prosocial behavior on social networking services (SNS) by manipulating the different types of isomorphisms in a controlled experiment. Parga-Dans, Barreiro, and Varela-Pousa (2016) also used institutional isomorphisms to explain the influence of institutionalization on the Spanish contract archaeology industry, and how institutionalization influenced both embeddedness and change in the Spanish archaeology industry. Researchers also discussed the effects of institutional isomorphisms on sustainability and sustainable development in a variety of industries. This research will be discussed with more detail in the next subsection of the paper.

3.3. SUSTIANABILITY LITERATURE

Several researchers attempted to provide a definition for sustainability through their research. The definition that seemed to be the most commonly used by researchers is the one presented by the UN World Commission on Environment and Development stating that sustainability "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Aarseth, Ahola, Aaltonen, Økland, & Andersen, 2016; Labuschagne & Brent, 2005; Seay, 2015; World Commission on & Development, 1987). Most of the sustainability and sustainability development research found in this review focused on the economic, social, and environmental aspects and impacts of sustainability.

Part of the project management/typology research has been focused on sustainability and sustainable development in recent years. By examining the papers selected for this review, several sustainability project management/typology papers can be found. For example, Labuschagne and Brent (2005) developed a framework to incorporate sustainability and sustainable practices into the project management life cycle, as well as a framework to assess the sustainability of operational activities in projects. Qin et al. (2012) also created a framework to evaluate the effectiveness of alternative energy strategies. They provided a hierarchical structure of effects as a quantitative method to evaluate the social, economic, and environmental effects of sustainable projects. They also provided a hierarchical structure of costs to present all the major costs associated with alternative energy projects and the interrelationships between these major costs. The project management field also includes creating sustainable projects typologies (Rangarajan et al., 2012).

The institutional isomorphisms literature also focused on sustainability, especially how institutionalization can promote sustainability and sustainable development. Looking at the literature considered in this review, several papers discuss the connection between institutional isomorphisms and sustainability in a variety of fields. For example, Rivera (2004) discussed how institutional isomorphisms affected proactive sustainable behavior in hotel facilities participating in a voluntary environmental program in Costa Rica. He found that institutional isomorphisms helped in promoting beyond-compliance sustainable behavior by the participating hotels. Glover et al. (2014) used institutional theory to identify the influence of supermarkets on the development of sustainable practices in the dairy supply chains. They concluded that supermarkets are considered in a position of power in the dairy supply chain. They also found that although some smaller organizations across the supply chain wanted to adapt sustainable practices, supermarkets exerted pressures on those organizations to follow a more cost reducing strategies. These two articles provide an example on how significant the influence of institutional pressures is on the implementation of sustainability and sustainable development.

3.4. CROSS-EXAMINATION OF PRIMARY GROUPS LITERATURE

A cross-examination of the primary research groups is done in an effort to identify gaps in the research (Table 3). The summary shows that five project management/typology papers discuss sustainability and sustainable development, representing 14% of total literature found. However, only one out the five papers present a sustainable project typology (Rangarajan et al., 2012), while the other four papers either discuss various aspects of project management and their relationship to sustainability, or present case studies where specific sustainable projects are presented. This shows that although researchers developed a wide range of project typologies (Niknazar & Bourgault, 2017), there has been little focus on typologies focusing on sustainable projects and the economic, social, and environmental impacts of these projects.

The summary also shows that the institutional isomorphism literature also discusses sustainability in five out of the nine institutional isomorphisms literature considered in this review, representing 14% of total literature found. This literature mainly focuses on the effects of institutional isomorphisms on either promoting or hindering sustainability and sustainable practices in a variety of fields. The literature reflects the dominant effects of institutionalization on the process of sustainability and how institutionalization can help promote sustainability or hold it back.

The final stage of the cross- examination of the literature shows that only 2 papers discuss the relationship between institutional isomorphisms and project management/typology. Bresnen (2016) attempted to discuss the impact of institutionalization on the project management discipline, but failed to discuss the impact of institutional isomorphisms on projects. Svejvig and Andersen (2015) through their review of the project management literature state that the analysis of project organizations failed to address the effects of the institutional environments, and how institutionalization can significantly affect projects. These two papers indicate that the effects of institutionalization, and more specifically institutional isomorphisms, has been neglected by the project management literature despite the great impact of these effects on project management.

Table 3. Summary of Cross-Examination of Primary Research Groups.

Topics Discussed	Number	Percentage
Institutional Isomorphisms and PM/Typology	2	5%
Inst. Isomorphisms and Sustainability	5	14%
PM/Typology and Sustainability	5	14%

4. CONCLUSION

Every project can be affected by a variety of external factors, and that includes sustainable projects. Understanding these factors is crucial to the decision-making process. Project management typologies are created to help decision makers and project managers in the decision-making process by categorizing projects based on different factors and characteristics. This research focused on reviewing literature from the project management/typology, institutional isomorphisms, and sustainability to find gaps and trends in the research concerned with the effects of institutionalization on sustainable projects.

This paper used an integrated literature review and the State-of-the-Art Matrix (SAM) analysis to examine literature gathered in six research groups. literature from the fields of institutional isomorphisms, project management/ typology, sustainability, economic aspects, social aspects, and environmental aspects was gathered and analyzed using quantitative and qualitative analysis. A limitation of this paper is that a more detailed statistical analysis could not be conducted due to the limited number of articles found. Moreover, the present work is not meant to be comprehensive and thus, the research may not represent a comprehensive analysis of the literature from the six presented groups. Instead, this research is meant to provide a holistic view of the literature presented in each group and highlight any trends and gaps in the literature.

The review in this paper suggests that, while all six research fields would benefit from further research, some areas fall behind the rest presenting research gaps that could be filled. These gaps are especially evident when looking at the intersection of two or more of the suggested research groups. One area that could certainly benefit from further research is sustainable project typologies. The literature review suggests that there is a lack of research in developing project typologies that especially consider sustainable projects and the economic, social, and environmental impacts of these projects. Developing such typologies serves as a tool to help project managers and decision makers better develop sustainable projects, especially with the increased focus on sustainability and the development of sustainable projects in recent years.

Another gap emerges when exploring the relationship between project management and the institutional environment. This review indicates that the impact of institutionalization on project management and projects has been greatly ignored. More specifically, the project management research failed to address the effects of the coercive, normative, and memetic isomorphisms on projects including those related to sustainability and sustainable development. Understating how these institutional isomorphisms affect project characteristics such as level of change, uncertainty level, project team skills and experience, and level of technological information exchange is invaluable to help project managers make better decisions in different institutional environments.

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II. EXPLORING THE RELATIONSHIP BETWEEN SUSTAINABLE PROJECTS AND INSTITUTIONAL ISOMORPHISMS: A PROJECT TYPOLOGY

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ABSTRACT

With the increase in awareness about the wide range of issues and adverse effects associated with the use of conventional energy sources came an increase in project management research related to sustainability and sustainable development. Part of that research is devoted to the development of sustainable project typologies that classify projects based on a variety of external factors that can significantly impact these projects. This research focuses on developing a sustainable project typology that classifies sustainable projects based on the external institutional influences. The typology explores the influence of the coercive, normative, and mimetic institutional isomorphisms on the expected level of change, level of uncertainty, project team skills and experience levels, and the level of technology information exchange in sustainable projects. Two case studies are presented to demonstrate the use of the typology to classify sustainable projects based on the external institutional influences.

Keywords: sustainable projects; project typology; institutional isomorphisms; monte carlo.

1. INTRODUCTION

This research focuses on developing a sustainable project typology that considers the impact of institutionalization on sustainable projects and how different institutional drivers can affect projects and project characteristics, as well as providing indicators that are used to measure the economic, social, and environmental impact of these projects. Developing such a typology would be extremely beneficial to engineering managers and decision makers in the early stages of the planning phase. The typology would essentially provide a guideline to engineering managers and decision makers in making objective judgements about a sustainable project based on what institutional driver is influencing the project and identify the different areas that require attention in the early planning phase.

A significant portion of the project management literature is devoted to the concept of sustainability and sustainable development, showing a significant increase over the past 10 years (Silvius, Kampinga, Paniagua, & Mooi, 2017). Part of that research is devoted to developing project typologies in which projects are classified into sets of ideal types where the degree to which a project fits any of these ideal types can provide an indication of the outcome of the project (Niknazar & Bourgault, 2017). Given the fact that all projects could be affected by a wide variety of external forces (Musa, Amirudin, Sofield, & Musa, 2015), it is important to explore how these factors can impact different project characteristics.

One of the external factors that can potentially influence sustainable projects in a significant way is the concept of institutionalization. Institutional theory provides an insight into how institutional influences in a society can provide legitimacy to organizational practices based on culture, social values, and regulations in an institutional environment (Glover, Champion, Daniels, & Dainty, 2014). It suggests that groups and organizations seek legitimacy by conforming to external institutional influences best known as institutional isomorphisms (DiMaggio & Powell, 1983). This indicates that business decisions are not always made based solely on the economic benefits, but instead may be based on what is viewed as favorable or acceptable in an institutional environment (Rivera, 2004).

It is important to note that institutional theory mainly focuses on the organizational perspective as a whole in an institutional environment. However, the modern theory of project management describes projects as temporary organizations that are essentially vulnerable to the same external factors as regular organizations located under the same environment (Silvius et al., 2017; Svejvig & Andersen, 2015; Turner & Müller, 2003). Following this theory of project management, it is then crucial to understand the effects of institutionalization on sustainable projects.

Developing a sustainable project typology based on external institutional isomorphisms can help answer the following two primary questions in this research:

- What is the relationship between institutionalization and sustainable projects?
- How can institutional isomorphisms be used to create a project typology?

Two case studies presenting sustainable projects are included in this research to demonstrate how the developed typology model can be used to classify projects based on the institutional isomorphic influences. Qualitative project data in these case studies is collected and analyzed to determine how the projects are classified. Quantitative data is also collected to determine the economic performance of these sustainable projects.

This article is organized into six sections. After the introduction, the second section provides a literature review of relevant literature and major literature gaps. The third section presents the sustainable project typology and explains the various aspects of the typology. The fourth section presents the two case studies used to demonstrate how the typology can pe applied, as well as the data collection and analysis methodologies. In the fifth section, a discussion of the qualitative and quantitative case study data used to classify the case study projects is provided. The last section presents the conclusion and limitations of this article.

2. LITERATURE REVIEW

In an effort to acquire the necessary knowledge to develop a sustainable project typology that is based on the external influences of institutionalization, this research reviews literature related to project typologies, sustainability or sustainable development, and institutional isomorphisms in institutional theory. Exploring the literature in these three areas as well as literature with different combinations of these areas would provide the necessary basis in developing the typology.

Project management typologies are important tools found in the project management literature that are often used by project managers and decision makers in the decision-making process (Alyamani & Long, 2018). They provide important realistic predictions about several project characteristics early in the planning phase, allowing engineering managers and decision makers to be better prepared thus, increasing the project success rate. The project management literature is filled with project typologies each using a different combination of characteristics such as newness to market and newness to firm (Griffin & Page, 1996), system scope and technological uncertainty (Shenhar & Dvir, 1996), novelty, technology, complexity, and pace (Shenhar & Dvir, 2007), ability to generate other projects and the proximity to target (Mazouz, Facal, & Viola, 2008), and ability to generate future projects, the proximity to the target customers, and quality of life (Rangarajan, Long, Ziemer, & Lewis, 2012).

