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Research Article

Value Creation Assessment Tool for Green Buildings: Development and Implementation

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Green buildings are predestined for the sustainability of arid regions. Presently, professionals working on building construction projects have no assessment tool that integrates value creation and associated risks in the development phase to enhance the value created by green buildings. The present study developed and tested a value creation assessment tool to evaluate the total added value and associated risks that can impact the created value by green building design. The tool consisting of 51 performance value drivers and 35 risk factors was tested on three different buildings in Saudi Arabia. Using a questionnaire survey, each of these projects was scored by its value engineering team and weighted mean scores (Wms) as percentages were calculated. The study revealed that the environmental driver was given less importance in the design process with Wms of less than 60% for all three types of buildings, while the functional driver was given higher importance with Wms of 80% or more. All the buildings showed moderate financial risks ranging between 40 and 50% and a higher potential of management risks with scores around 60% or higher. A wide variation between 20 and 60% was observed for operational risks. The study also found that large-scale buildings are less threatened by financial risks. The developed tool will facilitate the stakeholders and designers in identifying project development contextual issues and provide opportunities to optimise the design and operations to enhance performance efficiency and obtain more value from investment in GB assets during the early stages of development in Saudi Arabia and elsewhere.

1. Introduction

Green buildings are designed, consructed, and operated with minimum environmental impacts for long-term sustainability. In the recent past, the global construction industry has acknowledged the substantial benefits of value management without compromising the quality and function of sustainable green buildings, e.g., processes efficiency, waste minimization, and premium price [1–3]. Lützkendorf and Lorenz [4] reported direct and indirect benefits of value created by the green buildings for investors and other stakeholders, including (i) operational cost reduction and improved marketability, (ii) longer useful lifespans, (iii) cash flows stability, (iv) minimal impact of changing environmental legislation stringency, and (v) improved occupant productivity and wellbeing. On the contrary, various types of operational (e.g., failure to consider desired increase in routine maintenance with time), functional (e.g., failure to consider construction implications during design), management (e.g., incorrect time estimate), environmental (e.g., failure to consider obsolescence of equipment impact), and financial (e.g., uncertainty in price increase) risks can potentially destruct the value created by green buildings [5].

The development of green buildings is more complicated compared to conventional ones due to the involvement of multiple stakeholders with different interests, e.g., investors, engineers and design consultants, contractors, equipment and material suppliers, governmental institutions, and the general public [6]. Generally, the investor looks for high financial return and market value, the buyer is interested in comfort and aesthetics, and the designer wants to follow the green building regulations that might lead to high cost. Nevertheless, the investor should be aware of possible legislative changes in the future, which might affect their asset value and their income streams. In addition to defending the economic viability of green buildings, coordination amongst the involved stakeholders becomes challenging for the developer [7–9]. Value management tools improve stakeholders' coordination, develop mutual consent on objectives and definitions, and eliminate redundant costs [10].

Value and risk management improve both of quality and cost of construction. The concept of value appreciates the multitude of dimensions of a project through economic, cultural, and social interpretations [11]. Value management intends to attain the anticipated value with minimal cost without compromising the quality and functions, while risk management evaluates rational strategies to minimise uncertainties to maximise the organization's performance. The indicator of perceived value in construction projects obtained success in the projects that offer risk tolerance, reasonable cost, timely completion, and compliance with quality parameters [12]. The whole life-cycle value exchange mechanisms are risky and complex, so a deeper investigation of the risks associated with value exchange is needed to develop value targets throughout the project's life cycle [13].

Vision 2030 of KSA focuses on the need for sustainable housing and targets related laws and regulations in the near future [14]. There is a need to set up a framework for improving the creation of value during the building development stage in Saudi Arabia by integrating value with project management. The efficiency in delivering value by integrated risk, value drivers, and corporate objectives has the potential to link a project's outcome to the company's strategic objectives. Value analysis and value management are increasingly becoming part of the construction industry's development in the country [15]. Therefore, the Saudi Arabian construction industry will obtain significant benefits from the application of value and risk management in all projects. Presently, there is no exclusive value creation assessment tool that can simultaneously assess the value creation and associated risks in the Saudi Arabian GB construction industry. A framework integrating value and risk has great potential for the application of green building development in order to manage investments in construction projects and ensure the positive contribution of value drivers to the particular business outcomes of products, services, and projects during the life cycle of building assets. The present study specifically aims to (i) develop an assessment tool for assessing value creation in GB development and (ii) apply (test) the assessment tool on real case studies.

