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Most Relevant Sustainability Criteria for Urban Infrastructure Projects—AHP Analysis for the Gulf States

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Abstract: Infrastructure projects require lifecycle-based assessment, considering the interests of multiple stakeholders concerning the three pillars of sustainability. There has been a heightened curiosity in employing sustainability indicators for gauging the impacts of developmental projects. Even though the literature is abundant on sustainability assessment methods, there is no proper one for the assessment of urban infrastructure projects in the context of Gulf states. Thus, our research intends to fill in this research gap and recommend an incorporated, hierarchically coordinated approach of sustainability indicators to be employed for the sustainability assessment of urban infrastructure development projects. This aim is achieved through a questionnaire survey, by identifying the sustainability indicators related to the infrastructure projects for the cities, in the context of Gulf states. The survey uses the criteria; "Important", "Practicality", "Reliability", and "Relevance" to assess those indicators. Based on expert opinions, the weights of the indicators are approximated through the analytical hierarchy process (AHP) method. Thus, the study proposes an innovative hierarchically defined structure of sustainability indicators fitting for the Gulf context. Further, it informs urban planners and policymakers, particularly in the Gulf states, about the shift in the direction of sustainability of urban infrastructure systems.

Keywords: sustainable assessment; sustainability indicators; urban infrastructure; sustainability criteria; AHP; Gulf states

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Citation: Khan, K.; Depczyńska, K.S.; Dembińska, I.; Ioppolo, G. Most Relevant Sustainability Criteria for Urban Infrastructure Projects—AHP Analysis for the Gulf States. *Sustainability* **2022**, *14*, 14717. https://doi.org/10.3390/su142214717

Academic Editor: Alessio Ishizaka

Received: 28 September 2022
Accepted: 7 November 2022
Published: 8 November 2022

1. Introduction

Urban areas are on the rise spectacularly in an uncontrollable way across the globe [1,2]. They become economic hubs, offer jobs, and provide better health services, and thus many people are moving to cities to improve their quality of life [3,4]. However, this uncontrollable growth causes negative environmental, social, and economic impacts on cities [5]. Sustainable development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" [6]. The concept of sustainability is seen as a joint consideration of socioeconomic and environmental components. These components interweave with each other in a means as they are inextricable. According to Kline [7], affecting one component of sustainability will also affect other components. So, for sustainable development, one must consider all these components interlinked in a comprehensive view.

It is widely accepted that urban infrastructure is one of the important contributors to sustainable development [8–12]. Any infrastructure in the perspective of urbanization is termed sustainable as it reflects all three-fold pillars of sustainability, i.e., social integration and economic and environmental aspects [13]. The sustainability of infrastructure projects for urbanization planning is a fact that cannot be flouted since it influences the environmental, social, and economic prosperity of a state. Nevertheless, this model's revolution into the decision-making process to give a pragmatic structure is not obvious. It is proved that construction authorities are encountering a very demanding task of translating sustainability aims into actual actions in their construction projects. The process is exacerbated by the multiple bottom-line perceptions of sustainability with the inadequacy of a rigid practical framework for various hierarchical levels. Consequently, it was necessary to build instruments and systems that permit the environmental and socioeconomic commitments to be met [14,15].

In recent decades, Gulf states have experienced an infrastructure boom due to rapid growth in oil production and the revenue that comes from this production. It has also grown because of the rapid expansion of its population and urbanization. Currently, these states spend additionally on their infrastructure in both public and private sectors, with billions of urban development infrastructure projects [16,17]. Infrastructure systems in the Gulf, particularly in the United Arab Emirates (UAE) and Saudi Arabia, mainly focus on sustainability. However, there are many challenges in the sustainability assessment of these infrastructure systems because the objectives of the assessment do not constantly have an obvious boundary. There is no comprehensive assessment framework so many infrastructure projects have developed their systems of assessment based on their project-specific needs [18,19].

Sustainability indicators are very commonly applied tools for evaluating the impact of sustainable development. The sustainability indicators for infrastructure development contribute significantly to decisions regarding the sustainability value of the project. These indicators are viewed as a reference framework and determine the progress of sustainable infrastructure development toward accomplishing its certain aims and objectives [20]. These indicators ought to be comprehensive and consolidative to entirely ascertain the advancement achieved towards sustainability. Infrastructure experts believe that sustainability indicators are effective and should cover socioeconomic and environmental components of sustainability [21,22].

The literature review highlights that the researchers have proposed various tools and methods for the sustainability assessment of urban infrastructures. Still, less focus has been given to the integrated evaluation of socioeconomic and environmental indicators for infrastructure projects. The proposed methods in the literature have various degrees of reliability and relevancy for assessing sustainability. They are different in the area and context for evaluating the indicators and interpreting the results [22–37]. Further insufficiency in the selected studies is their lack of practicability for other regions and projects since all these works were intended for a particular task such as energy, wastewater management, and urban water with country-specific indicators [28,29,31,34,38–46]. Moreover, there are limitations in the work proposed by them. They have not proposed incorporated modeling approaches that evaluate semi-quantitatively all three dimensions of sustainability in terms of multiple scales, domains, and generation [47]. Therefore, they are inadequate in their scope. In addition, the ability to scrutinize the various stakeholders' preferences is inappropriate as well. However, they provide a basis for the selection of indicators to be considered for the infrastructure projects' sustainability.

This study aimed to address the question of the most relevant sustainability criteria for infrastructure projects by focusing on the Gulf states. In other words, the objective of this study is the development of sustainability indicators in the context of Gulf states, specifically UAE and Saudi Arabia. Literature shows that many sustainability assessment indicator frameworks are used for infrastructure projects. This study, however, is unique in the context of Gulf states. This study is also unique because of the fact that the authors evaluated the indicators based on four elements: "Importance", "Practicality", "Reliability", and "Relevancy" towards sustainability. Furthermore, in our view, we have covered all three dimensions of sustainability. There is a study that covered all aspects of sustainability, but it is limited to Makkah city in Saudi Arabia [18,19].