Another set of the most commonly used characteristics found in the project typology literature include the level of change (Shenhar & Dvir, 1996), project uncertainty, or more specifically technological uncertainty (Shenhar & Dvir, 1996, 2007; Stock & Tatikonda, 2000), the level of technological information transfer between the provider of the technology and the recipient of the technology (Stock & Tatikonda, 2000), and the level of skill and experience required in different types of projects to ensure project success (Shenhar & Dvir, 1996; Stock & Tatikonda, 2000).

The concept of institutional isomorphisms was first introduced by DiMaggio and Powell (1983) in an effort to identify the different types of external institutional influences that shape organizations. They identified three types of institutional isomorphisms: coercive, normative, and mimetic. The coercive isomorphism represents the influences that are exerted from a position of power by putting pressures on organizations to follow a certain behavior (Rivera, 2004). The normative isomorphism represents the pressures that are exerted through professionalization and academic institutions to integrate new rules, regulations, or practices in an effort to seek legitimacy in a social environment (Glover et al., 2014). Mimetic isomorphism represents pressures that organizations face when seeking legitimacy and competitiveness by mimicking other successful organizations within the same industry (Rivera, 2004).

Institutional isomorphisms have proven to be an effective tool in identifying the impact of institutionalization on organizations and thus, have been used by many researchers in a wide variety of fields and industries. Kondra and Hurst (2009) studied the impact of institutional isomorphisms on organizational culture. Shin, Lee, and Kim (2015) studied how institutional isomorphisms can be used to promote prosocial behavior in social networking services (SNS). Parga-Dans, Barreiro, and Varela-Pousa (2016) used institutional isomorphisms as well to identify the impact of institutionalization on the Spanish contract archaeology industry, and how the industry evolved under these institutional pressures.

Researchers provided a wide range of definitions for sustainability in the literature, none more common than the one presented by UN World Commission on Environment and Development stating that sustainability is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”(Aarseth, Ahola, Aaltonen, Økland, & Andersen, 2016; World Commission on & Development, 1987). The topic of sustainability is usually divided in the literature into three major parts: economic, social, and environmental. These three parts represent the bottom line of sustainability and are referred to as “the three pillars of sustainability” (Alyamani & Long, 2018; Seay, 2015).

The project management literature has shown a greater focus on sustainability and sustainable development in recent years (Silvius et al., 2017). Labuschagne and Brent (2005) presented a project management framework that effectively addresses the three pillars of sustainability in an effort to incorporate the principals of sustainable development into the project management life cycle. Qin, Grasman, Long, Lin, and Thomas (2012) developed a framework that summarizes the major effects associated with using different types of alternative energy. It is intended as an evaluation of different alternative energy strategies to help engineering managers and decision makers make better decisions in sustainable development. Rangarajan et al. (2012) developed an economic development typology that focuses on sustainable rural development by considering the economic, social, and environmental impacts at early stages of project planning.

Another field that is also contributing to the concept of sustainability is institutional theory. Several institutional theory researches are exploring how institutional isomorphisms can affect the implementation of sustainability and sustainable practices in organizations and industries. Glover et al. (2014) implemented the concept of institutional isomorphisms to explore the influence of supermarkets on the development of sustainable practices in the dairy supply chain industry. Rivera (2004) also used institutional isomorphisms to explore the impact of institutional forces on sustainable development in the Costa Rican hotel industry. Other additional examples exist on the effects of institutional influences on sustainability and sustainable practices (Ball & Craig, 2010; Lounsbury, 1997).

When cross-examining literature from the three research fields, some patterns reveal gaps in the literature. Although the project management literature does in part focus on sustainability and sustainable development, there is little research that is dedicated to developing sustainable project typologies and their impact on the pillars of sustainability (Alyamani & Long, 2018). The institutional isomorphism literature mainly focuses on the effects of institutional forces on sustainable development and practices. However, there seems to be little research that is dedicated to the effects of institutional forces on sustainable projects (Svejvig & Andersen, 2015). Bresnen (2016) explored the effects of institutionalization on the project management discipline and how it can shape the project management discipline. However, he did not go beyond that to explain the effects of institutional isomorphisms on projects.

3. METHODOLOGY

The typology model is divided into three different levels (Figure 1). The first level represents the coercive, normative, and mimetic institutional isomorphisms that can influence sustainable projects. The second level represents the chosen sustainable project characteristics that can be affected by the external institutional influences. The third and final level represents the economic, social, and environmental factors that are commonly used to measure the impact of sustainable projects. By combining these three levels, a comprehensive evaluation can be performed to identify how the external institutional isomorphisms can influence the different sustainable project characteristics and measure the overall performance of these projects.

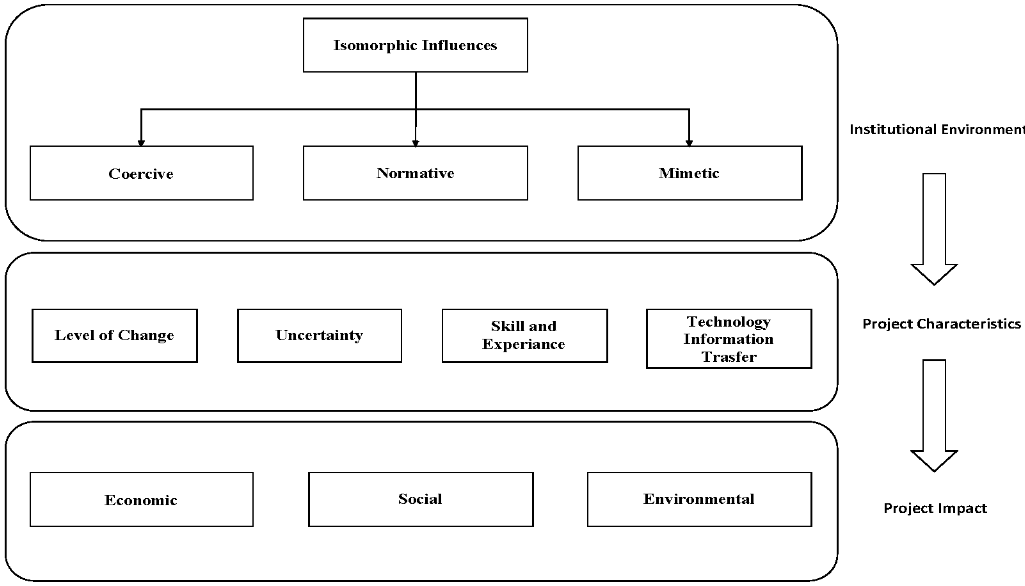

Figure 1. Isomorphic sustainable project typology model.

3.1. TYPOLOGY ELEMENTS

Institutional theory is used by researchers to identify and examine influences on organizational practices towards survival and improved legitimacy in a social environment (DiMaggio & Powell, 1983; Glover et al., 2014). The theory suggests that external social norms, values, and beliefs create standards of legitimacy to organizations which in turn, influence their management decisions and practices (Rivera, 2004). Through the modern theory of project management that identifies projects a temporary organization, these coercive, normative, and mimetic pressures can also be explored from the perspective of projects in general or, more specifically, sustainable projects (Alyamani & Long, 2018).

Coercive: in this typology, coercive pressures would represent the forced changes imposed on existing sustainable practices and technologies to comply with institutional norms and the regulatory environment. The most common example of such pressures would be a government-enforced change to existing regulations related to sustainability or sustainable development. These changes would force engineering managers and decision makers to adapt their projects to the new changes to avoid any legal repercussions. Coercive pressures are believed to be essential in promoting sustainability and sustainable practices (Glover et al., 2014).

Normative: in this typology, normative influences represent pressures that are exerted on sustainable projects through the norms of conduct in professional networks and academic institutions. These pressures involve integrating new processes, technologies, or sustainable practices in an effort to be viewed as being sustainable (Glover et al., 2014). An example of such pressure would be an organization undertaking a project to integrate a completely novel sustainable technology in an effort to be seen as a leader in implementing sustainable practices.

Mimetic: mimetic pressures in this typology would represent projects that copy other completed projects that are seen as being successful in an effort to replicate the same success the copied project accomplished, and gain the same legitimacy and competitiveness in the social environment (Aerts, Cormier, & Magnan, 2006). It is also done to reduce uncertainty and help predict the project outcome (Kondra & Hurst, 2009).

3.2. TYPOLOGY CHARACTERISTICS

As mentioned previously, the typology classifies projects based on the effects of the coercive, normative, and mimetic institutional isomorphisms. It explores these effects on four common project characteristics used in project typologies (Alyamani & Long, 2018). These characteristics are level of change, uncertainty level, project team skills and experience, and level of technological information exchange. These characteristics, among others, are explored in many other typologies in different combinations based on the purpose of the typologies. It is important to note that, as with all typologies, the levels suggested in this research are chosen ideal levels and may not necessarily represent real projects.

Level of change: This characteristic describes the degree of change in a project from known standards and established practices, processes, and technologies, which can also be referred to as the novelty of the project. Under coercive pressure, the level of change is considered as moderate since only some changes to the established practices, processes, and technologies are needed while the basis still exists. Normative pressures however would provide entirely new practices, processes, or technologies and thus would create higher levels of change. Finally, mimetic pressures would provide lower levels of change because one project would be almost entirely copying other projects by using established practices, processes, and technologies with no or minimal change.

Uncertainty: uncertainty is defined in the literature as negative events in projects for which both the consequence and probability of occurrence are unknown (Clarke, 2014; Mentis, 2015; Toma, Chiriţă, & Şarpe, 2012). In the typology presented in this research, uncertainty is another important factor in demonstrating the potential effects of institutional isomorphisms on sustainable projects. Under coercive pressures, the level of uncertainty is at a moderate range. It presents the uncertainties associated with the enforced changes on the established practices, processes, and technologies. Under normative pressures, the level of uncertainty is at the higher ranges. The higher level of uncertainty is associated with the higher level of change stemming from implementing entirely new practices, processes, or technologies (Stock & Tatikonda, 2000). On the other hand, the level of uncertainty is considered in the lower ranges under mimetic pressures since there are little to no changes to established practices, processes, and technologies used by the mimicked projects.

Skills and Experience: this characteristic describes the required level of skill and experience possessed by the project team to be able to carry out project tasks correctly and efficiently. It is concerned with matching the work force capabilities with the requirements of the projects. The higher the level of change and uncertainty in practices, processes, and technologies used, the higher the level of project team skill and experience required to successfully implement the project (Stock & Tatikonda, 2000). Based on that, under coercive pressures the level of skill and experience in a project team is considered in the moderate levels. Under normative pressures, the high levels of change associated with the high levels of uncertainty would require a highly skilled and experienced project team to be able to implement the entirely new practices, processes, or technologies successfully. Under mimetic pressures, the required level of project team skill and experience is in the lower levels.

Technological Information Exchange: this characteristic was presented by Stock and Tatikonda (2000). It describes the amount of interaction required between the supplier and the recipient to ensure the successful implementation of the supplied technology in the project. Ensuring that the right technology is correctly implemented in these projects is a major step in achieving the desired project goals. As the novelty and uncertainty of the used sustainable technology increases, the amount of interaction between the supplier of the technology and the recipient increases. Under coercive pressures, the level of interaction between the supplier and recipient of the technology is at moderate levels since the level of change and uncertainty are at medium levels. Under normative pressures, the level of interaction between the supplier and recipient is high since the level of change in the technology is high, which also results in higher uncertainties. Finally, under mimetic pressures, the interaction between the supplier and recipient of the sustainable technology is at lower levels and may sometimes be described as routine since the level of change and uncertainty are low. In this case well-established technologies are copied from other successful projects and used with little to no change.

3.3. PROJECT IMPACT

The selection process of sustainable projects requires a detailed analysis of several aspects of the different project options and identifying the project with the best possible outcome (Rangarajan et al., 2012). When evaluating sustainable projects, the evaluation does not only consider the economic return of the project but also includes social and environmental considerations. These three pillars of sustainability are an ideal way to determine the success of sustainable projects.