2. Literature Review

Although a tangible value in GB might be hard to achieve [3], literature has reported tangible and intangible environmental values provided by GB, such as waste reduction and socioeconomic benefits. Alyami and Rezgui [16] emphasised the importance of social and cultural aspects in a building's design by using environmentally sustainable materials and evaluating their functionality, usability, durability, and reliability. A good building design responds to the site's microclimate and contributes to the environment, which can result in a range of wider socioeconomic [17]. Improving function longevity and productivity enhances the performance, reliability, quality, safety, and life-cycle cost of GB. Such improvements generate additional revenue for the building owner and effectively compensate the additional cost spent on value addition and make more GB initiatives worth the investment. Although GB has strategically attained attraction in most of the countries, a push is yet required from the governments' leadership to promote them at regional and national levels [18].

The perceived value has a multidimensional concept that can be affected by the dynamic nature of risks or benefits [19]. It is important to connect value creation dimensions through the life-cycle stages and measure the impacts of perceived risk on perceived value [20]. A deeper investigation of the risks associated with value exchange is needed. In addition, a substantial disconnect does exist between the builders and investors on how to quantify and validate the value added by GB [8]. Both the value and risk analysis identify project development contextual issues and provide opportunities to optimise the design and operation of GB during the early stages of development. The construction sector in Saudi Arabia did not consider risk management in development projects and identified a need to set up a framework for improving project value by integrating value and risk in the development of construction projects [5].

A variety of assessment tools were used to assess the building design performance. As these tools were applied and used in different countries to meet their local requirements, some of them are not applicable in their original forms for achieving best practices in other regions [21–23]. Due to the importance of environmental sustainability in construction projects, environmental assessment procedures have been developed worldwide since the first attempt by the UK building research establishment environmental assessment method (BREEAM) in 1990 [16, 24]. Subsequent efforts developed tools to specify, predict, evaluate, and measure a building's performance. The main tools for the environmental assessment of buildings are BREEAM, leadership in energy and environmental design (LEED), and the green building tool (GBTool), which can evaluate resource use, ecological impact, indoor environmental quality, and financial and management aspects. The existing tools have some limitations, such as avoiding the financial aspects, complexity, regional variation, and the use of weighting mechanisms [24–26]. The constructs of these tools significantly vary based on the interests of the involved parties. For instance, the owners are more interested in financial returns, while the occupants are concerned with health and safety and indoor environment [27]. These interests should be taken into consideration in the design of the assessment tool to ensure its success [25].

In general, an assessment tool consists of three main components, including assessment criteria and subcriteria, criteria scoring and weights estimation, and criteria aggregation to generate an overall sustainability score [24, 28–31]. Finally, the assessment tool has to be validated with a practical application [32]. Although similarities exist amongst different assessment tools in terms of their aims, structure, and approach, they differ as well in terms of scope, metrics, and standards [33]. Nevertheless, an assessment tool should be simple, practical, and flexible and covers all the required aspects in the context of the assessment.

To date, many versions of BREEAM have been developed for different regions, such as BREEAM Gulf/Middle East which is used in Saudi Arabia and HK-BEAM, which give the BREEAM tool a strong and mature system [16, 24]. However, it has been criticised for its limited transparency [24, 30]. Alyami and Rezgui [16] stated that there is a strong similarity between the criteria of BREEAM Gulf/Middle East and BREEAM-UK, with few modifications due to the differences between the socioeconomic and environmental conditions of the two regions. In addition, the LEED system is based on ISO standards which are not aligned with European standards [24]. Zou [34] evaluated LEED and 3-Star rating systems based on their potential for GB assessment and found LEED more appropriate for commercial and industrial buildings, while 3-Star was found to be a more suitable choice for residential buildings. Therefore, it can be said that the region, culture, and type of building should be considered in the development of a new assessment tool.

Although there are some similarities in the assessed categories, each assessment system has its speciality in the weighting mechanisms and the rating scales. For instance, some differences and similarities between BREEM and LEED are as follows [24, 30]:

(i) BREEAM: the evaluation categories are management, health and wellbeing, energy, transport, water, materials, land use, ecology, pollution, and innovation. It uses a percentage score for rating: <30% Unclassified, ≥30% Pass, ≥45% Good, ≥55% Very good, ≥70% Excellent, and ≥85% Outstanding.

(ii) LEED: the evaluation categories are sustainable sites, water efficiency, energy and atmosphere, indoor quality, materials and resources, innovation, and regional priority. It uses a point score for rating: 40–49 points Certified, 50–59 points Silver, 60–79 points Gold, and 80 points and above Platinum.

The GBTool is one of the most comprehensive evaluation tools. As it covers most of the evaluation categories that are either ignored or poorly mentioned in other assessment tools, including resource consumption, loadings, indoor environmental quality, quality of service, economics, management, and commuting transport, the tool can be applied in different regions, with some adjustments [35]. However, users may face difficulties in using GBTool due to the inherent complexities of its framework.