The sustainability performance of infrastructure networks is subordinated to the adaptive behaviors of the various stakeholders and the involvement of institutions in the planning of technical structures [31]. Hence the analytic hierarchy process (AHP) is used to value and prioritize the indicators. It is one of the extensively employed methods of multi-criteria decision analysis (MCDA). Two excel equations have been developed for the AHP analysis of the indicators. The proposed work aims to support urban planners and policymakers in the transition toward the sustainability of urban infrastructure systems.

The paper has been organized into five sections. Section 2 deals with the materials and methods used for the development of sustainability indicators. Section 3 describes the results and Section 4 discusses the study findings and presents the AHP analysis. The study is concluded in Section 5.

2. Materials and Methods

Questionnaire Design and Selection of Indicators

To fulfill the aim of this research and to identify the sustainability indicators for infrastructure projects, an aptitude study (qualitative approach) is applied to perceive the importance of socioeconomics and environmental aspects of sustainability and the indicators. The authors analyzed a collection of feasibility reports and other previous research referring to infrastructure projects. Our research began with a state-of-the-art analysis of similar studies and the sustainability indicators were chosen from the topic-related literature. The sources for the selection of indicators are [19,23,25,27,28,31,33,48–58]. Many indicators were found from these sources however proper steps were taken to select the appropriate indicators suitable for infrastructure projects. The authors have taken four basic actions based on [23], for the selection of indicators. They are (1) scope definition, (2) data collection (from the literature), (3) extraction of indicators, and (4) indicators breakdown. These steps are mentioned in Figure 1. The suitable indicators for the infrastructure project were selected and then divided into three groups—economic, environmental, and social indicators—through mutual consultation of the research team.

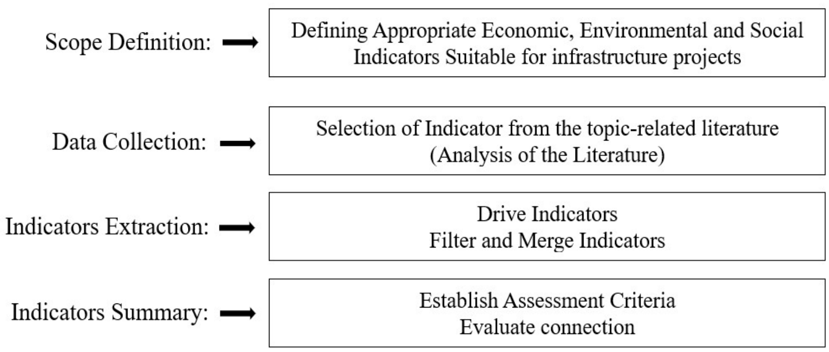

Figure 1. Systemic process for the selection of indicators [23].

To validate the appropriateness of the indicators selected from the literature, a questionnaire survey has been carried out. The main purpose of the questionnaire survey was to examine whether the infrastructure experts validate the indicators chosen from the literature as relevant to infrastructure projects. The experts were selected from the Gulf states, specifically the UAE and Saudi Arabia infrastructure industries. Preceding data gathering, the early questionnaire form was checked and pre-tested for content authenticity by a group of experts that included academics and construction experts. We requested the experts to critically revise the questionnaire in terms of clarity, structure, and comprehensiveness and give an opinion about the indicators we have chosen for the evaluation of sustainability in infrastructure systems. Then, a questionnaire was modified according to their suggestions and recommendations. In general, the survey questionnaire was structured in 3 sections. Part 1 included the demographic information of the respondents, Part 2 included the questions regarding their knowledge of sustainability, and Part 3 focused on gaining knowledge of the appropriateness of the selected indicators.

In Part 2 of the questionnaire, we added questions about the "United Nations Commission on Sustainability Development" and the "Global Reporting Initiative" to see if the respondents are familiar with them. Further, it has also queried about knowledge of sustainability assessment tools and the participation of the respondents in sustainable projects. The purpose of these questions is to learn the awareness of the respondents about the tools and to confirm that we have collected data from experienced and qualified individuals.

In Part 3, the selected from the literature sustainability indicators were categorized into environmental (10 indicators), social (8 indicators), and economic (7 indicators) criteria. The questionnaire was distributed among 205 experts through email, fax, or directly handed over to them. They were experts from the construction industry with more than 5 years of experience in the industry. Respondents (infrastructure projects experts) were invited to value these indicators for infrastructure projects. The elements given to them include the importance, practicality, reliability, and relevance of the indicators for their infrastructure projects. The elements of scrutiny were defined on the scale as "High, Normal, Less, and Not" and the choice of "No Opinion" if the respondent has no understanding of the selected indicators. Furthermore, we also asked the respondents about the importance of socioeconomic and environmental aspects of sustainability. This question was asked to understand the intention of the construction industry for sustainability in the context of Gulf states. A total of 174 responses were returned, of which 11 were incomplete so 163 questionnaires were further analyzed. Before starting the analysis, outlier statistics were carried out to identify outliers. A total of 38 outliers were detected and removed from the dataset. 125 questionnaires were left in our dataset for further analysis. Figure 2 shows the process of questionnaire development and data collection process.

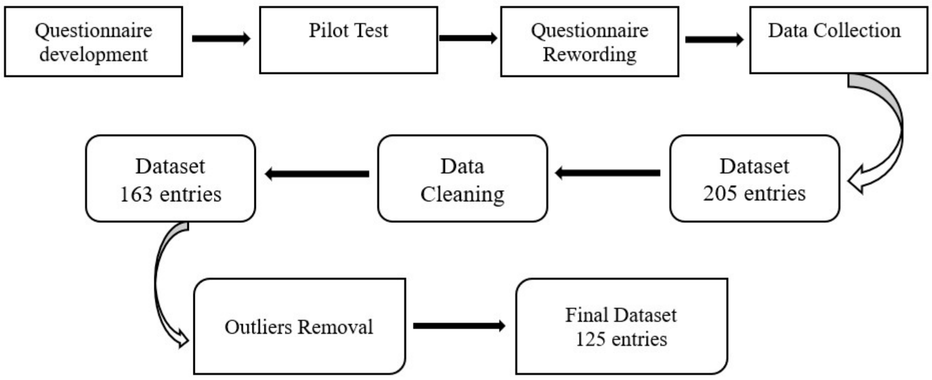

Figure 2. A systematic process of questionnaire data collection.