The environmental impact of sustainable projects can be categorized into air, land, and water as well as how the projects contribute to the conservation of existing natural resources in the surrounding environment. Indicators to measure such impacts include the reduction in Green House Gases (GHGs) caused by using renewable technologies instead of fossil fuels, the reduction of solid pollutants on land, and the reduction of both land and water waste. Sustainable projects can also have a positive social impact on employment either directly or indirectly, health, learning, and general welfare. Successful sustainable projects can also provide income-generating activities for project stakeholders. They can help support economic development by providing investment opportunities, providing new industrial activities, and reducing costs. Sustainable projects can also provide easy access to reliable energy sources with little to no negative effects on the environment.

Table 1 provides a more detailed explanation of some of the environmental, social, and economic benefits that can be attained through sustainable development projects. Table 1 is adapted and modified from Olsen and Fenhann (2008).

Table 1. Sustainability development dimensions and indicators.

Dimension	Criteria	Indicators
Environmental	Air	Reduction in Green House Gases (GHGs), suspended particulate matter, non-methane volatile organic compounds, dust, fly ash and odor.
	Land	Reduction of solid pollutants on land, reduction of waste, and improvement of the soil through the production and use of e.g. compost, manure nutrient and other fertilizers.
	Water	Reduction in water waste production, wastewater management, water savings, safe and reliable water distribution, purification/sterilization and cleaning of water.
	Conservation	Conservation of natural resources such as natural minerals, landscape, and biodiversity.
Social	Employment	Creation of new jobs and employment opportunities either directly through the projects or through spinoffs of the original projects.
	Health	Reduction of diseases caused by pollutants, climate change, and depletion of resources. Improvement of health conditions through activities such as construction of a hospital, running a health care center, and preservation of food.

Table 1. Sustainability development dimensions and indicators. (Cont.)

Social	Learning	Promote education and research regarding sustainable technologies and practices, construction of a school, running of educational programs, and site visits and tours.
	Welfare	Improving the local working and living conditions, poverty alleviation, and community upliftment, and income redistribution through e.g. increased municipal tax revenues.
Economic	Growth	Income generating activities for project stakeholders, support economic development by providing investment opportunities, provide new industrial activities, cost reduction, enhancing productivity, setting an example for other industries, and creation of business.
	Energy	Improved access, availability and quality of electricity and heating services such as coverage and reliability.
	Balance of payments (BoP)	Reduction in the use of foreign exchange through a reduction of imported fossil fuels in order to increase national economic independence.

Source: adapted and modified from Olsen and Fenhann (2008).

4. CASE STUDIES

In this section, two case studies are presented in an effort to demonstrate how the sustainable project typology can be used to classify sustainable projects based on the external institutional influences exerted on the project. The first case study is a solar photovoltaic (PV) energy project implemented on a private university campus in Riyadh, Saudi Arabia. The second case study is a solar village project on a public university campus in Missouri, USA. These projects are explored to determine the type of institutional pressures influencing the projects, and the impact of these pressures on the four project characteristics discussed above.

As it is extremely difficult to quantitatively measure the impact of the institutional environment, or more specifically the institutional isomorphisms, on sustainability and sustainable practices, a qualitative approach is traditionally used to gather data on the impact of these institutional pressures. In this research, a qualitative approach in the form of informal interviews was used to measure the impact of the coercive, normative, and memetic institutional isomorphisms on the two sustainable project case studies. The qualitative project data was collected through interviews with key people involved in the projects. For the first case study located in Saudi Arabia, the interview was conducted with the project manager directly overseeing the project. As for the second case study located in Missouri, the interview was conducted with the director of the solar villages and microgrids on campus who is also one of the people who the project team directly reported to and who was also directly involved in the project. These informal interviews followed a predetermined narrative in an effort to maximize the amount of relevant data gathered while reducing irrelevant data (Appendix A). The interview narrative focused on six different topics related to the projects. The interview included a description of the projects including their purpose and the type of technology used in these projects. The second topic of the interview covered the project background including the circumstances that led to the creation of these projects in an effort to determine the type of institutional pressures that influenced these projects. The remaining four topics of the interview cover how the projects compare to other similar projects (level of change), project uncertainties, the project teams, and the relationship between the project team and the sustainable technology suppliers.

The conversations with the interviewees were recorded and notes were also taken with permission from the interviewees. The recorded conversations and notes were then organized and analyzed in an effort to determine where each project fits in the isomorphic sustainable project typology. The member checking methodology was used where the analysis and conclusions from the interviews were then presented back to the interviewees for respondent validation (Creswell & Creswell, 2017).

In this research, the social and environmental impacts of the projects can be measured against the sustainable development criteria and indicators discussed in Table 1. Some of these social and environmental measures are qualitative in nature and are difficult to quantify with high a level of certainty. Due to the lack of available data, the social and environmental impacts of the case study projects will not be included in this research. Nevertheless, measuring the social and environmental impact of sustainable projects is crucial in identifying the overall benefits of these projects.

The net present value (NPV) and internal rate of return (IRR) are the primary methods used to evaluate the economic impact of the projects (Moynihan & Triantafillu, 2012). They are used to identify the income gathering activities for stakeholders by determining the economic viability of the projects. A project is considered economically viable when the NPV is greater than zero, and when the IRR is greater than a minimum return (Rangarajan et al., 2012). The NPV is defined as the current value of a project by taking into consideration all future and present cash flows and discounting them to the present time. NPV is defined mathematically in Equation (1)

$$NPV = -I_0 + \sum_{t=0}^{n} \frac{CF_t}{(1+i)^t} \tag{1}$$

where I_0 is the initial investment, n is the time horizon of the project, CF_t is the cash flow at time t, and i is the required interest rate of the project. The IRR is defined as the interest rate that makes the NPV equal to zero. IRR is defined mathematically as shown in Equation (2).

$$NPV = -I_0 + \sum_{t=0}^{n} \frac{CF_t}{(1+i)^t} = 0 \tag{2}$$

The results from Equations (1) and (2) should represent an accurate indication of the economic viability of the sustainable projects.

In an effort to determine the economic robustness of the sustainable projects in this research, the sensitivity of the different economic variables affecting the projects is considered. The Monte Carlo analysis is an effective and established technique to quantitatively measure the economic sensitivity of a project to changes in input variables that stem from uncertainty (Gu et al., 2018). In a Monte Carlo simulation, a calculation is performed thousands of times where at each iteration, a different set of input variables is chosen randomly from a pre-defined distribution. In the case where the distribution for a specific input variable is not known, a triangular distribution is recommended (Rangarajan et al., 2012). A triangular distribution is comprised of three points: A minimum, maximum, and mode which represents the most likely value of the variable. In this research, the Monte Carlo technique is deployed to calculate the possible NPV and IRR values of the projects based on five thousand iterations. The results are presented in histogram charts showing the possible NPV and IRR outputs, the frequency of occurrence of these outputs, and the probability of getting a favorable output.

4.1. CASE STUDY 1: PREPARATORY YEAR PROGRAM (PYP) BUILDING SOLAR PROJECT

The Preparatory Year Program building is a large structure located on a private university campus in Riyadh, Saudi Arabia. The building was constructed in 2017 to accommodate freshmen students as well faculty members and staff. It contains a large number of smart classrooms equipped with smart boards, computers, and a wide variety of technological equipment. It also holds a large number of offices, labs, two dining areas, and a large auditorium. The large number of technological equipment accompanied with the air conditioning and lighting systems in the building has led to high electricity costs for the PYP building compared to the other campus facilities, especially during the summertime.

Due to high electricity costs, the university decided to make use of the available solar resources to power the PYP building in an effort to reduce costs. Another reason for converting the PYP building to use solar energy is Saudi Arabia's Vision 2030, which promotes the use of renewable energy sources in an effort to shy away from relying on oil and other fossil fuels for energy production. With the country wide focus on the use of clean sustainable energy, a growing number of organizations in Saudi Arabia decided to take advantage of the almost constant sunny weather in the country by using solar energy to generate power, especially with the expected increase in the price of electricity from $0.05/kWh to around $0.11/kWh in the next 10 years. Following in the footsteps of these organizations, the university also made the decision to build a solar PV project to supply the PYP building's average annual electricity demand of 3.4 GW by using commercially available solar PV technology in Saudi Arabia.

The uncertainties surrounding the project were considered from the social, technical, and environmental perspectives. When considering the social uncertainties associated with the project, social acceptance was determined as a major issue that needed to be discussed. By considering the positive feedback on similar sustainable projects done by other organizations and the increased awareness on the importance of environmental sustainability in the country, it is expected the PYP building solar project would be widely accepted by both the university and surrounding communities. When considering the technical uncertainties related to the PYP project, two issues were considered and discussed. One issue was related to the possibility that the solar PV technology would be obsolete within the next 10 years. It was decided by the project management team that the probability of occurrence is very low considering the continuous decrease in the production costs of solar panels which would make it extremely difficult to overcome such technology especially with the increasing electricity prices in Saudi Arabia. The other issue was related to the location where the solar panels would be placed and the uncertainty around whether or not future construction on the university campus would obstruct the currently chosen locations. To avoid this issue, the university construction master plan was shared with the project team to help them choose the optimal locations to install the solar panels and reduce the effects of any future construction. When considering the environmental uncertainties, the major concern was related to the loss of sunlight due to cloud coverage or dust. However, the weather in Riyadh is known for the lack of clouds and strong and direct sunlight almost every day of the year. Nevertheless, the solar panels should have sufficient sunlight exposure even during cloudy weather or dust winds due to the strong and direct sun exposure in Riyadh. Moreover, planned cleaning of the solar panels will be performed every month as well as any emergency cleaning if needed after dust storms. In addition, these conclusions are also supported by the similar solar projects in Riyadh where the local weather did not pose an issue for these projects.

As mentioned previously, the project will be built and maintained by a local contractor specializing in solar energy projects. The contractor as well as project members from the university were all involved from the beginning of the project. The project team mainly consists of members from the contracted company with a project manager assigned from the university to oversee the progress of the project. In other words, the project team will mostly consist of project technicians who will handle the on-the-ground installation and maintenance as well as project manager to oversee the overall progress. The team was given access to the PYP building design blueprints in addition to the university construction masterplan previously mentioned to assess the layout and determine the optimal location to place the solar panels. The university also shared the building's electricity demand and bills over a six-month period to determine the required solar system type and capacity.

In order to determine the economic viability of the PYP building solar project, several cash flows are considered to calculate the NPV and IRR of the project (Table 2). The PYP building solar project has an initial investment of $3.31 million. The Operation and maintenance cost is $24,000 with an annual increase of 1.5% per year. By considering the electricity price per kWh, the expected increase in electricity price per year, and the PYP building's annual electricity demand, the project's savings per year can be calculated as a positive income to the project. The NPV and IRR of the project are calculated using a 7% interest rate and a project time horizon of 30 years. Applying the inputs from Table 2 to Equations (1) and (2) yields an NPV of $533,401 and an IRR of 8.27%.

Table 2. Financial analysis for the PYP building solar project.

Input	Value
Initial Investment	$3,318,165
Operation and Maintenance Cost in year 1	$24,000
Increase in O&M Cost/Year	1.5%
Electricity price/kWh in year 1	$0.05
Increase in Electricity price/Year	2%
Electricity Demand/Year	3,438,442 kWh
Project time horizon	30 years
Discount Rate	7%
NPV	$533,401
IRR	8.27%

The Monte Carlo simulation was performed using the Microsoft Excel software to determine the economic sensitivity of the project based on the input and output variables. A triangular distribution was used for the input variables listed in Table 3 along with each variable's minimum value, most likely value, and maximum value. The lower and upper limits were assumed based on inputs from the project interviewee.