CASBEE, developed in Japan, distinguishes between the building environmental loading and building environmental quality and performance [26]. CASBEE consists of four main aspects, energy and resources efficiency, and local and indoor environment, which are categorised into two groups, loading and quality [16]. Determining the building's environmental efficiency by scoring the groups separately and then calculating the ratio of environmental quality to building environmental performance differentiate this tool from others. CASBEE's weakness is related to its specific regional character, i.e., it is for Japan and its national standards [24].

The design quality indicator (DQI) supported by the construction industry council in the UK has been used as a complementary system for measuring performance in construction and aims to capture the perceptions of design quality associated with buildings. The DQI consisting of three main building assessment categories, including function, build quality, and impact, enables the client to define their aspirations that obtain the project's success and then measures the project success against these aspirations [25, 26, 31, 36]. The DQI assesses a wider range of considerations than other building environmental assessment tools, so it can be considered one of the most useful tools to improve the design, functionality, and sustainability of a building [31].

The following theoretical and practical gaps still exist to assess the GB design in the existing assessment tools [21]. The gaps in available tools are (i) dimensionality of performance value drivers, (ii) no consideration of the risks impacting value creation, and (iii) no integration between the value creation drivers and the associated risk factors. Most of the existing building performance assessment tools, such as DQI, use a hierarchical framework consisting of criteria at the top of the hierarchy, subcriteria in the middle, and indicators as the main building blocks. The value assessment tool developed in the present research also adapts points and percentages as a rate to assess the performance of value creation aspects, similar to BREEM and LEED.

Recognizing the research gap, authors [37] in their previous study identified 98 performance value drivers (PVDs) from the literature, evaluated them through a hand-delivered questionnaire survey and statistical analysis, and finally selected 51 most important PVDs to cover the five primary value creation drivers (VCDs), including financial, functional, operational, environmental, and management of a green building. In the subsequent research, Alattyih et al. [5] examined various risks that may lead to GB value destruction in KSA. In this research, they identified 66 potential risk factors from the reported literature and conducted a hand-delivered questionnaire survey to 300 practitioners (managers, engineers, and architects) having knowledge of value engineering in the construction industry. The SAVE International reported over 1,350 people in KSA with value engineering certificates [38]. It was also found that out of around 8800 certified professionals worldwide, around 16% were from KSA at the time of the study. For the confidence interval and confidence level of 10% and 95%, respectively, the research demanded at least 76 respondents from the population of 1,356. To overcome the problem of nonresponsiveness, the questionnaire was sent to 300 professionals (sample size) serving the KSA construction industry. Based on an overall response rate of 29.7%, the 35 most significant risk factors were finally grouped into 5 clusters, i.e., 8 in functional risk, 13 in financial risk, 3 in operational risk, 3 in environmental risk, and 8 in management risk cluster. The study enhanced the understanding of the importance of the risk factors' impact on value creation in KSA. Readers interested in the detailed selection process of PVDs and risk factors are referred to Alattyih et al. [37] and Alattyih et al. [5].

The present research developed a tool for assessing value creation in green building development and associated risks. For evaluating pragmatism, the tool has been applied to three real case studies (buildings) in Saudi Arabia. The assessment tool can provide a unified platform for all the stakeholders for the development and application of value management of green buildings in KSA.

3. Methodology

3.1. Methodological Framework. Figure 1 presents the methodological framework developed in the present study. The assessment tool for value created by green building design was developed and integrated based on a critical literature review, extracting value attributes, refining them, and comparing the methodology of existing tools. Five primary VCDs were developed to cover the financial, functional, operational, environmental, and management aspects of a green building. Based on a questionnaire survey followed by detailed statistical analysis, the 51 most important performance value drivers (PVDs) were selected for GB design in KSA. PVDs were also grouped into ten subcriteria (two under each VCD), including capital expenditure cost (CAPEX) and operating expenditure cost (OPEX), longevity, reliability, manageability, energy and efficiency, ecoresources, adaptability, control, and planning. Likewise, the 35 most significant risk factors that can destruct the value of GB were selected for the same (as VCDs) five risk categories from the response of experts in the country. The questionnaire consisting of the list of identified PVDs and risk factors was hand-delivered to 300 practitioners (managers, engineers, and architects) having knowledge of value engineering in KSA. An overall response rate of around 30% was obtained [5, 37].

The weights of all the PVDs (and VCDs as a whole) and the risk factors were established using the DQI weighting mechanism. Subsequently, the assessment tool was applied to three GB in KSA. Professional responded to the following two questions, related to the selected PVDs and the risk factors, using the Likert scale from "0" corresponds to "not implemented" and "5" to "highly implemented": (i) To what extent are the following indicators (PVDs) considered and implemented in this design? and (ii) To what extent is the value creation in the design of this project impacted by the following risk factors? For the second question, "0" corresponded to "not impacted" and "5" to "highly impacted." Finally, the scores and weights were aggregated to estimate the total gained score for each subcriteria and risk category and the weighted mean scores. Details for all the steps are given in the following subsections.