The development of sustainability indicators in infrastructure projects was determined through consultation processes among construction experts to achieve a consensus on applicable sustainability indicators [23]. A consistent weighting approach must be constructed to recognize these indicators. The weighting approach of these sustainability indicators is the key to any assessment method [19]. Therefore, the analytic hierarchy process (AHP) by Saaty [59] is applied to build a proper weighting system for the indicators selected for sustainable infrastructure.

A literature study showed that AHP is a valuable technique for weighting the sustainability indicators as (a) AHP has the properties of a hierarchical composition, which is allied with the structures of very frameworks of sustainability and makes up the process simple to understand for stakeholders; (b) it stipulates a constant corroboration operation; (c) AHP is flexible and easy; (d) it can be applied with both quantitative and qualitative data [60–63]. Furthermore, the AHP method is recognized as efficient and broadly applied by numerous studies for various sustainability-associated task solutions [49,60,61,64–69].

The responses to the questionnaire were verified for each of the indicators using descriptive statistics techniques. Alongside this step, the indicators were prioritized using the AHP analysis. The AHP was performed to find out the preferences and value of the indicators through their weighting score to outline the extent of consistency and the uncertainties amongst the experts (the respondents of the questionnaire) on how to systematize, and which indicators or criteria must be incorporated to assess sustainability.

3. Results

To achieve the desired goals, this study organized a comprehensive questionnaire survey and revealed the perspective of the research to the interviewees. The interviewees were experts in construction projects, including planning engineers, managers of the project, senior managers of the project, and project directors. The questionnaires were returned from the respondents which conferred an approximately 45% response rate. The objective was to define the area of compliance among the stakeholders regarding the sustainability indicators. Table 1 summarizes the key demographic information of the respondents, which represents Part 1 of our questionnaire. Furthermore, Part 2 of the questionnaire illustrates the sustainability initiatives knowledge and related expertise of the respondents (Table 2).

Table 1. Respondents' demographic information.

Questionnaire Part 1	Division/ Range	No. of Respondents (163 Entries)	Respondents % (163 Entries)	No. of Respondents (125 Entries)	Respondents % (125 Entries)
Gender	Male	123	75%	97	78%
	Female	40	25%	28	22%
Age (in years)	25–40	86	53%	69	55%
	41–60	59	36%	43	34%
	>60	18	11%	13	11%
Work experience (in years)	0–5	40	25%	28	22%
	6–10	58	36%	45	36%
	>10	65	39%	52	42%
Qualification	Ph.D.	17	10%	08	7%
	Master's	114	70%	98	78%
	Bachelor's	23	14%	14	11%
	Other	9	6%	5	4%

Source: own elaboration.

Table 2. Respondents' sustainability knowledge and expertise.

Respondents		Participation in Sustainability-Led Projects		Understanding of Sustainability Initiative		Exp. in Employing Sustainability Evaluation Tools	
Project Director	26%	Yes: Participated in the Projects	(56%)	GRI (Global Reporting Initiative)	(72%)	Yes: Employed	(46%)
Senior Project Managers	28%	No: Not Participated in the Project	(44%)	UNCSD (United Nations Commission for Sustainability Development)	(66%)	No: Not Employed	(54%)
Project Managers	24%						
Planning Engineers	22%						

Source: own elaboration.

The diverse sustainability concerns were also applied as a decision criterion, and indicators were scored based on their significance level. The subsequent Figures 3–5 illustrate the detailed scrutiny of Part 3 of the questionnaire. The figures reveal and discuss experts' perceptions on the significance level of the indicators towards infrastructure sustainability. The survey data were examined for every indicator using descriptive statistical techniques based on the four elements mentioned above. The figures explain the mean score of the indicators, which are additionally analyzed by the "ANOVA" and "Tukey post hoc" statistical tools, used for determining significance variations among the selected four elements.

Then, an AHP analysis was carried out to rate the weight and preferences of the indicators chosen for the analysis.

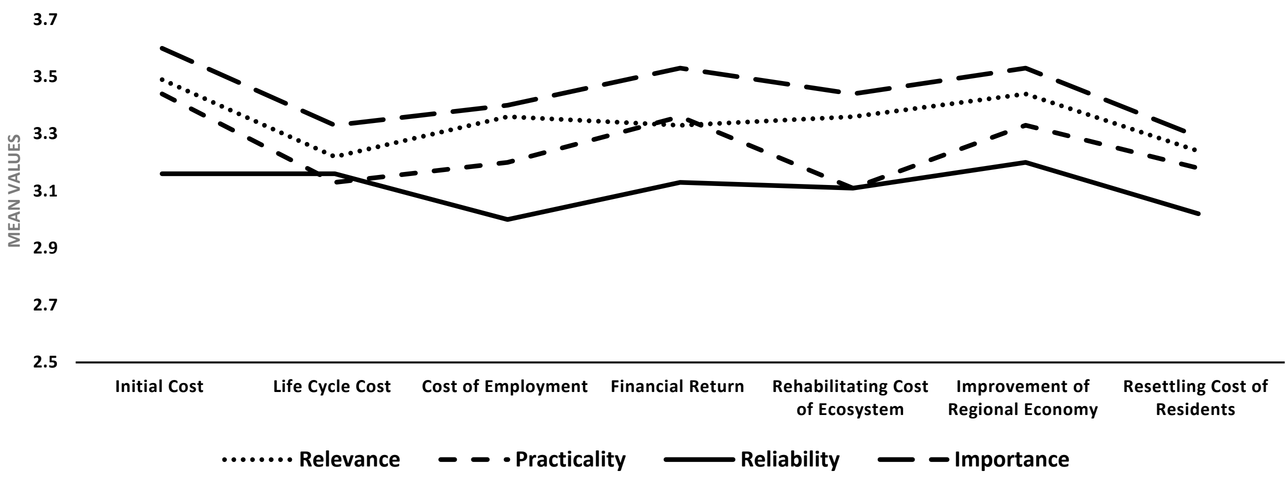

Figure 3. Economic indicators. Source: own elaboration.