Table 3. Monte Carlo PYP Project Input Variables.

Input Variables	Lower Limit (%)	Most Likely	Upper Limit (%)
Initial Investment	90	$3,318,165	120
Operation and Maintenance Cost in year 1	90	$24,000	110
Increase in O&M Cost/Year	90	1.50%	120
Increase in Electricity price/Year	85	2%	125
Electricity Demand/Year	90	3,438,442 kWh	105

Figure 2a,b show the two histograms representing the NPV and IRR results from the Monte Carlo simulations.

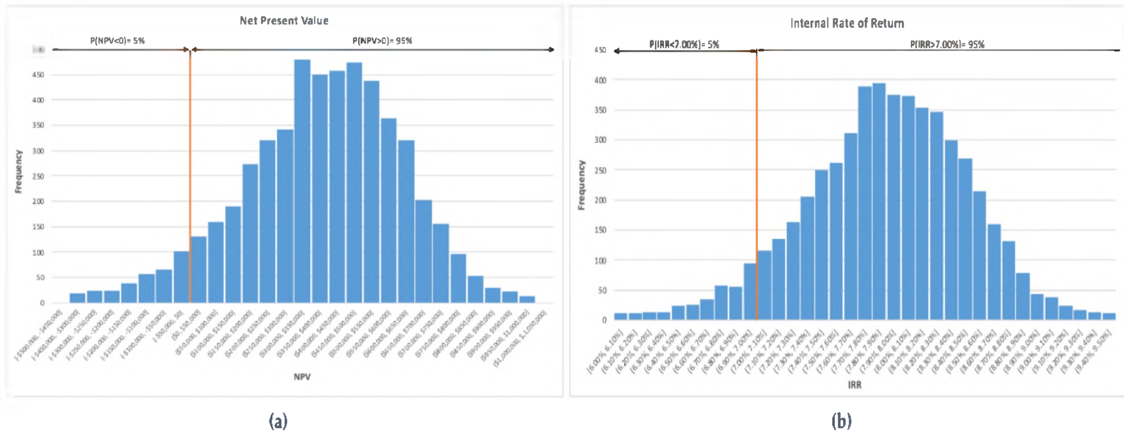

Figure 2. PYP Project Monte Carlo Result Distribution. (a) NPV Monte Carlo Result Distribution; (b) IRR Monte Carlo Result Distribution.

4.2. CASE STUDY 2: THE SOLAR HOUSE PROJECT

The Solar House Project is a renewable energy project located in a public university campus in Missouri, USA. The project consists of two student-designed solar houses that run on their own solar power. These houses were used to compete in the 2013 and 2015 editions of the Department of Energy (DOE) Solar Decathlon Competition. After the completion of each competition, the participating houses were then placed back on the university campus to serve as student housing facilities, and to facilitate different avenues of research in solar technology including energy production, sustainable living, and power sharing. The aim of the solar house project is to provide a window into what the neighborhoods of the future would look like with the use of sustainable solar technology.

The 2013 solar house is a 900 square foot box-shaped house. It is fitted with a 10.5 kW solar photovoltaic system that is designed for flat roofs by placing the solar panels at an inclined angle to optimize sunlight exposure. The power produced from the solar PV system is used to power all electrical systems in the house including heating, ventilation, lighting, and air conditioning. The 2015 solar house is a 1000 square foot house built using shipping containers as the main body with a tilted rooftop. The house is also fitted with a 10.5 kW solar photovoltaic system used to supply all electrical systems in the solar house. Each solar house is connected to its own Lead Acid battery system to store excess power for use during nighttime and during cloudy days. The Solar House Project can be compared to many existing solar projects including a solar project that was completed in 2009 on the same university campus. The Solar House Project was also built using commercially available solar PV technology supplied by local and national companies.

The technical, environmental, and social uncertainties surrounding the Solar House Project were studied in an effort to determine the impact of these uncertainties and develop appropriate mitigation plans. When considering the technical uncertainties surrounding the project, one major concern was related to the disposability and recyclability of the solar panels and batteries once they are out of service. To solve this issue, a recycling plan was set in an effort to find the best methods to recycle out of service equipment. The use of Lead Acid batteries is an integral part to this plan since lead acid batteries can already be easily recycled. Another major technical uncertainty is related to the effects of permanently placing the portable houses on campus after they were transferred back from the competition site. To solve this issue, data collected from the 2009 solar project was used to create a permanent placement plan in an effort to reduce any necessary design changes once the competition was over. When considering the environmental uncertainties, the major concern was related to supplying the houses with power during nighttime and frequent cloudy weather conditions in Missouri throughout the year. To avoid this issue, Lead Acid battery system were used to store enough power to run each house separately for several days. When considering social uncertainties surrounding the project, the major issue was related to social acceptance in addition to any project related ethical or privacy issues. As a result, several community outreach programs were launched reaching thousands of community members including students, businesses, local families, and industry professionals to explain what the project is and collect feedback. The feedback gathered showed an overwhelming sense of acceptance and support by the community for the project and the benefits of sustainable energy and sustainable development. In addition, positive feedback on previous solar projects can be a good indication that the demand for such projects is increasing within the local community.

The project was completely designed by students, with limited experience, under the supervision of expert faculty members on campus who also worked on the 2009 solar project. The faculty members only provided guidance into the basics of the project, leaving the students with the freedom to proceed with the project within the boundaries of the competition. The students also partially participated in the construction phase of the project working with the facilities department on campus. The solar panels and batteries used in the project were purchased from third-party contractors who also handled the installation under the supervision of the student design team. The project team provided the design and layout of the houses, the number of required solar panels, the required daily demand, and battery requirements and capacities. The contractors, in turn, provided and installed the appropriate solar systems and batteries to meet these requirements.

In order to determine the economic viability of the Solar House Project, several cash flows are considered to calculate the NPV and IRR of the project (Table 4). The project has a total initial investment of $860,000. It also has an average operating and maintenance cost of $1000 per year and an annual utility costs and fees of $674. Considering the project's average annual electricity generation of 17,754 kWh and local electricity costs, the savings in electricity is calculated to be $1580 per year. The project's NPV and IRR are calculated using a 7% interest rate and a 20-year project time horizon. The project has a calculated NPV of –860,994. The IRR cannot be calculated since, under these conditions, there is no interest rate at which the NPV would be equal to zero.

For further validation, the Monte Carlo method is used to determine the economic sensitivity of the project as well as the possible NPV and IRR output range. The input variables were defined using a triangular distribution (Table 5). Figure 3 shows the histogram representing the NPV results from the Monte Carlo simulation.

Table 4. Financial Analysis for the Solar House Project.

Input	**Value**
Initial Investment	
Solar House	$760,000
Microgrid (PV system, batteries...etc.)	$100,000
O&M Cost/Year	$1000
Utility Costs and Fees/Year	$674
Electricity Cost/kWh	$0.09
Electricity Demand/Year	17,754 KWh
Project time horizon	20
Discount Rate	7%

Table 5. Monte Carlo Solar House Project Input Variables.

Input	Lower Limit (%)	Most Likely	Upper Limit (%)
Initial Investment			
Solar House	40	$760,000	105
Microgrid (PV system, batteries...etc.)	80	$100,000	120
O&M Cost/Year	60	$1000	140
Utility Costs and Fees/Year	80	$674	120
Electricity Demand/Year	70	17,754 KWh	110

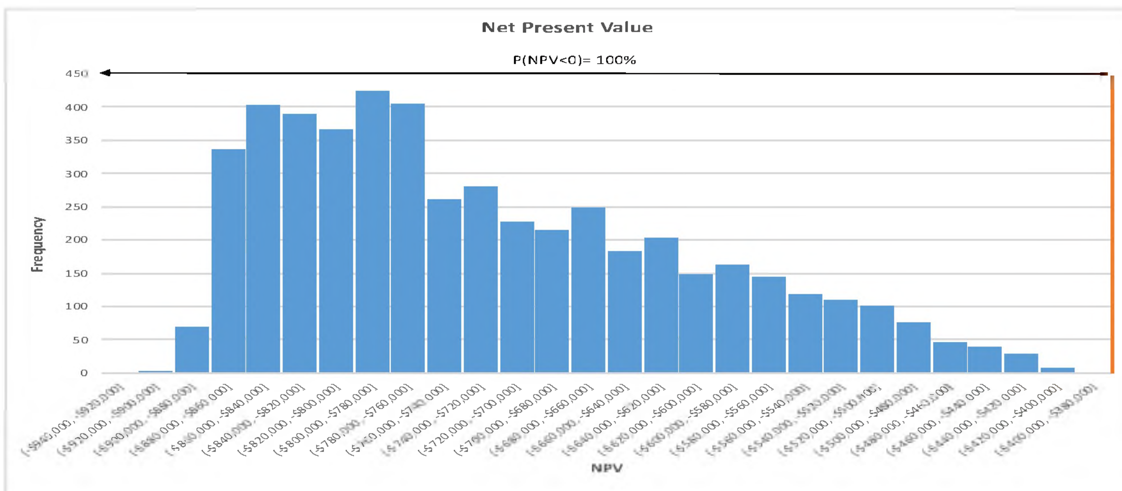

Figure 3. Solar House Project NPV Monte Carlo Result Distribution.

5. DISCUSSION

5.1. THE PYP BUILDING SOLAR PROJECT

The information collected in the PYP building Solar Project case study indicate that the project can be classified as mimetic. The growing number of solar projects in Riyadh, and the country in general, have been successful in implementing sustainable solar projects, which in turn exerted pressures on the university to mimic such success. By using the same standard and commercially available solar technology, the university can achieve its goal of reducing the high electricity costs associated with the PYP building. Furthermore, the positive feedback received by other solar projects in the area for following the country's Vision 2030 regarding the implementation of renewable practices created additional mimetic pressures on the university to replicate such practices. Mimicking such projects achieves the university's goal of reducing costs, as well as improves the legitimacy of the PYP Solar Project within local communities.

The technical, social, and environmental uncertainties surrounding the PYP building solar project can be categorized as relatively low. Considering the various similar projects in the area, these uncertainties can be mitigated or even eliminated by mimicking what has already been done in other solar projects. The project team's level of skill and experience varies with most of the team being certified technicians from the contractor's side with sufficient skill to install and maintain the equipment under the supervision of a project manager. The type and amount of information exchange between the university and the contractor is confined to the essential information required to build the project. This type of information exchange can be described as routine and does not include any required changes or modifications to a well-established and widely used solar technology.

Despite obtaining a favorable NPV and IRR results using the most likely input variables, the Monte Carlo simulation shows that such results are not guaranteed. Figure 2a shows that the project has a 95% probability of achieving an NPV greater than zero with a maximum and minimum NPVs of $986,853 and –$440,561 respectively. Similarly, Figure 2b shows that the project has a 95% probability of achieving an IRR greater than the minimum required rate of return of 7%, with a maximum and minimum IRRs of 9.48%

and 6.02% respectively. Moreover, the results in the two figures are skewed towards the positive side which indicate that the project is relatively economically robust and would be economically attractive to invest in.

5.2. THE SOLAR HOUSE PROJECT

The information presented in the Solar House Project case study indicate that the project can be classified as mimetic. Participating in the Solar Decathlon Competition exerts pressure on the project team to successfully implement the project. By using the same standard and commercially available solar technology as many other projects participating in the DOE Solar Decathlon Competition, as well as mimicking the previous successful solar projects on campus, the project team can replicate such success in the competition. The project also aims to replicate the success of the 2009 solar project by serving as a solar energy research facility on campus. Considering the overwhelmingly positive feedback received by other solar projects in the area, mimicking such projects achieves the university's goal of successfully competing in the DOE solar competition as well as improves the legitimacy of the Solar House Project as a prominent solar energy research facility in the area.