3.2. Selection of Indicators. First of all, lists of controllable value attributes were extracted in each one of the five VCDs. A questionnaire survey is a fast and effective technique for collecting statistical data and opinions [39]. Therefore, the most important attributes were examined by sending a questionnaire to the relevant professionals possessing knowledge and experience of value engineering applications in the KSA's construction industry to rate the level of importance of each value attribute to value created by green building design. After that, the most effective value indicators were extracted through statistical analysis followed by data ranking, factor analysis, and data reduction techniques. The value creation indicators were identified in each component, and then the components were grouped into clusters based on their relation to each other. The data reduction technique analysed the value attributes and removed the redundant data in order to reduce the number of attributes. The most effective indicators for value creation were 10 financial indicators distributed into two clusters (OPEX and CAPEX); 18 functional indicators distributed into two clusters (longevity and reliability); nine operational indicators distributed into two clusters (manageability, energy, and efficiency); eight environmental indicators distributed into two clusters (ecoresources and adaptability); and six management indicators distributed into two clusters (control and planning). Details can be seen in Alattyih et al. [37]. Later, Alattyih et al. [5] identified the most effective risk factors that can impact the value created by GB. These include 13 financial risk factors, eight functional risk factors, three operational risk factors, three environmental risk factors, and eight management risk factors.

Authors in their past studies used analysis of variance (ANOVA) to statistically differentiate the responses of the respondents. The Statistical Package for the Social Sciences (SPSS) software examined the importance of PVDs defined by different groups. The following anticipated hypothesis for a significance level of 0.05 was established for PVDs selection [37]:

(i) H_0: $p > 0.05$. There is no significant difference among the respondents' ratings for the importance of the PVDs
(ii) H_1: $p < 0.05$. There is a significant difference among the respondents' ratings for the importance of the PVDs (at least one of the groups is significantly different from other groups)

The following hypothesis for the selection process of risk factors was adopted [5]:

(i) H_0: $p > 0.05$. There is no significant difference among the respondents' ratings for the likelihood of risk factors impacting the value created by green building design
(ii) H_1: $p < 0.05$. There is a significant difference among the respondents' ratings for the likelihood of risk