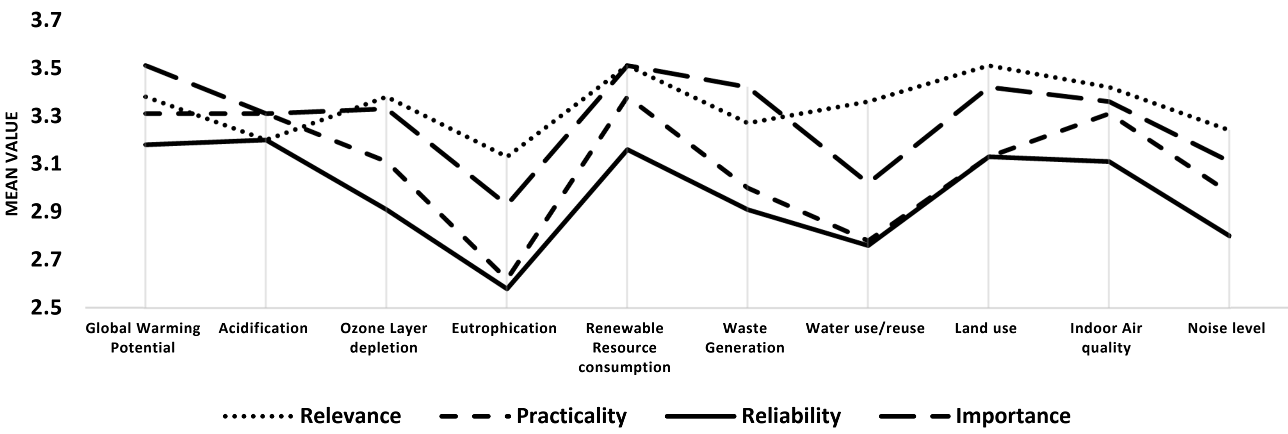

Figure 4. Environmental indicators. Source: own elaboration.

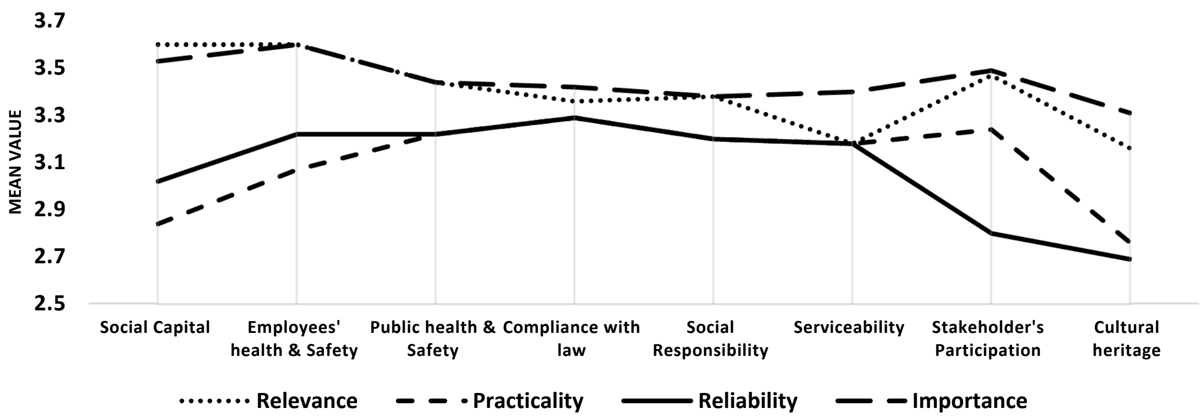

Figure 5. Social indicators. Source: own elaboration.

Interpreting the median values, indicators in the economic aspect showed more significance, followed by social and environmental indicators. In the attribute of "Importance", economic and social indicators were found as highly important indicators. Furthermore, social indicators were also rated as more relevant, which shows the preferences of the stakeholders (respondents) towards social values. It demonstrates that the Gulf construction segment is further concerned regarding societal standards, or else it may perhaps be recommendations of respondents for community infrastructures.

Additionally, it may also be possible that the social indicators we have chosen are more practical and are considered important for sustainable infrastructure. The economic indicators, from the viewpoint of practicality attributes, are more practical. However, it is a common fact to have financial gains from public infrastructures. The indicators' reliability element is not rated high; however, the score given to them demonstrates that most of the indicators are more reliable to be considered for sustainability assessment. One of the opinions of this evaluation and ranking order of the indicators may perhaps be that experts gave a high-ranking value to the indicators which they know the best.

Furthermore, we see significant differences between the four attributes rated by each indicator after performing ANOVA and Tukey multiple comparison tests. When an ANOVA assessment is completed, the investigator may require identifying subcategory variations among the various investigational and monitor groups. ANOVA does not support tests of subcategory variations. Post hoc tests are required to identify subcategory variations and many post hoc tests can be performed to further illuminate the group variations. Each one has certain functions, benefits, and shortcomings.

It is consequently critical to opt for the test that best fits the data, the sorts of information regarding group differences, and the essential strength of the assessment. Tukey multiple comparison analysis tests are particularly significant because although the ANOVA offers considerable information, it does not give comprehensive information regarding variations between certain study groups, nor it can offer information on intricate comparisons. The resultant evaluation with these post hoc tests might offer the investigator the very crucial results of the analysis [70]. Table 3 shown below illustrates the indicators with highly significant variations with those without significant variations.

Table 3. Indicators with significant variations.

	Economic Indicators	Environmental Indicators	Social Indicators
Indicators with Significant Differences	Initial Cost Importance > Reliability Cost of Employment Importance > Reliability Financial Return Importance > Reliability	Ozone Layer Depletion Relevant > Reliability Renewable Resource Consumption Importance/Relevant > Reliability Waste Generation Importance > Reliability Importance > Practicality Water Use Relevant > Practicality Relevant > Reliability	Social Capital Relevant/Importance > Practicality Relevant/Importance > Reliability Employees Health and Safety Relevant > Practicality Relevant/Importance > Reliability Stakeholders Participation Relevant/Practical/Importance > Reliability Cultural Heritage Importance > Reliability Importance > Practicality
Indicators without Significant Differences	Life Cycle Cost Ecosystem's Rehabilitation Cost Regional economy Improvement Residence Resettling Cost	Global Warming Potential Acidification Eutrophication Land Use Indoor Air Quality Noise Level	Public Health and Safety Compliance with Law Social Responsibility Serviceability

Source: own elaboration.