The Solar House Project uncertainties regarding the disposal and recycling of solar panels, house designs, weather conditions, and social acceptance, can be considered as low. Solutions and mitigation plans were set to deal with such uncertainties. What also helps in further decreasing the level of uncertainty is mimicking what has already been done with similar projects in the area. The project team level of skill and experience can be considered low. The students managed the project by the limited skills gained through their academic studies and with the guidance of faculty members. Considering that the project did not require any changes to already established processes or technologies, the technological information exchanged between the project team and the contractors supplying the technology is limited to the essential specifications required to select and install the appropriate technology. This type of technology information can be described as routine or standard with no changes to well established and widely used processes or technologies.

With an NPV of –$860,994 and a non-existing IRR, the project is economically not viable and should not be pursued from an economic standpoint. The Monte Carlo simulation confirmed the previous conclusion showing that the probability of the project yielding a positive NPV is equal to zero. The results from the simulation yielded a maximum NPV of –$406,859 and a mean of –$725,563. The simulation was also unable to calculate a valid IRR further confirming the previous findings. These findings support the narrative that not all management decisions are made based on economic benefits, but instead on what is viewed as favorable or acceptable in an institutional environment in an effort to improve the legitimacy of the project (Rivera, 2004). In this case, the purpose of the Solar House Project is not financial gain, but to replicate the non-monetary benefits associated with sustainability and sustainable development from the previous solar project on campus.

6. CONCLUSIONS AND LIMITATIONS OF THE STUDY

Although the project management literature does in part focus on sustainability and sustainable development, there is little research that is dedicated to developing sustainable project typologies. Moreover, there seems to be a lack of research that is dedicated to the effects of institutional environments on sustainable projects through the different institutional pressures known as institutional isomorphisms.

To help fill in these gaps, this research focuses on developing a sustainable project typology that explores the effects of the mimetic, coercive, and normative institutional isomorphisms on the project's level of change, uncertainty level, project team skills and experience, and level of technological information exchange. The typology model also describes some of the indicators commonly used to measure the economic, social, and environmental impacts of sustainable projects. Such a typology would be extremely beneficial as an objective decision-making tool for project managers and decision makers by providing them with a guideline to make better judgements about a sustainable project based on what institutional driver is influencing the project in the early stages of the planning phase.

In the typology model, coercive pressures represent forced changes imposed on existing sustainable practices to comply with institutional norms and the regulatory environment. These pressures would cause medium levels of change, uncertainty, skill and experience required, and technological information exchange since only some changes to the established practices, processes, and technologies are needed while the basis is still preserved. Normative isomorphism represents pressures that are exerted on sustainable projects through the norms of conduct in professional networks and academic institutions. These pressures would represent higher levels of change, uncertainty, skill and experience required, and technology information exchange since they would provide entirely new (novel) practices, processes, or technologies. Mimetic pressures in this typology represent projects that copy other completed projects that are seen as being successful in an effort to replicate that success, gain the same legitimacy, or reduce uncertainty. This type of pressure would represent low levels of change, uncertainty, skill and experience required, and technology information exchange since one project would be almost entirely copying other projects by using established practices, processes, and technologies with no or minimal changes.

The two case studies presented in this research demonstrate how the typology can be used to classify sustainable projects and provide an indication into the different project characteristics based on the type of institutional pressures exerted on the project early in the planning phase. The results indicate that both the PYP and Solar House projects are subject to mimetic pressures to replicate the success of other solar projects in their immediate institutional environment. These mimetic pressures led to a relatively low level of change, lower level of uncertainty, low levels of required project team skill and experience, and low-level technology information exchange. The case studies also included measuring the economic impact of the projects on immediate stakeholders by calculating the NPV and IRR of each project. Further analysis was done using Mote Carlo method to determine the economic robustness of the projects by considering the sensitivity of the different economic variables affecting the projects.

Limitations in this research include the small project sample size used to implement the typology, which led to only one type of projects being explored. A larger sample size could provide an opportunity to further validate the typology model as well as explore the other project types presented in the typology. Another limitation would be the lack of data required to fully explore the economic impact and measure the social and environmental impacts of the case study projects. Future research should focus on further testing the isomorphic sustainable project typology on a larger sample of projects. Additional testing of the typology could also provide an opportunity to further develop the model and possibly include additional project characteristics which can uncover additional relationships within the typology model that were not included in this research.

APPENDIX

INTERVIEW PROTOCOL

PROJECT AREAS OF INTEREST AND QUESTIONS

Description of Project

- Project Definition
- Project purpose
- Location
- Technology (Solar, wind, geothermal…etc.)

Project Background

- How the project came about?
- Inspiration behind the project (other similar projects? government regulations? new technology?)

Level of Change

- How this project compares to other similar projects? New or unique processes or technology?

Uncertainty level

- Technical? Social? Environmental?
- Any project specific uncertainties

Project Team Skill and Experience

- Who did the project team consist of? (Contractors?)
- Special experts hired or included in the project team
- Experience of project team members in dealing with similar projects.

Technical Information Exchange

- What type of information was shared with the renewable technology provider?
- Any special modification to the technology required? If so, what are the modifications?
- Relationship between project and technology provider (Purchasing only, purchase and install)

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III. 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.

2.1. 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].

$$\mu_A(x) = \begin{cases} 0 & x < l; \\ \dfrac{x-l}{m-l} & l \le x \le m; \\ \dfrac{u-x}{u-m} & m \le x \le u; \\ 0 & x > u. \end{cases} \qquad (1)$$

The geometric representation of the fuzzy number *A* from Equation (1) is shown in Figure 1, adapted from Lespier, Long [7] and Sun [26].

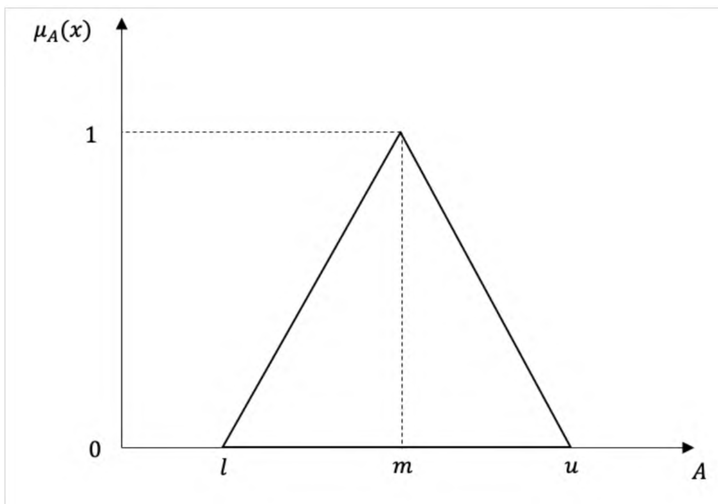

Figure 1. A triangular fuzzy number, *A* [7, 26]

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 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.

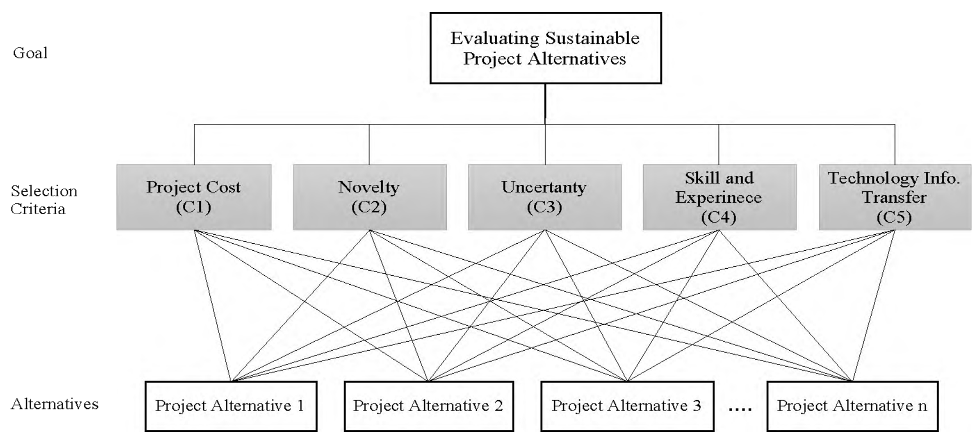

Figure 2. The hierarchy model for sustainable project selection.

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, Al Badi [20]
E2	Alyamani, Long [10]
E3	Sabaghi, Mascle [17]
E4	Shenhar and Dvir [29], Stock and Tatikonda [32]
E5	Chen, Kang [33]
E6	Wang, Song [28]
E7	Işik and Aladağ [34]
E8	Hatefi and Tamošaitienė [16]
E9	Luthra, Kumar [35]
E10	Solangi, Tan [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 [24]

Table 4. Pairwise comparison matrix using linguistic variables.

Criteria	Expert	C1	C2	C3	C4	C5
C1	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
	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
C2	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
	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
C3	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
	E5	F^{-1}	F	E	F^{-1}	F
	E6	F^{-1}	S	E	S	W^{-1}

Table 4. Pairwise comparison matrix using linguistic variables. (Cont.)

C3	**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
C4	**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}
	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
C5	**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
	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. 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.

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)
	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)
C5	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)
	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)

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 $G = \{g_1, g_2, g_3, \dots, g_n\}$ be a goal set. Each criterion is taken and the extent analysis for each goal g_i is performed respectively [24, 39]. Accordingly, the m extent value for each criterion is obtained as follows: $M_{g_i}^1$, $M_{g_i}^2$, $M_{g_i}^3$, …, $M_{g_i}^m$ where g_i $(i = 1,2,3, \dots, n)$ is the goal set and $M_{g_i}^j$ $(j = 1,2,3, \dots, m)$ 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).

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

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 fuzzy number process shown in Sun [26].

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

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) ⊕ (4.813, 6.883, 9.404) ⊕ (4.760, 6.457, 8.915) ⊕ (2.425, 3.205, 4.302) ⊕ (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) ⊗ (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 [26] and Lespier, Long [7], is used to obtain the best non-fuzzy priority (BNP) or crisp weights of the criteria.

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

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

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

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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IV. EVALUATING DECISION-MAKING IN SUSTAINABLE PROJECT SELECTION BETWEEN LITERATURE AND PRACTICE

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ABSTRACT

A robust project selection process is critical for the selection of sustainable projects that meet the needs of an organization or the community. There are multiple factors or criteria that can be considered in the selection of the appropriate sustainable project, but it can be challenging to find sufficient depth of expert opinion to perform a strong evaluation of these criteria. Several researchers have turned to the sustainable project literature as a source of expert opinion to evaluate the criteria used in sustainable project selection and rank them based on importance using different Multi-Criteria Decision-Making (MCDM) methodologies. However, using the literature as a source of expert opinion poses a different set of challenges and may not accurately represent the actual opinions of sustainable project Subject Matter Experts (SMEs) and practitioners. In this study, the Fuzzy Analytic Hierarchy Process (FAHP) methodology is used to determine the importance of project cost, project maturity, skill and experience, uncertainty, and technology information transfer as selection criteria using collected opinions from sustainable project academia experts and practitioners. The results are then compared with previous research that used the literature to rank these five criteria based on importance when selecting between multiple sustainable project alternatives. The results show that project cost is still considered the major driver of decision-making in sustainable project selection by both the literature and practice. However, unlike the literature-as-experts approach, SMEs prioritize skill and experience and technology information transfer over project maturity and uncertainty. Project managers and decision makers can use these findings to best prioritize the types of challenges that may occur depending on inputs for the FAHP analysis.