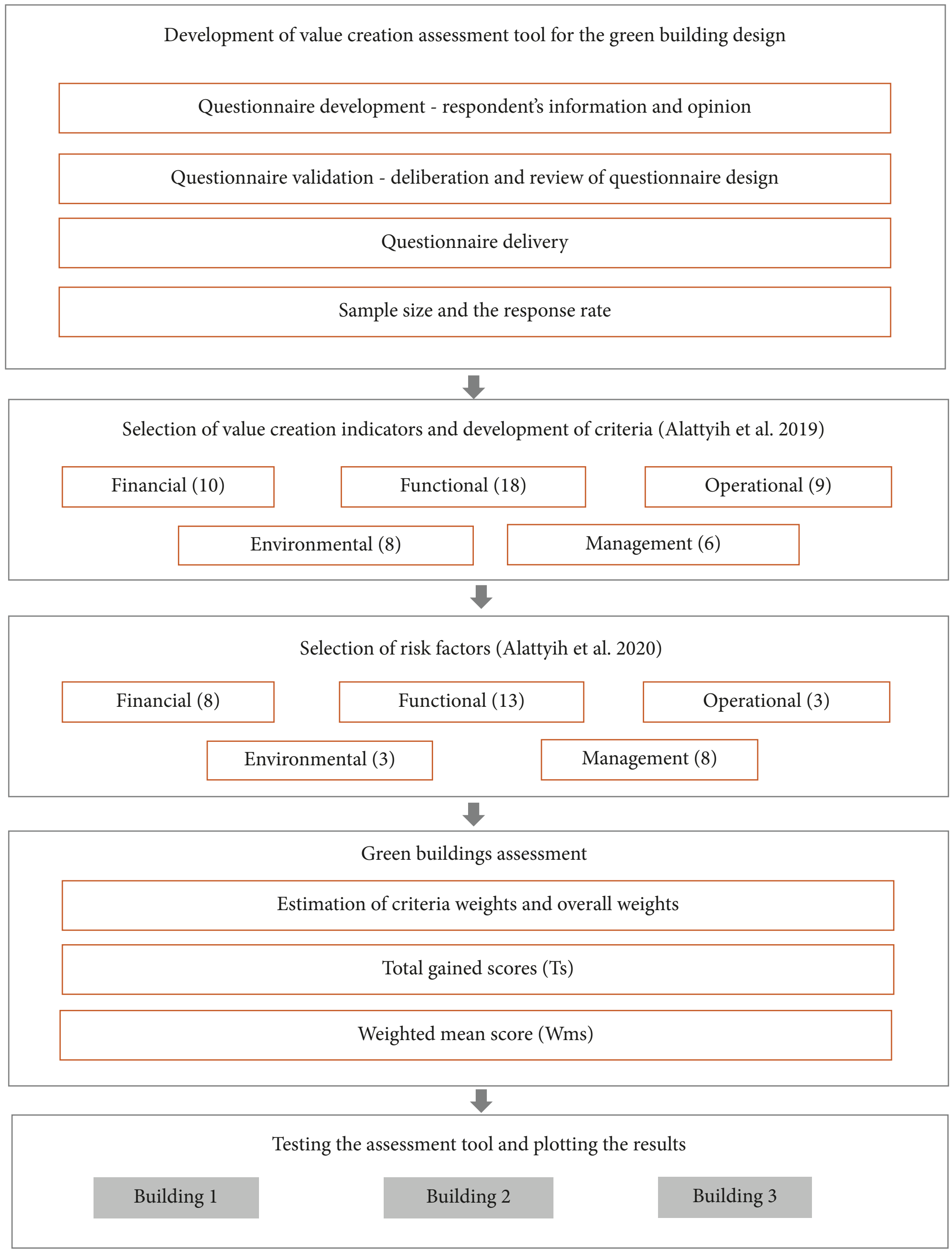

Figure 1: Methodological framework for value creation assessment tool.

factors impacting the value created by green building design (at least one of the groups is significantly different from other groups)

Later, a follow-up test (Turkey test as post hoc multiple comparison test with uneven sample size) carried out multiple comparisons to recognize the significant differences among the respondents.

3.3. Weighting System. The weighting system was applied to estimate the weighting value for each indicator based on its impacts or importance within each group. The weighting factors obtained the priorities of each factor to find out performance scores at different levels of the hierarchy [40]. The main value groups in the tool are financial performance, functional performance, operational performance, environmental performance, and management performance. The clusters are OPEX, CAPEX, longevity, reliability, manageability, energy and efficiency, ecoresources, adaptability, control, and planning. The main risk groups are financial, functional, operational, environmental, and management risks.

A simple and easily understandable questionnaire was developed for the participants in the design process. The questionnaire structure encompassed three main aspects of the framework, including VCDSs (groups), clusters, and controllable attributes (PVDs and risk factors). The questionnaire hierarchy consisted of statements assessed by using a scale, from strongly disagree to strongly agree or not applicable. The participants' scores obtained the weights for each group, cluster, and attribute. The weighting system estimated the weighting value for each attribute based on its impacts or importance within each group. The weighting factors helped to obtain the priorities of each attribute and to find out an accurate rating for the overall performance [40]. The most important part of the assessment process was the weighting coefficients, which were determined through a questionnaire survey in order to gain opinions from users who are suitable for the specific regional conditions. The weighting system used in this assessment made the total summation of all indicators equal to 100%. Details on the selection of professionals and the methodology used to develop and validate the questionnaire survey can be seen in Alattyih et al. [37].

Supplementary materials 1 and 2 show the overall weight for each indicator. Based on the results of the questionnaire survey and the scientific approach of statistical analysis of data ranking, factor analysis, and data reduction, the optimum value created green building design consists of 19.07% financial performance, 35.49% functional performance, 17.66% operational performance, 15.66% environmental performance, and 12.12% management performance. The risk factors that might destroy the value created by green building design consist of 37.09% financial risks, 23.19% functional risks, 8.50% operational risks, 8.00% environmental risks, and 23.23% management risks. The weighted values were calculated through the average weighted mean for each indicator based on its value performance criteria. Then, the overall weight for each indicator was calculated so that the total summation of all indicators is equal to 100%, as shown in the following equations:

$$\text{criteria weight} = \frac{\text{indi cator average weighted means}}{\sum \text{criteria indi cators average weighted means}}, \tag{1}$$

$$\text{overall weight} = \text{criteria weight} \times \text{criteria percentage}. \tag{2}$$

Equations (1) and (2) help the designer and the value engineering team to evaluate the level of design performance and value created by a green building design throughout the design process.

3.4. Scales and Scores. In the present study, the scoring system for the value created by the green building design assessment tool was developed and was similar to the scales used by BREEAM and LEED. Moreover, a similar 5-Likert scale has been frequently used in several past studies on the sustainability of green buildings [41, 42]. The value created by the green building design assessment tool was tested by asking value engineering professionals to evaluate the building design related to one of the value engineering projects designed by their practice by asking them to what extent the selected indicators were considered and implemented in this design. The scale adopted for the value indicators goes from 0 not implemented to 5 high implemented, with 3 being considered, whilst the scale adopted for the risk factors goes from 0 no impact to 5 highly impacted, with 3 being moderately impacted.