From the analysis of multiple comparison tests, significant variations exist in the score between the element of "importance" and "reliability" in evaluating initial cost, financial return, and employment cost. These indicators are more important, but reliability is low-ranked. A common view is that the project's initial cost is considered more for its financial valuation. Any infrastructure must have economic value and benefit from the initial capital; thus, the "financial return" is assessed as an important attribute. Furthermore, the initial cost of a project, the financial return of a project, and the employment cost are key indicators for the calculation of the cost-benefit analysis of the project. However, there is uncertainty connected at different times of the project, which cannot be assessed in the early phase which might cause the indicators less reliable.

Figure 2 demonstrates renewable resource energy and global warming potential as rated high and shows more importance and relevancy from the perception of environmental sustainability. To enhance energy-efficient infrastructure projects, the selection of appropriate materials is vitally important. The study showed that the selection of materials with minimal environmental effects and the reprocessing of resources and products in the new construction of infrastructure projects have very significant importance in the Baltic states [49]. Agreeing with Shen et al. [54], the lower usage and diminution of both constrained raw materials and prolonged-cycle renewable materials by replacing them with immediately renewable materials is vital in accomplishing the sustainability of building infrastructures.

These environmental indicators stand at the center of recent discussions among environmental policymakers, and worries regarding GWP are robustly adopted by the Paris Climate Agreement [71]. The indicator "Renewable resource energy" also offers financial benefits, which is considered a practically utilized indicator compared to other indicators in the infrastructure sectors, e.g., eutrophication and acidification, etc.

Furthermore, if we see the indicators "indoor air quality" and "land use", the rating is high because in the infrastructure systems indoor air quality is demanding and land use has economically positive impacts. In the Gulf states, due to the hot weather, appropriate indoor air quality systems are among the most vital considerations. Similarly, like in our study, the research by Nilashi et al. [69] also illustrated that indoor air performance is among the most crucial criteria in assessing green building infrastructure.

Regarding land use, the sustainability of new infrastructure projects directly depends on applicable land use, as it is a restricted resource and has an influence on other categories of sustainability. Other studies also revealed land use as one of the important indicators for various infrastructures [19,69].

Noise level, eutrophication, and water use are rated low but are relevant for sustainability. However, these may not be the most practical and important indicators for infrastructure in the Gulf perspective. The reason for this rating could be that the respondents may be more oriented toward economic benefits, and thus rated highly those indicators in the environmental aspect which also have financial benefits. Water use/reuse is a very important criterion in the context of Gulf states and is scored very relevantly for infrastructure projects. However, it is scored less in other attributes (importance, practicality, and reliability) [19]. There are significant variations between the attributes of the indicators, for example, renewable resource energy, water use, ozone layer depletion, and waste generation. The stakeholders rated them highly in the attribute of importance and relevancy (Table 3).

According to the social indicators analysis in Figure 5, compliance with law and public health and safety indicators are highly rated. These indicators also have no significant variations among the elements of analysis (Table 3). Still, employees' health and safety was substantially different as it was rated highly relevant and important concerning the characteristics of reliability and practicality. Overall, the social indicators we have selected are highly important and relevant.

Regarding differences between the attributes for the social responsibility and serviceability indicators, there are also no significant differences between the attributes. The "Stakeholders' perception", "Culture Heritage", and "Social capital" observed variations in the assessment of all elements. The stakeholders' perception and social capital are seen as more important and relevant. The perception of social capital might be due to the culture that is socially oriented in targeted nations in the Gulf. Stakeholders' participation is deemed the most problematic indicator to be quantified. There is no international compliance in the scientific community on this indicator and its justification of inclusion (Hurley et al., 2008). Nevertheless, there is growing disquiet about the considerable role of stakeholders' perception and public awareness of the industrial professional in accomplishing and knowing sustainable development [55].

Analytical Hierarchy Process Analysis

The analytical hierarchy process (AHP) is a known approach utilized for ranking the sustainability criteria of a system. They are preferred when decisions need to identify the desired solution for a system. It is used not just for the choice of the preferred solution but could be exploited to evaluate a particular project based on several indicators of sustainability [31,59]. Due to the complex condition, it lets the stakeholders to decision-making by abridging this activity into pairwise comparisons amongst the indicators [60,65,72].

This study used the pair comparisons technique to analyze the indicators based on their weighting score. The questionnaire respondents are divided into four groups: "Project planning Engineers", "Project Managers", "Project senior Managers", and "Directors". The questionnaire in which the respondents answered *"no opinion"* to a question is not included in our analysis. Saaty [59] acknowledged that the Likert scale of 1–9 is a suitable scale used in applications for weight ratio. A study suggests the usage of an equitable scale while addressing two-fold aspects [73]. Other researchers argue that the selection of the scale is contingent on the evaluation question and the entities who carry the issue [74,75]. However, our data have not used the 1–9 Likert scale, therefore we have developed an innovative approach by generating two excel equations for our data analysis process. In detail, we analyzed the rates of the metrics units by finding the "distinction between the two indicators' average values". The eigenvalue or eigenvector is used to estimate the weighting score of the indicators. In addition, we also calculated the consistency ratio (CR) to validate the experts' responses. The consistency ratio was checked for each matrix using the formula:

$$\mathrm{CR} = \mathrm{CI}/\mathrm{RI} \tag{1}$$

The accepted value of CR for different matrix sizes is 0.05 for a 3 by 3 matrix; the CR value for a 4 by 4 matrix is 0.08; and for the larger matrix, it is 0.1 [76]. The analysis of our study showed us that the survey was sufficiently consistent. Table 4 shows one of the analyses, and the rest are in the attached Supplementary Materials.

If MV (A) $\geq$ MV (B),

$$\mathrm{X} = (\mathrm{MV}\ (\mathrm{A}) - \mathrm{MV}\ (\mathrm{B})) \times 4 + 1 \tag{2}$$

If MV (A) < MV (B),

$$\mathrm{X} = 1/(\mathrm{MV}\ (\mathrm{A}) - \mathrm{MV}\ (\mathrm{B})) \times 4 + 1 \tag{3}$$

The purpose is to find the weight for each indicator as these indicators can be employed to evaluate the sustainability of a project. The above section pointed out, "Regional economy improvement", "Financial return", and "Initial cost" are significant indicators in their aspects. Still, they also have a high weighting value in the pair comparison analysis.