Keywords: Sustainable Projects, Project Selection, Fuzzy AHP, Multi-Criteria Decision-Making.

1. INTRODUCTION

This study focuses on comparing how the decision-making process that occurs during the selection between multiple sustainable project alternatives is approached in both the literature and practice. More specifically, this study aims to use the Fuzzy Analytic Hierarchy Process (FAHP) to rank project cost, project maturity, skill and experience, uncertainty, and technology information transfer based on importance as sustainable project selection criteria based on the collected opinions of Subject Matter Experts (SMEs) and practitioners. The results from this study are then evaluated against the results presented by Alyamani and Long [1] who used existing project management and sustainable development FAHP literature as an alternative source of expert opinion to rank these criteria in the context of sustainable projects. Doing so will provide an opportunity to compare how these five key selection criteria are prioritized in both literature and practices, as well as identify any variation in opinion between the two perspectives regarding how these selection criteria are prioritized in sustainable project selection.

An extremely useful approach to the sustainable project selection process is the use of an established list of key project selection criteria to identify the project that can best meet the needs of an organization or the community. Ranking these selection criteria based on importance can help project managers and decision makers differentiate between the multiple project alternatives and focus on important areas that may require additional attention. Several researches have utilized the FAHP as a Multi-Criteria Decision-Making (MCDM) methodology to rank multiple selection criteria in the context of sustainable projects while using the sustainable project literature as a source of expert opinion. For example, Hatefi and Tamošaitienė [2] used a combination of literature and experts' opinion to identify and rank sustainability development criteria used in the assessment of construction projects. Pérez, et al. [3] utilized the literature to rank the environmental performance criteria for maritime transportation system projects. Finally, the most relevant literature for the purpose of this study is presented by Alyamani and Long [1] who implemented FAHP to rank project cost, novelty, uncertainty, skill and experience, and technology information transfer based on importance as five key sustainable project selection criteria by utilizing the literature as expert opinion.

Even though the literature may be considered a reliable, inexpensive, and readily available source of expert opinion, it is still subject to the interpretations and judgments of the authors. This, in turn, can add an additional level of uncertainty that may not be included in the FAHP analysis [1]. Also, the conclusions that are drawn using the literature may not necessarily reflect what is being observed in practice. In addition, there seems to be little research that explore the variation of opinion regarding the relative importance of the selection criteria used in the research between literature and practice, especially variation in opinion that is related to project cost, project maturity, skill and experience, uncertainty, and technology information transfer.

The remainder of this study is organized as follows: Section 2 presents a description and the implementation of the fuzzy AHP methodology used in this research and the obtained results. Section 3 provides a discussion of the results from this study and a comparison of the criteria ranking between the literature and practice. Finally, Section 4 presents the conclusions drawn from this study, limitations, and opportunities for future work.

2. METHODOLOGY

Alyamani and Long [1] applied the FAHP methodology to rank project cost, novelty, skill and experience, uncertainty, and technology information transfer based on importance as selection criteria in sustainable project selection using the literature as a source of expert opinion. This study extends their work by applying the same FAHP methodology to rank the criteria by instead using collected opinions from sustainability and sustainable development experts and practitioners on the importance of these selection criteria when selecting between multiple sustainable project proposals. The results from this study are then compared to the results from their work in an effort to explore any variation of opinion between the SMEs and the literature regarding the importance of these selection criteria. Accordingly, the steps used to conduct the FAHP analysis in this study are as shown in Alyamani and Long [1] and Pérez, et al. [3].

The project selection process is considered a complex process due partly to the many interrelated variables that are considered in the selection process, the difficulty in providing exact decisions, and to the uncertainties in the subjective judgments and opinions of the decision makers who are making the selection between the project alternatives [4-6]. This in turn, makes the project selection process highly susceptible to the opinions of the decision makers leading to a large variety of different opinions and thus, disagreements on the importance of the project selection criteria used in making the selection [3, 7]. To overcome this issue, Fuzzy AHP has been developed to account for these uncertainties and inconsistency in subjective judgments [8]. FAHP applies the fuzzy set theory to convert vague and uncertain linguistic variables used by experts and decision makers into specific decision intervals that are more convenient to deal with [9]. Consequently, a single linguistic variable will instead be translated into a fuzzy number which consists of a range of numbers representing that variable [10]. It is generally considered more convenient to apply Triangular Fuzzy Numbers (TFNs) in FAHP due to their computational simplicity and ease in representing information related to the fuzzy variables. Accordingly, TFNs are expressed as three numbers (l, m, u) where l represents the lowest possible value, m represents the most likely value, and u represents upper or highest value. A mathematical representation of a fuzzy number M with $\mu_M(x)$ as its membership function is shown in Equation (1) as presented by Alyamani and Long [1].

$$\mu_M(x) = \begin{cases} 0 & x < l; \\ \dfrac{x-l}{m-l} & l \le x \le m; \\ \dfrac{u-x}{u-m} & m \le x \le u; \\ 0 & x > u. \end{cases} \tag{1}$$

As such, the geometric representation of the fuzzy number M according to Equation (1) is shown in Figure 1 as presented by Pérez, et al. [3] and Ballı and Korukoğlu [11].

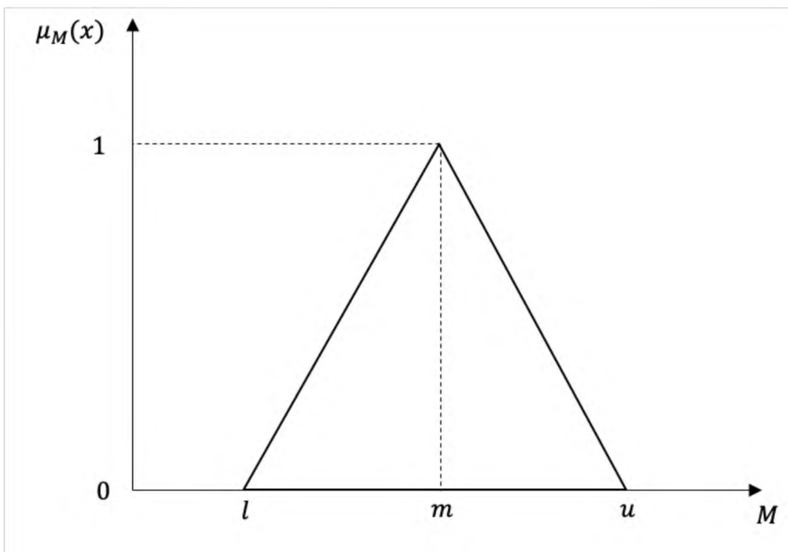

Figure 1. Geometric representation of TFN *M*.

2.1. SUSTAINABLE PROJECT SELECTION CRITERIA

The criteria chosen for this study extends the work of Alyamani and Long [1] in an effort to compare the weights of importance of five key sustainable project criteria when using the literature and practice as two different sources of expert opinion. They used the literature as a source of expert opinion to rank project cost, novelty, skill and experience, uncertainty, and technology information transfer while this study collects opinions from sustainable project academia experts and practitioners to rank these five criteria as they are described by Alyamani and Long [1] and Alyamani, et al. [12]. Accordingly, the criteria used in this study are described as follows:

- **Project Cost:** this criterion refers to the combined cost of the project through its overall life cycle. This includes the project's investment cost, operating and maintenance (O&M) cost, taxes and fees, labor, and any other subsequent annual costs associated with the project. Cost is considered one of the main drivers of sustainability and sustainable development. The reason for that is the current difficulty for sustainable energy sources to compete with conventional energy sources when it comes to cost in spite of the recent and continuous decrease in sustainable energy costs in recent years [13].
- **Project Maturity:** this criterion, referred to as "Novelty" by Alyamani and Long [1], describes the maturity and originality of the sustainable practices and technologies used in the sustainable project. An original and novel project that utilizes original and novel sustainable technologies and practices would pose a different level and type of challenges and would require a different set of resources as opposed to a more mature project [12]. In addition, project maturity is considered an indicator of how widespread and standardized the sustainable practices and technologies used in the project and whether or not there is still space for improvement for these sustainable practices and technologies [14].
- **Uncertainty:** this criterion describes the level of uncertainty surrounding each of the different sustainable project alternatives. Uncertainty, as defined in the literature,

describes negative events for which both the probability of occurrence and consequence cannot be quantified [15]. There are many potential sources of uncertainty associated with sustainable projects whether it is economic, technological, environmental, social, political, or any other source of uncertainty. Regardless of the source, the different uncertainties surrounding the project should be identified and appropriately addressed and mitigated to minimize their potential impact on the sustainable project [12].

- **Skill and Experience:** this criterion refers to the required level of skill and experience for the project team members to be able to effectively and efficiently undertake the different project tasks, as well as provide the required operating support and maintenance requirements to ensure project success [16]. Essentially, this criterion refers to matching the human resource capabilities and know-how with the sustainable project requirements [17].
- **Technology Information Transfer:** this criterion refers to the amount of technical information regarding the sustainable technology that needs to be shared between the party supplying the sustainable technology and the project team integrating the sustainable technology into the project. This information sharing or interaction between the supplier and recipient of the sustainable technology can vary from a basic purchase transaction with routine and standard information sharing all the way to a more collaborative or mutual development process that involves an intense and comprehensive information exchange to successfully integrate the sustainable technology into the project [12, 18].

An outline of these criteria and their notation as applied in the FAHP methodology in this study is shown in Table 1.

Table 1. Project selection criteria and notation.

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

The next step after defining these criteria is building the typical FAHP decision model representing the three different levels of decision making in project selection as shown in Figure 2 adapted and modified from Alyamani and Long [1]. The first level represents the overall goal of evaluating the different sustainable project alternatives. The second level represents the five key sustainable project criteria chosen in this study that will be ranked based on importance and used to evaluate the project alternatives. The third and final level of the decision tree outlines the different sustainable project alternatives that will be evaluated and selected from using these criteria.

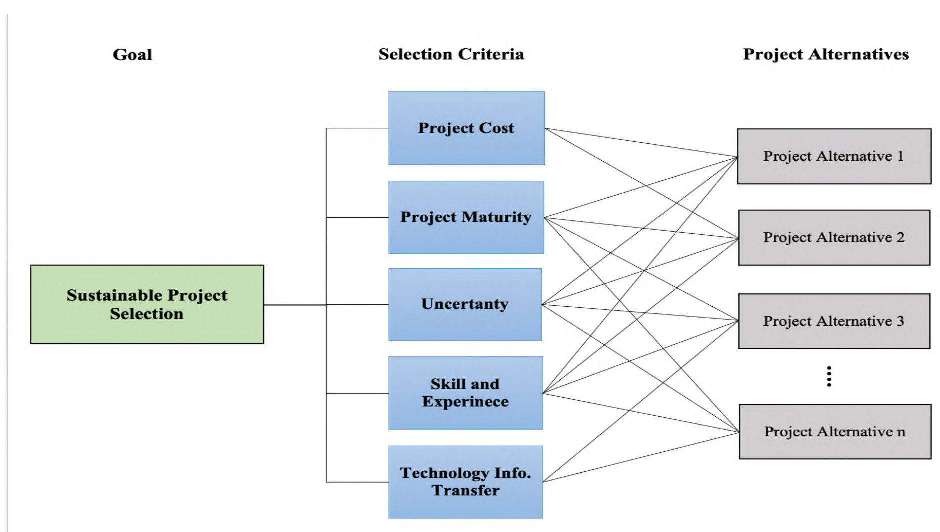

Figure 2. Sustainable project selection decision hierarchy. [1]

2.2. CALCULATING CRITERIA WEIGHTS USING FAHP

The next step after defining the sustainable project selection criteria, as previously outlined, is the collection of sustainability and sustainable development expert opinions on the relative importance of these criteria with respect to sustainable project selection. To do that, a survey tool was developed to gather subjective judgments from experts in academia and the industry. In this survey, an explanation of this study was presented to the experts detailing the purpose and objectives. The experts were also provided with a description of all five criteria as presented in this study in an effort to maintain a level of consistency between the different experts regarding criteria definitions. The experts were then asked to make a pairwise comparison between the different criteria with respect to the overall goal of evaluating sustainable project alternatives. They were asked to select one of the five linguistic variables shown in Table 2 based on their opinions when comparing one criterion versus another. The rating scale shown in Table 2 is adapted from Alyamani and Long [1].