The score computing method is initiated by giving each value creation scale separately; these are called indicator scales (ISs) and should be identified based on the respondents' rating for each indicator. Then, the score was calculated by multiplying each IS by the given overall weight (Ws) for the same indicator, and then all gained scores were summed together to obtain the total gained score, as shown in the following equation:

$$\text{total gained score}\,(Ts) = \sum_{i=1}^{n} I.S. \times Ws. \tag{3}$$

Then, the result of *Ts* is divided by the total weight multiplied by 5, which is the highest scale for each indicator. Finally, the result was multiplied by 100 in order to obtain a percentage result for each cluster and for all performance criteria, i.e., weighted mean score (Wms), as illustrated in the following equation:

$$\text{Wms} = \frac{Ts}{\sum_{i=1}^{n} W \times 5} \times 100. \tag{4}$$

3.5. Plotting the Results. The assessment tool for value created by green building design developed visualisation of the outputs of the tools by graphical representation of the results to be easy to read and interpret. A spider diagram represents the scores scaled between 0 and 100. This graph displays the selected participants' answers to each section. A result further shows out a higher weighted mean score, which gives the client and the design team a better overview of the evaluation of the design and enables them to check the achieved added value for the building's s performance. The idea of the graph is to assess how well a building or design is thought to have performed in relation to value creation in each section and look at the risks associated with each group. This assessment tool shows three graphs for data sets of main groups and subgroups, i.e., clusters.

4. Results and Discussion

4.1. Results. As part of the development process testing, the assessment tool needs to be tested through pilot studies in order to refine it if required. Therefore, the tool was tested on three buildings in KSA to evaluate the pragmatism of the proposed assessment tool. Three buildings were selected where value engineering had been applied during project development. The assessment tool was sent to the members (participants) of the value engineering team for scoring each value creation indicator. They were then asked to assess the level of consideration or implementation of each indicator. The design quality indicator equation was adopted to calculate the gained scores. Each value creation group was given a code as follows: financial value creation indicator VFI, functional value creation indicator VFU, operational value creation indicator VOP, environmental value creation indicator VEN, and management value creation indicator VMA. The highest points can be obtained from $\sum VFI + VFU + VOP + VEN + VMA = 500$ points. The value creation assessment tool $= \sum (VFI + VFU + VOP + VEN + VMA) \div 500 \times 100$, and it can calculate each value creation group and cluster separately as required. Table 1 presents the value creation and risk impact rating results, which are adapted based on the BREEAM and LEED rating systems. This table evaluated the total value created by green building design. The value engineering team and the client can find out to what extent the design has brought value to the project. The following subsections apply this assessment tool to some projects and check the value obtained.

4.1.1. Building 1: A Multistorey Hotel. The first building was a hotel in Riyadh City. This multistorey commercial building has two basements, one ground floor, four upper floors, and a parking facility. In addition, it has lounges, a women's banqueting hall, cafeteria, courtyard and landscaping, wet area, restaurant, spa, swimming pool, sauna, meeting rooms, business centre, suites and studio suites, studios, and family apartments. The total cost of the project was estimated to be SAR. 167 million (44.5 million USD). The purpose of the study was to define the functions of different facilities to generate other alternative solutions and recommendations to optimise the project's total cost, and the VE team identified the following objectives during the introduction process:

(i) Confirm required performance and functional requirements
(ii) Reduce overall project cost without compromising necessary functions
(iii) Optimise the design by refining all systems
(iv) Standardise the components of the project for easier operation and maintenance during the life cycle of the project
(v) Enhance project value and quality
(vi) Maintain required aesthetic
(vii) Confirm use of new technology in all selected systems

The assessment tool was applied to all three buildings. The results for Building 1 are presented in Tables 2 and 3. Figures 2(a)–2(c) illustrate the scores in the form of spider diagrams scaled between 0 and 100. The results in Figure 2 present the value groups plots value, clusters plot results, and risk group plot results. Figure 2(a) illustrates that the PVDs under the subcriteria OPEX, longevity, reliability, manageability, and control were considered in the design process more (>70%) than CAPEX (68.13%), energy and efficiency (65.14%), and ecoresources (63.9%). Adaptability and planning were given the least importance in the design performance with Wms less than 50%. The results presented in Figure 2(b) finally yield a low overall performance of environmental and management drivers. Figure 2(c) presents the results of the risk assessment tool for building 1. The figure depicts that environmental risks impacted the value creation most (80%) during the design process, followed by functional risks (69.7%). Table 4 shows that the overall rating result for the value created by Building 1 would be an added value with a neutral risk impact.