According to this analysis, the respondents in the group of *project directors* weighted the priority of the indicators "Regional economy improved" and "Initial cost" 20% each. Subsequently, "Rehabilitating the cost of the ecosystem" and "Financial return" are 14% each, and a weight of 12% is given to "Cost of employment" and "Life cycle cost". Furthermore, in the environmental aspect, the respondents (project directors) assigned a high weight of 14% to the indicator "Renewable resource consumption" and 13% to "Noise level". In social indicators, "Employees' health & safety", and "Social capital" have priority with weight (16%) each, followed by "Compliance with the law" (15%).

Table 4. AHP analyses for weighing indicators.

	Initial Cost	Life Cycle Cost	Cost of Employment	Financial Return	Rehabilitating Cost of the Ecosystem	Improvement of the Regional Economy	Resettling Cost of Residents
Initial Cost	1.0	1.69	1.69	1.46	1.46	1	2.08
Life Cycle Cost	0.59	1.0	1	0.81	0.81	0.59	1.38
Cost of Employment	0.59	1	1.0	0.81	0.81	0.59	1.38
Financial Return	0.68	1.23	1.23	1.0	1	0.68	1.62
Rehabilitating Cost of Ecosystem	0.68	1.23	1.23	1	1.0	0.68	1.61
Improvement in Regional Economy	1	1.69	1.69	1.46	1.46	1.0	2.07
Resettling Cost of Residents	0.48	0.72	0.72	0.62	0.62	0.48	1.0
Total	5.03	8.57	8.57	7.17	7.17	5.03	11.15

	Initial Cost	Life Cycle Cost	Cost of Employment	Financial Return	Rehabilitating Cost of Ecosystem	Improvement of the Regional Economy	Resettling Cost of Residents	Total	Average	Consistency Measure
Initial Cost	0.20	0.20	0.20	0.20	0.20	0.20	0.19	1.39	0.20	7.00
Life Cycle Cost	0.12	0.12	0.12	0.11	0.11	0.12	0.12	0.82	0.12	7.00
Cost of Employment	0.12	0.12	0.12	0.11	0.11	0.12	0.12	0.82	0.12	7.00
Financial Return	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.98	0.14	7.00
Rehabilitating Cost of Ecosystem	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.98	0.14	7.00
Improvement in Regional Economy	0.20	0.20	0.20	0.20	0.20	0.20	0.19	1.39	0.20	7.00
Resettling Cost of Residents	0.10	0.08	0.08	0.09	0.09	0.10	0.09	0.62	0.09	7.00
									CI	0.00
									RI	1.32
									CR	0.00

Source: own elaboration.

Furthermore, analyzing the responses of the senior project managers, the "Initial cost" has a high weight in the economic indicators. From the environmental aspects, the indicator "Global warming potential" is given 20% weight and "Land use" 17%. "Acidification" and an imperative environmental indicator (renewable resource consumption) weighted 14% and 13%, respectively. For social indicators, respondents focused more on the "stakeholders' participation" indicator, a more crucial indicator considered in decision-making for evaluating project sustainability. Moreover, the indicators "Serviceability" and "Stakeholders' participation" are placed high-ranking with a weighted score of 17% each. "Employee health & Safety" and "Public health & safety indicators are given 14% weight by the respondents.

In the pair comparison analysis for the third group of respondents (Project managers), the "Ecosystem' rehabilitating cost", "Employment cost", and the "Financial return" are weighted 20%, 18%, and 17%, respectively, in the economic aspect. From an environmental point of view, "Indoor air quality" weighted 18%, the "Renewable resource consumption" and "Global warming potential" weighted 17%. In the project managers' analysis of the social indicators, the response weight for "Social responsibility" is 21%, then "Public health & safety" and "Employee's health & safety", also highly valued by the senior manager respondents. From the analysis of the project managers' responses, these indicators ranked 2nd highest with a weighted score of 19%.

The analysis of the planning engineers found that the indicators "Financial return", "Initial cost", and "Regional economy improvement" are highly weighted. From the economic aspect of sustainability, these indicators need to be considered for the sustainability of a project, especially an infrastructure. They cover various features of sustainability; therefore, the stakeholders are involved in them more while evaluating sustainability. From the responses of the planning engineers, these indicators are weighted 23%, 22%, and 17% each. In the environmental aspect, they also gave more priority by weighting 14% to "Ozone layer depletion". "Renewable resource consumption" and "Global warming potential" are ranked second with a 13% weighting score. The analysis of the social aspect indicators, "Compliance with the law" is weighted 22%, then "Employees' health & safety" 14%, and "Social capital" 14% too. "Public health & safety" is given a weighted 13% score. All the analyses are presented in the Supplementary Materials of this research work.

4. Discussion

A set of some potential indicators frequent in infrastructure sustainability assessment was created from a rigorous literature review of previous studies, government guidelines, and case studies project data. The subsequent questionnaire-based survey was addressed to the validation of the selected indicators. One of the objectives was to find the degree of significance of key sustainability aspects and diverse indicators choices that would have the maximum environmental, economic, and social gains. The objective is to identify the conformity and uncertainty along with the experts on infrastructure projects, how to establish them, and what measures to incorporate for assessing sustainability. The above part showed the outcomes of each indicator at a certain attribute. We have evaluated seven indicators in the economic aspect, and they were assessed as highly important. The social indicators are also ranked very important for the sustainability assessment, which is very different from the previous studies. The previous studies have not given much importance to the social aspect, and in our studies, they were assessed as very relevant and important. However, the social sustainability aspect necessitates an in-depth investigation, mainly in the urban infrastructure sector. Researchers ignore it and now progressively receive some consideration for its implication in urban infrastructure development [77–79]. Environmental and social sustainability issues are also the subject of modern debate between policymakers and practitioners. Although social aspects are commonly qualitative, they are therefore deemed challenging to address their quantification for sustainability. In our research, eight social sustainability indicators were selected from diverse literature to be assessed by the infrastructure experts (the respondents). Additionally, the experts also suggested some of the indicators be considered for infrastructure projects. They are public access, public perception, and respect for minorities. Furthermore, it should be noted that each region has its own country and project-particular sustainability priorities. Generally, some of the social indicators have extensive and unpredicted impacts even after the project's construction has been completed.