Table 2. Linguistic scale and corresponding triangular fuzzy numbers (TFNs).

Linguistic Variable	**Triangular Fuzzy Number (TFN)**	**TFN Reciprocal**
Equal Importance (E)	(1, 1, 1)	(1, 1, 1)
Weak Importance (W)	(1, 3, 5)	(1/5, 1/3, 1)
Fair Importance (F)	(3, 5, 7)	(1/7, 1/5, 1/3)
Strong Importance (S)	(5, 7. 9)	(1/9, 1/7, 1/5)
Absolute Importance (A)	(7, 9, 11)	(1/11, 1/9, 1/7)

Source: adapted from Alyamani and Long [1]

The survey was originally sent to 25 sustainability and sustainable development experts including academic researchers, practitioners, or both to gather their opinions with regards to the relative importance of the five chosen criteria in sustainable project selection.

A total of 12 experts responded to the survey with two out of the 12 responses being deemed unusable due to major errors in taking the survey making them invalid. Ultimately, a total of 10 expert responses were included in this study. Out of the 10 experts whose opinions were included in this study, three served as academic researchers while seven served as both researchers and practitioners. The linguistic pairwise comparison from each of the 10 experts was then gathered to develop a combined pairwise comparison matrix consisting of all verbal expert ratings. The verbal ratings in that matrix were then converted into the triangular fuzzy numbers and TFN reciprocals following the scale shown in Table 2. Doing so led to the creation of the combined TFN pairwise comparison matrix shown in Table 3.

Table 3. Combined TFN pairwise comparison matrix.

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

Table 3. Combined TFN pairwise comparison matrix. (Cont.)

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

In order to calculate the criteria weights, the fuzzy pairwise comparisons from each of the 10 experts were first combined for each of the five criteria in this research. This is done using the geometric mean method introduced by Buckley (1985). This resulted in the geometric mean of the combined TFN pairwise comparison matrix shown in Table 4. This matrix basically shows the pairwise comparison of all five criteria that combines the opinions of all 10 experts used in this research shown in Table 3.

Table 4. Geometric mean of combined TFN pairwise comparison matrix.

Criteria	C1	C2	C3	C4	C5
C1	(1, 1, 1)	(3.3, 4.663, 6.089)	(1.969, 2.646, 3.813)	(2.088, 3.215, 4.296)	(2.141, 2.979, 3.849)
C2	(0.164, 0.214, 0.303)	(1, 1, 1)	(1.116, 1.764, 2.782)	(0.296, 0.387, 0.582)	(0.448, 0.689, 1.052)
C3	(0.262, 0.378, 0.508)	(0.359, 0.567, 0.896)	(1, 1, 1)	(0.379, 0.517, 0.775)	(0.563, 0.823, 1.359)
C4	(0.233, 0.311, 0.479)	(1.719, 2.581, 3.380)	(1.291, 1.935, 2.641)	(1, 1, 1)	(1.823, 2.881, 3.743)
C5	(0.260, 0.336, 0.467)	(0.950, 1.452, 2.233)	(0.736, 1.215, 1.778)	(0.267, 0.347, 0.549)	(1, 1, 1)

Using the fuzzy geometric mean pairwise comparisons shown in Table 4, the fuzzy wights of importance of the five criteria can be calculated using Chang's [20] extent analysis methodology as shown in Equations (2-5). In this methodology, the fuzzy criteria weights are referred to as the fuzzy synthetic extent. Let $G = \{g_1, g_2, g_3, \dots, g_i\}$ be a goal set. Then, the extent analysis for each goal g_i is calculated for each criterion respectively. Therefore, the m extent value for each criterion is calculated as $M_{g_i}^1$, $M_{g_i}^2$, $M_{g_i}^3$, …, $M_{g_i}^m$ where g_i $(i = 1,2,3, \dots, n)$ is the goal set, and $M_{g_i}^m$ $(j = 1,2,3, \dots, m)$ are the TFNs [1, 3]. Accordingly, the fuzzy synthetic extent (S_i) for each criterion i is defined as illustrated in Equation (2).

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

So as to calculate $\sum_{j=1}^{m} M_{g_i}^{j}$ from Equation (2), a fuzzy addition operation to the m extent [21] is employed on the matrix in Table 4 as shown in Equation (3) in which l represents the lowest possible value, m represents the most likely value, and u represents upper or highest value as explained earlier is this section.

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

Next, to calculate the $\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j}$ portion of Equation (2), another fuzzy addition operation is performed for $M_{g_i}^{m}$ $(j = 1,2,3, \ldots, m)$ 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, the inverse of the vector from Equation (4) is taken to calculate $\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{g_i}^{j}\right]^{-1}$ as shown in Equation (5).

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

By using the outlined Equations (2-5), as explained above, on the geometric means of the combined pairwise comparison matrix shown in Table 4, the fuzzy synthetic extent value (S_i) or the fuzzy relative importance weights for each of the five criteria is calculated leading to the fuzzy synthetic extent values shown in Table 5.

Table 5. Fuzzy relative weights of importance for sustainable project selection criteria.

Criteria	S_i - Low	S_i - Med	S_i - Upper
C1	0.225	0.416	0.751
C2	0.065	0.116	0.225
C3	0.055	0.094	0.179
C4	0.130	0.250	0.443
C5	0.069	0.125	0.238

Finally, calculating the relative wight of importance of the each of the five criteria is done by defuzzifying the fuzzy relative weights of importance shown in Table 5. This is done by employing the defuzzification method shown in Equation (6) as presented by Sun [21] and Alyamani and Long [1]. This defuzzification method results in obtaining the Best Non-Fuzzy Priority (BNP) or crisp weights of importance of the criteria shown in Table 6. These BNP values are then used to rank the importance of the five sustainable project selection criteria where the criterion with the highest weight is considered the most important while the criterion with the lowest weight is considered the least important.

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

Table 6. Sustainable project selection criteria crisp weights or importance.

Notation	Selection Criteria	BNP	Ranking
C1	Project Cost	0.464	1
C2	Project Maturity	0.136	4
C3	Uncertainty	0.109	5
C4	Skill and Experience	0.274	2
C5	Technology info. Transfer	0.144	3

3. DISCUSSION AND COMPARISON OF RESULTS

In this study, a fuzzy multi-criteria decision-making methodology, or more specifically FAHP, has been implemented to rank the importance of five key sustainable project criteria in sustainable project selection. This is done in an attempt to help project managers and decision makers in the sustainable project selection process. The results from this study that are determined based on the opinions of sustainable project experts and practitioners are then compared with a previous research by Alyamani and Long [1] who utilized the literature to rank the importance of these five criteria in the sustainable project selection process. This is done in an effort to compare the two different perspectives stemming from the literature and practice on the importance these five criteria in sustainable project selection.

The results from this study as shown in Table 6 indicate that the most important selection criterion out of the five criteria considered in this study when evaluating different sustainable project alternatives is project cost with a BNP of 0.464. As explained earlier, this criterion describes the overall project cost throughout the project's life including the initial investment cost and any other costs associated with the development of the sustainable project. The second most important selection criterion when evaluating sustainable project alternatives according to the results from this study is the required project team skill and experience with a BNP of 0.274. This criterion is concerned with matching the human resource capabilities with the requirements of the selected sustainable project. The third most important selection criterion when evaluating sustainable project alternatives according to experts is the amount of technology information transfer between the supplier of the sustainable technology and the project team utilizing that technology in the project with a BNP of 0.144. The fourth most important criterion in sustainable project selection out of the five identified in this study is project maturity, or "Novelty" as identified by Alyamani and Long [1], with a BNP of 0.136. Again, this criterion describes the maturity, or novelty, of the sustainable practices and technologies implemented in the sustainable project. Finally, the least important criterion out of the five chosen in this study is project uncertainty with a BNP of 0.109. This criterion describes the level of uncertainty surrounding the sustainable project that can stem from different sources whether it is economic, technological, environmental, social, political, or any other source of uncertainty that can potentially impact the sustainable project.

The results presented by Alyamani and Long [1] who utilized the literature in ranking these five criteria based on importance show that the most important selection criterion to consider when evaluating sustainable project alternatives is project cost with a BNP of 0.528. The second and third most important criteria were project maturity and project uncertainty with BNPs of 0.216 and 0.206 respectively. The least important criteria out of the five according to their results were the required level of project team skill and experience and the amount of technology information transfer between the party supplying the sustainable technology and the project team with BNPs of 0.101 and 0.100 respectively. A graphical representation of the results utilizing the literature from Alyamani and Long [1] and the results utilizing sustainable project subject matter experts (SMEs) from this study are shown in Figure 3.

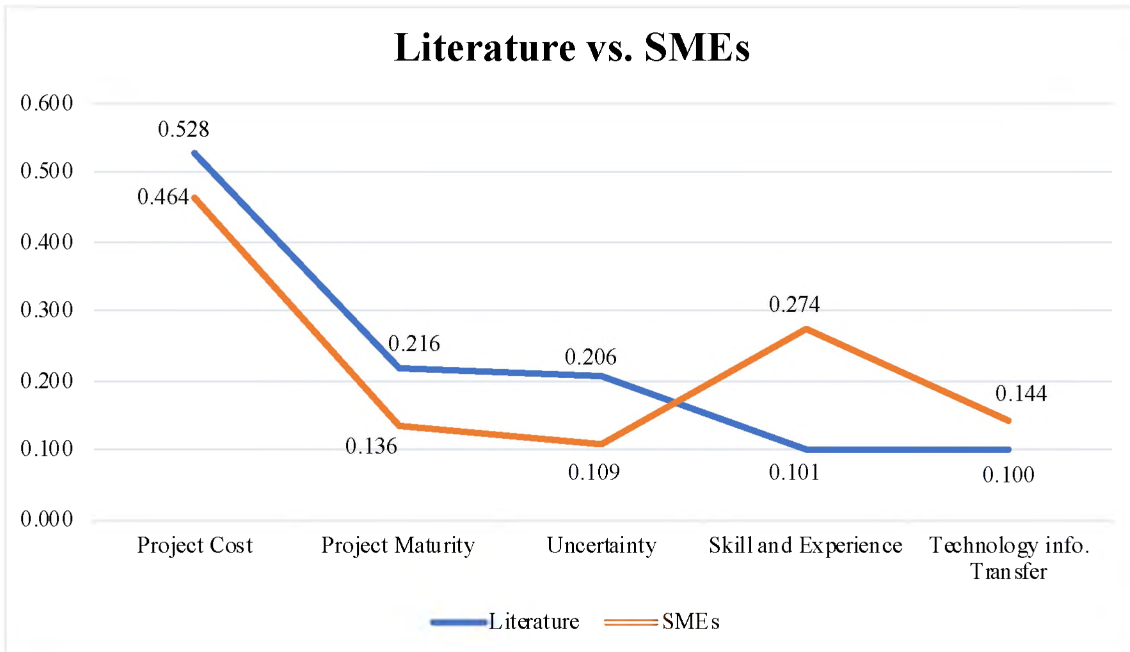

Figure 3. Graphical comparison of criteria weights (Literature vs. SMEs)

Looking at the results shown in Figure 3 and comparing the weights of each criterion it is clear that both the literature and SMEs prioritized project cost as the most important criterion when evaluating between multiple sustainable project alternatives with BNPs of 0.528 and 0.464 respectively. This is consistent with what has been discussed in the literature and what was previously discussed in this study in which project cost in considered one of the main drivers in development of sustainable projects [13]. It is actually believed that one of the biggest concerns associated with sustainable projects is the high cost that is usually associated with sustainable development which makes more difficult for these projects to compete with conventional energy sources [22]. Accordingly, the development of low-cost sustainable technologies and practices can help lead to a significant boost in sustainable development.