4.1.2. Building 2: An Office Building. The second building was an office building in Riyadh that comprised three basement floors with car parking area for 168 cars, two water tanks, and filtration and treatment units. There were eight floors above ground: ground floor (entrance/technical/control), three floors of rentable spaces, four floors for offices, and the last floor for socialising. The VE results grant significant cost saving in various disciplines as well as adding some extra costs to improve the project value. Since frequently the VE savings are not cumulative, as some ideas are alternatives, therefore, it is estimated that the best implementation will yield an initial net saving of SR 47,535,939, which represents 34% of the total project cost, which is estimated to be SR 139,100,888, in addition to life-cycle cost saving of SR 499,120 per year. Tables 5 and 6 present the value and risk assessment results.

Figures 3(a)–3(c) illustrate spider diagrams to represent the assessment scores scaled between 0 and 100. In this project, only the PVDs for functional performance were given desired importance during the design process, i.e., Wms = 80%. Operational performance was also considered that obtained a Wms of around 70%. The planning PVDs were not considered in the design process at all, which yielded "zero" Wms for this subcriteria. Based on the overall Wms, the financial performance is low (36.53%). Similar to Building 1, environmental and management VCDs obtained the least performance scores less than 30%. The risk assessment tools revealed that the value creation in Building 2 during the design process was mostly impacted by management (60.6%), functional (50.23%), and financial (47.97%) risks. The overall rating result for the value created by this project would be moderate value with a neutral risk impact, as shown in Table 7.

Table 1: Value creation and risk impact rating result.

Value creation rate	Risk impact rate	Respondent score			Weighted respondent score	
		Points for value drivers	Points for risk factors	Percentage (%)	Points	Percentage (%)
No value	No risk impact	0–51	0–35	Less than or equal 20	0–100	Less than or equal 20
Low value	Low-risk impact	52–102	36–70	More than 20	101–200	More than 20
Moderate	Neutral	103–153	71–140	More than 40	201–300	More than 40
Add value	High-risk impact	154–204	141–175	More than 60	301–400	More than 60
Excellent value	Extreme risk impact	>204	>175	More than 80	>400	More than 80

4.1.3. Building 3: A Commercial Plaza. The third building project was remodelling an existing residential suites system into a five-star hotel in the northern area of the central area of Al Madinah. The project covered a total land area of 2300 square metres, which was owned by a local real estate development, which is a shareholding company with a capital of three billion riyals and a branch of one of the leading real estate companies in KSA.

Before development, the status of the building was a commercial and residential centre with a system of residential suites consisting of 14 typical floors, which constitute 182 residential apartments and one ground and commercial floor and four basements that were used as parking and services. The project was designed to transform the centre into a five-star hotel consisting of 598 rooms. The study took place to transform 13 typical floors from a residential apartment system into a hotel room system. After development, the first floor was transformed into a restaurant with the addition of a kitchen to the fourth basement floor. New entrances have been added to the ground floor towards the two main streets with the expansion of the reception. Tables 8 and 9 present the value and risk assessment results.

The value engineering focuses on architectural, structural, mechanical, and electrical disciplines and transmitting and developing the function of the building from the furnished apartments system into a 5-star hotel room system. Figures 4(a)–4(c) illustrate the spider diagrams showing the results of the assessment tool for Building 3. As the building intends to serve the customers with a high level of service, the functional performance obtained the highest Wms of 96.2%, followed by operational (79.89%), management (76.78%), and financial (73.8%). Although the environmental performance was not given sufficient (42.87%) importance, it is higher than the other two buildings. The results of the risk assessment tool in Figure 4(c) describe management risks at the top (62.79%), followed by environmental (47.57%) and operational (46.76%). Functional risks relatively less (20.39%) impacted the value creation in the design process. The overall rating scores given in Table 10 show that this project adds value with neutral risk impacts.

4.2. Discussion. The proposed tool's potential for value-creating assessment of GB has been demonstrated in the three case studies. The assessment tool was created based on a combination of features reported in the literature. The adopted method uses scores and weights (most of the existing tools do not use weights) to compute indicators for value creation and risks. An excellent project that includes most of the features that contribute to value creation should have a 100% score in each of the five value creation indicators. At the same time, such a project should have the lowest risk scores for each of the five categories so that the value created is preserved. For example, the testing carried out on building one showed that the project performed well in functional performance as compared to other value creation indicators. Furthermore, the project performed very well in relation to mitigating environmental risks but not well in including strategies to mitigate possible financial risks. By using this type of information, designers and consultants would be able to optimise the design to improve the building's performance, leading to value creation and preservation. It is well accepted that every building project has opportunities to improve the value, and the proposed tool has the objective of identifying those opportunities. Value is improved and optimised by taking into consideration the value creation indicators while reducing or mitigating the risks that can destroy value creation. There were numerous options and opportunities for implementing value creation during the evolution of the green building development process. The developed tool is based on a DQI methodology which was tested widely in the UK construction industry sector. The study results demonstrated how some aspects of value creation were not taken into consideration during the design of the test buildings. With further development and refinements, the tool can be used to assist in optimising value creation during the early stages of green building development projects.