Ten indicators were examined in the environmental aspect of sustainability, believed to be extremely essential indicators for the infrastructure sector. The environmental component of sustainability is primarily debated in the literature and is broadly employed in certification systems, hence requiring a huge number of indicators.

Our analysis shows that many of the designated indicators are acceptable for significant concern as they are recommended as highly important and relevant by the respondents. Specifically, financial return, initial cost, regional economy improvement, renewable resource energy, GWP, compliance with the law, employee health and safety, and public health and safety are the highly-rated indicators with a minimum mean value of 3.3/4. Additionally, in terms of the variance in score among the attributes, there are minimal variations between the indicators in the attributes of importance and relevance, which verifies that we have selected significant indicators. In general, all the indicators ask for more consideration to be more practical and reliable.

From the analysis and weight scoring of the selected indicators, there are several common indicators rated highly by all the groups of respondents that are significant and not to be ignored for the sustainable assessment. In the category of the economic aspect, these indicators are "Employment cost", "Financial return of the project", and "Project's initial cost". The "Global warming potential", "land use", "Indoor air quality", and "Renewable resource consumption" are in the environmental category. From the societal aspects, "Public health & safety", "Social capital", "Employees' health & safety", "Compliance with the law", "Participation of stakeholders' indicator", and "Social responsibility" are highly valued, significant, and should not be disregarded while carrying a sustainable project.

The result of environmental indicators in "Pair comparison analysis" would likely be dissimilar if the same number of indicators for each aspect was selected. However, as earlier noted, the environmental aspect is largely investigated in the literature and comprehensively employed in the certification systems; hence, it includes a large number of indicators. In our research, 10 indicators were selected for analysis. Nevertheless, we can recognize the most significant environmental indicators from the weighting. Furthermore, this analysis presents an imperative consideration of the indicators due to their significance for assessing project sustainability.

In short, we can say that the analyzed indicators have a significant part in the sustainability assessment of infrastructure projects and show their importance in one of the attributes. It shows that project sustainability can be affected if they are not considered. The indicators that are rated low practical and reliable show uncertainties and challenges associated with them for determining the project's sustainability. In general, the results demonstrate that the indicators we chose for experts' opinions are relevant and important for the sustainability of an urban infrastructure project.

Analysis of the Sustainability Dimensions

Finally, the experts were questioned concerning the ranking of the three most important sustainability dimensions. These dimensions are discussed in the majority of studies that emphasize sustainable development in infrastructure projects. The below figures illustrate the weighting sets of the sustainability aspects, i.e., the triple bottom line approach of sustainability. The life cycle sustainability aspects are illustrated in the triangles implemented by Hofstetter et al. [80] to weigh different environmental forces caused by the problems of chemical mixtures. This may perhaps be practical to weigh any triplet elements [81].

In this section of our work, the analysis of economic, environmental, and social sustainability aspects is ranked through a paired comparison analysis weighting score. Each point in the triangles corresponds to a specific weight set "W_E, W_{EC}, W_S". They correspond, respectively, to the weighting of environmental, economic, and social attributes. The triangles (Figure 6) are developed on the analysis produced in Supplementary Materials attached to this study. From the representation of the following figures, the *economic dimension* is weighted as an aspect of utmost importance for the sustainability of the infrastructures among all groups of stakeholders (the survey respondents). From the results, one might expect that one of the most important purposes is to have economic benefits from any infrastructure project, both at the state and individual levels. Previous research works within this field and in different regions have found similar results.

W_{EC} Weight of Economic Aspect
W_E Weight of Environmental Aspect
W_S Weight of Social Aspect
$W_E + W_{EC} + W_S = 100\%$