However, the two perspectives differ in opinion when it comes to the relative importance of the four remaining criteria. On one hand, SMEs view skill and experience and technology information transfer as being more important sustainable project selection criteria than project maturity and uncertainty, with skill and experience considered the second most important criterion after project cost as shown in Figure 3. This view is consistent with part of the sustainable project selection literature that emphasize the importance of matching the human resource capabilities with project requirements and the availability of sustainable technology information as major factors in successful sustainable development [16, 17, 22, 23]. On the other hand, the literature view puts more emphasis on project maturity and uncertainty as selection criteria as opposed skill and experience and technology information transfer with project maturity being just slightly more important than uncertainty. In this perspective, skill and experience and technology information transfer are seen as almost equal in importance. The literature views project maturity and uncertainty as major factors in sustainable project selection that can hinder or accelerate sustainable technology adaption [24]. Nonetheless, it is worth noting that the criteria with the lowest weights of importance, in both perspectives, does not mean that they have no importance in sustainable project selection. The results simply indicate that criteria with the highest weights should be assigned a higher priority when selecting between different sustainable projects.

One possible reason to why the collective judgment of SMEs in this study prioritized skill and experience and technology information transfer is that, lacking the required skilled workforce and technology information in the country or region in which these projects exist can pose a bigger concern for practitioners than the maturity of the sustainable project and level of uncertainty associated with it. This is supported by several researchers who argue the importance of having a skilled workforce and adequate information regarding the implemented technology. For example, Luthra, et al. [22] described the lack of skilled and experienced workforce in addition to the lack of technology information flow and communication as some of the biggest barriers to sustainable development and adoption in a given country or region. Solangi, et al. [23] also emphasize the importance of having the required human resource skill and experience and adequate technical information sharing in the region or county in which these sustainable energy projects exist. Alyamani, et al. [12] also argue the importance of possessing the required level of skill and experience and adequate technology information sharing to be able to deal with different sustainable projects with varying levels of novelty and uncertainty. What can essentially be concluded from these arguments is that the availability of the required skilled workforce and adequate information regarding the implemented sustainable technology provides the project team with the ability to deal with different sustainable projects with varying levels of uncertainty and maturity.

4. CONCLUSION

The ability to select and implement the appropriate sustainable projects is a crucial factor in sustainable development to ensure needs of an organization or the community are met. Part of the selection process involves considering different key sustainable project criteria that are used to select the best possible project out of the different sustainable project alternatives. Ranking these selection criteria based on importance in sustainable project selection can help decision makers differentiate between the different project alternatives and focus on important areas that may require additional attention. This study uses the Fuzzy Analytic Hierarchy Process (FAHP) as a MCDM approach to rank project cost, project maturity, uncertainty, skill and experience, and technology information transfer selection criteria based on importance by collecting opinions from subject matter experts (SMEs) consisting of sustainable project academia experts and practitioners. The results are then compared with previous research ranking these five criteria by utilizing the literature as the source of expert opinion in an effort to explore any variation of opinion between the SMEs and the literature. These results will help identify any variation in opinion regarding the importance of these key selection criteria between the literature and practice.

The results from this study show that the most important most important criterion when evaluating between multiple sustainable project alternatives out of the five considered based on SME opinion is project cost with a BNP of 0.464. The second and third most important criteria based on the results are skill and experience and technology information transfer with BNPs of 0.274 and 0.144 respectively. The two least important criteria in this study are project maturity and uncertainty with BNPs of 0.136 and 0.109 respectively. By comparing these results with the previous research utilizing the literature, it is shown that both the literature and SMEs agree that project cost is the most important criterion is sustainable project selection. However, the two perspectives differ regarding the importance of the remaining four criteria. SEMs put more emphasis on matching the human resource capabilities with the requirements of the selected sustainable project then adequate technical information sharing and communication over the maturity of the sustainable project and the level of uncertainty associated with it when selecting between project alternatives (Figure 3). On the other hand, the literature prioritizes project maturity and project uncertainty over having the required skill and experience and technology information transfer in sustainable project selection with project maturity being slightly more important than project uncertainty. A possible reason to such variation in opinion between the two perspectives is that lacking the required skilled and experienced human resources and the adequate technology information in a given country or region can present a larger concern to practitioners than dealing with an uncertain and novel sustainable project.

One main limitation of this study is the small number of SME opinions considered with a total of only 10 responses utilized to generate the results. Accordingly, the results shown in this study are limited to the opinions and preferences of the participating experts only. Obtaining a larger sample size of expert opinions can be used in future research to generate more accurate results when ranking these sustainable project selection criteria based on SME opinions. In addition, the research could be expanded to include additional key selection criteria and sub-criteria to create a more detailed selection tool that can help project managers and decision makers in the sustainable project selection process. A more extensive review of the literature can also be done for a more accurate and detailed comparison between the literature and SME perspectives regarding the priorities of the chosen selection criteria in sustainable project selection. Such an extensive analysis of both perspectives can lead to more accurately identifying possible reasons to why such variations in opinion exist between the two perspectives through detailed statistical analysis, and how these variations can be minimized to produce a more standardized ranking of the sustainable project selection criteria.

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SECTION

2. CONCLUSION AND FUTURE WORK

The work in this dissertation focuses on developing a sustainable project typology based on the impact of the coercive, normative, and memetic institutional pressures presented in institutional theory. Developing such a typology can help project managers and decision makers better plan for undertaking the project as well as improve their decision making early in the planning phase of the sustainable project. In addition, the research in this dissertation further develops this typology into a sustainable project selection tool by utilizing both the literature and SMEs as two different sources of expert opinion regarding the relative importance of the previously identified project characteristics from the typology as sustainable project selection criteria. Developing such a selection tool can help project managers and decision makers in the project selection process during the preceding project initiating stage.

The first paper in this dissertation employs an integrated literature review and the State-of-the-Art Matrix (SAM) analysis to review the literature from the fields of institutional isomorphisms, project management/ typology, and sustainability in an effort to determine how the coercive, normative, and memetic institutional isomorphisms can impact sustainable projects. Understanding the effects of these external pressures on sustainable projects is the first step in developing a sustainable project typology based on the impact of institutionalization on these projects. The results from the literature review indicate that there is a lack of research into sustainable project typologies that can help project managers and decision makers improve their decision making in the planning phase of sustainable projects. In addition, the literature review shows that there is a lack of research into the effects of institutional isomorphisms on projects in general, and more specifically sustainable projects.

Future work can include an expansion of this literature review to include a larger number of publications from a number of data bases to develop a more comprehensive review on developing sustainable project typologies as well as the effects of institutional isomorphisms on sustainable projects. Moreover, gathering a larger number of publications could provide an opportunity to perform a more detailed statistical analysis of the literature which could lead to the identification of additional gaps and crucial research trends.

The second paper in this dissertation addresses the gaps found in the first paper and utilizes the knowledge gained from the literature review process in an attempt to answer two main questions: "What is the relationship between institutionalization and sustainable projects?" and "How can institutional isomorphisms be used to create a project typology?". As a result, the paper develops a sustainable project typology that is based on the impact of institutionalization on specific sustainable project characteristics through the coercive, normative, and memetic institutional pressures from institutional theory. In addition, the research also outlines a number of common indicators that are used to measure the economic, social, and environmental impacts of sustainable projects to help measure the overall success of these projects. Using the developed typology, project managers and decision makers should have a good indication regarding the level of change, level of uncertainty, required level of project team skill and experience, and the required level of technology information transfer of the sustainable project depending on the type of institutional pressure influence the project. Two case studies are used to demonstrate how the sustainable project typology model can be used to classify sustainable projects.

Future work would include utilizing a larger sample size of sustainable projects to further validate the project typology. Testing the typology against a larger project sample size would also provide an opportunity to expand the typology by identifying additional project characteristics and relationships that may have not been explored in this research. This would also provide an opportunity to create a fully developed and more detailed typology that includes multi-tier or multi-level characteristics (Niknazar & Bourgault, 2017). Such a highly detailed typology would be an excellent decision-making tool for project managers and decision makers undertaking sustainable projects.

The third paper in this dissertation further develops the sustainable project typology from the second paper into a project selection tool that can help project managers and decision makers in the project selection process that occurs during the preceding initiating phase. The paper employs the Fuzzy Analytic Hierarchy Process (FAHP) as a Multi-Criteria Decision-Making (MCDM) technique to rank novelty, uncertainty, skill and experience, and technology information transfer identified in the typology in addition to project cost based on importance as selection criteria. It utilizes the project management and sustainable development literature as a source of expert opinion when implementing the FAHP. Doing so would help project managers and decision makers in the project selection process by prioritizing the selection criteria that are more important and would require additional attention.

The results from this paper show that project cost is the most important criterion to consider in sustainable project selection with an importance weight of 0.528. This is followed by novelty and uncertainty as the second and third most important criteria when selecting sustainable projects with importance weights of 0.216 and 0.206 respectively. Skill and experience and technology information transfer are considered the two least important criteria out the five considered in this research with importance weights of 0.101 and 0.1 respectively.

The fourth paper in this dissertation focuses in validating the results from the previous paper by utilizing subject matter experts (SMEs) and practitioners as a different source of expert opinion when implementing the FAHP technique to rank the project cost, project maturity (novelty), project uncertainty, skill and experience, and technology information transfer selection criteria from the previous paper based on importance in sustainable project selection. Accordingly, the results are compared with the results previously obtained from the third paper in an effort to examine how the chosen selection criteria are ranked in both the literature and practice. In this process, any variation in opinion regarding the importance of these criteria between the two perspectives when selecting sustainable projects is also identified. The results from this paper show that both the literature and practitioners agree that project cost is the most important criterion to consider when selecting sustainable projects. However, the two perspectives differ when it comes to the importance of the remaining four criteria with SMEs viewing skill and experience and technology information transfer as being more important than project maturity and project uncertainty. On the other hand, the literature puts more priority on project maturity and project uncertainty over skill and experience and technology information transfer.

The research in both the third and fourth paper could certainly benefit form additional future research to further develop the project selection tool. One possible avenue of future research could focus on further developing the selection tool in parallel with the development of the typology presented in the second paper by adding additional key selection criteria and sub-criteria leading to a more detailed and comprehensive sustainable selection tool. Another possible avenue of future research could focus on gathering a larger sample size of literature and SME opinions when implementing the FAHP in an effort to produce more accurate results regarding the importance of the chosen selection criteria. This in turn could provide an opportunity to develop a more accurate representation of the variations in opinion between the two perspectives. Doing so would provide an opportunity for future research that focuses on identifying why such variations in opinion exist between the two perspective which can help future researches minimize such variations and develop a more standard sustainable project selection tool.

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VITA

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