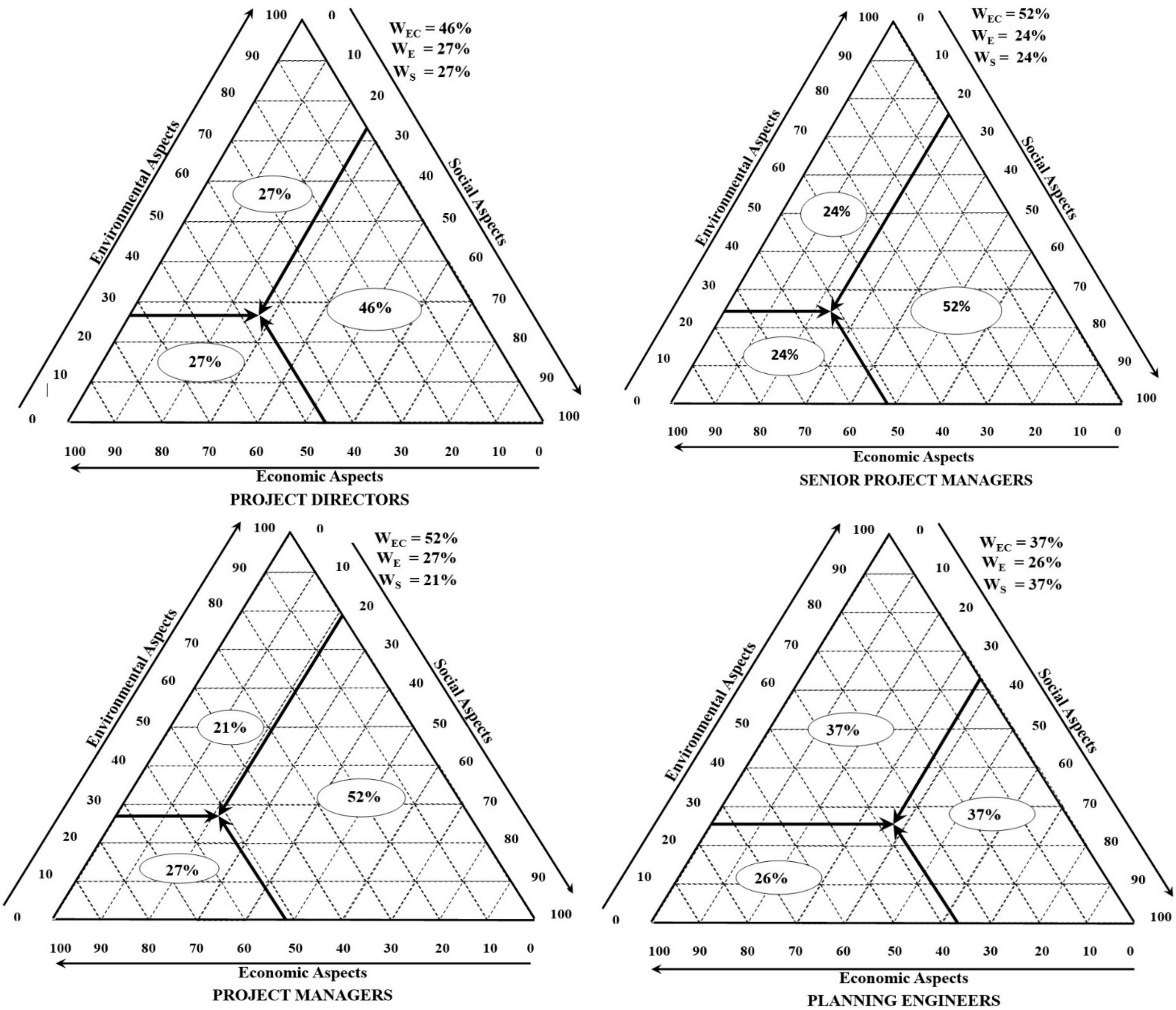

Figure 6. Pair comparison analysis of sustainability aspects. Source: own elaboration.

The social and environmental aspects are different in our study; they are considered equally important aspects, whereas in other studies, the social aspects are lower ranked.

The respondents "senior project managers" and the "project directors" gave equal ratings and importance to both aspects. The "planning engineers" classified the social aspect higher than the environmental one, given almost the same ranking as the economic aspect. At the same time, the "project managers" ranked it less than the environmental aspect and evaluated the environmental aspect with a weighting score of 27% and the social aspect at 21%. The results emphasize social and environmental responsibility and its implementation in the countries selected for the research. Furthermore, the results show that respondents were familiar with the tools and had skills in several projects (Table 1) where these tools were used to assess sustainability. Consequently, adequate assessment and monitoring of projects through the sustainability aspects and their indicators enhance the sustainable development of cities' infrastructures.

Certainly, the study also noticed several opinions in prioritizing the sustainability indicators and aspects. There may be dialogues between experts to reach a common consensus on the highly substantial indicators. In disparity with previous research work, our study noticed that the social sustainability indicators were very substantial, and some respondents gave additional weight to environmental sustainability indicators. This is conceivably because we have chosen more practical and relevant indicators in the category of social aspects. Producing quantitative and qualitative information and stakeholders' inputs comprehensively improves transparency and develops understanding, building consensus and reducing uncertainty among stakeholders.

5. Conclusions

The assortments of infrastructure systems have an enormous influence on the framework of urbanization. Infrastructure projects perform main roles in socioeconomic and environmental activities, especially in emerging countries. Their sustainability management should be appropriately evaluated while pondering implementation. Sustainability in infrastructures involves multi-dimensional practices that involve interdependency between sources, environmental and social aspects of a system, unified aims, and objectives that depend on stakeholders' dynamic behaviors. Therefore, a holistic assessment structure is required that integrates the different dimensions of sustainability and the dynamic behavior of various stakeholders. Furthermore, the correct quantification of the sustainability of infrastructure systems is managed through accurate indicators that embrace all the pillars of sustainability.

This study aimed to address the question of the most relevant sustainability criteria for infrastructure projects by focusing on the Gulf states. In other words, the objective of our research is to propose a cohesive, hierarchically incorporated structure of sustainability indicators to be applied to the assessment of infrastructure projects' sustainability in the context of Gulf states, as in the literature no prevailing comprehensive framework comprising the main three aspects of sustainability was found in the Gulf states context. Therefore, this work created a collection of key sustainability indicators for evaluating the infrastructure systems' sustainability. The indicators found are very practical and useful in describing environmental and socioeconomic concerns required for sustainable urban infrastructure systems. We examined the survey results to determine the experts' perception of sustainability aspects and the implication of indicators based on four chosen elements "Importance", "Practicality", "Reliability", and "Relevance". The elements were chosen to evaluate the indicators from all perspectives to be valuable for the sustainability assessment. This study is unique in that it evaluated the indicators according to the four stated elements, and also in that it was carried out in the context of the Gulf states.

This research highlighted that most selected sustainability indicators are highly relevant and important in determining sustainability. Thus, they must be deemed critical for an infrastructure that leads to sustainable urban development. The study implies that the indicators that were important and prioritized using the AHP can be integrated into different infrastructure projects. It will better achieve the goal of urban development from the infrastructure side. Furthermore, this could be a practical and useful decision-making tool for the construction industry and infrastructure policymakers because it ranked all the indicators corresponding to their potential to enhance the sustainability of infrastructure in the context of urbanization. Thus, policymakers could put their existing resources on these indicators and achieve major development in sustainability.

In this investigation, certain limitations occur which ought to be deciphered in future research. First, the survey was fulfilled by a small number of experts, i.e., (a) project directors, (b) senior project managers, (c) project managers, and (d) planning engineers. Thus, in future research, the researchers can consider various groups of construction experts who could improve the hierarchical structure of criteria and define the significance of sustainability indicators. Second, the suggested structure of sustainability indicators is constrained to the assessment of infrastructure projects in the context of Gulf states, specifically Saudi Arabia and the UAE. Thus, for the assessment of other sorts of projects in the context of other countries, individual structures must be developed. Third, in future research, the established hierarchical structure of sustainability indicators should be verified in the assessment of a real developmental project.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/su142214717/s1, AHP Analyses.

Author Contributions: Conceptualization, K.K. and K.S.D.; methodology, K.K.; software, K.K.; visualization K.S.D. and I.D.; formal analysis, K.K.; writing—original draft preparation, K.K.; writing—review and editing, K.K., K.S.D., I.D. and G.I.; supervision, K.S.D. and G.I. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data was collected through a questionnaire survey during the Ph.D. research period at the University of Tokyo and can be requested from the corresponding author.

Conflicts of Interest: The authors declare no conflict of interest.

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