The majority of existing tools are concerned with the assessment of the environmental performance of a building design in the early design phase of building development. The underlying theme of these assessment tools is assessing how a building performs throughout its life cycle in relation to its environmental impacts. It has been pointed out that these assessment tools aim to answer the following questions [43]:

(i) What was the basis for environmental design decisions?

(ii) What was the method of assessment?

(iii) Have the environmental impacts of the consumption of materials, energy, water, and other resources been considered?

Table 2: Building one value assessment tool results.

To what extent are the following indicators considered and implemented in this design? 0 not implemented ← 3 considered ⟶ 5 highly implemented				Weight	Scale	Total points	Scores gained	Cluster Wms (%)	Group Wms (%)
		VFI11	Maximise residual value	1.83	2		3.66		
		VFI6	Increase economic lifetime	1.96	4		7.85		
	OPEX	VFI15	Optimise risk-return ratio of alternative options	1.82	5	19	9.10	76.17	
		VFI2	Efficiency of operational expenditure (OPEX)	1.99	4		7.95		
Financial performance 19.07%		VFI5	Improve economic efficiency	2.00	4		8.00		72.15
		VFI3	Maximise the cost efficiency to build	1.89	4		7.56		
		VFI1	Efficiency of capital expenditure (CAPEX)	1.99	4		7.97		
	CAPEX	VFI12	Minimise cost of capital	1.87	2	17	3.74	68.13	
		VFI4	Deliver/achieve cost certainty	1.88	3		5.63		
		VFI9	Return on investment	1.84	4		7.35		
		VFU26	Provide functional ability of the foundation's requirements (strength and stability)	1.92	3		5.74		
		VFU27	Ensure substructure functional requirements meet a satisfactory level of performance	1.91	3		5.73		
		VFU28	Ensure superstructure functional requirements meet a satisfactory level of performance	1.92	4		7.68		
	Longevity	VFU2	Increase life of services	2.04	4	27	8.16	77.42	
		VFU3	Provide function-fitness for purpose	2.04	5		10.2		
		VFU23	Configure design to enable an efficient construction process	2.00	4		8.02		
Functional performance 35.49%		VFU24	Ensure construction efficiency is considered in specification	1.97	4		7.87		79.64
		VFU19	Maintain security-health and safety	1.93	3		5.79		
		VFU21	Meet all statutory requirements and building regulations	1.97	4		7.89		
		VFU22	Ensure designed elements are standardised	2.05	4		8.21		
		VFU20	Suitability and maintainability of materials	2.03	4		8.14		
		VFU15	Provide durable building-last longer	1.93	4		7.72		
	Reliability	VFU14	Assure convenience	1.99	5	45	9.93	81.87	
		VFU18	Create reliable building-safer	1.97	4		7.89		
		VFU1	Maintain adaptable building-useful to all	2.00	4		8.02		
		VFU8	Increase efficiency-add capacity	1.91	4		7.64		
		VFU13	Provide disability access	1.97	5		9.84		
		VFU16	Maintain durability	1.93	4		7.70		

Table 2: Continued.

To what extent are the following indicators considered and implemented in this design? 0 not implemented ← 3 considered ⟶ 5 highly implemented				Weight	Scale	Total points	Scores gained	Cluster Wms (%)	Group Wms (%)
Operational performance 17.66%	Manageability	VOP8	Easy to operate	1.92	4	19	7.68	76.03	70.59
		VOP6	Easy to maintain	1.91	4		7.62		
		VOP9	Easy to inspect and maintain	1.90	3		5.69		
		VOP11	Provide building systems that are easy to operate and control	1.91	4		7.62		
		VOP15	Reduce operational risk	1.92	4		7.68		
	Energy and efficiency	VOP1	Reduce/minimise/save energy usage	2.09	4	13	8.35	65.14	
		VOP2	Maintain efficiency in terms of energy	2.12	3		6.36		
		VOP3	Increase efficiency of utilities	1.94	3		5.83		
		VOP4	Increase efficiency of heating, cooling, and lighting	1.96	3		5.89		
Environmental performance 15.66%	Ecoresources	VEN5	Increase use of natural ventilation	1.98	4	16	7.93	63.9	55.4
		VEN3	Provide indoor environmental quality	1.98	4		7.93		
		VEN4	Access to natural light, management of air quality, and temperature	2.03	2		4.07		
		VEN7	Specifying low-maintenance, durable, environmentally preferable materials, and equipment	1.99	3		5.94		
		VEN10	Minimise consumption of resources	1.91	3		5.73		
	Adaptability	VEN8	Maximise resource reuse	1.89	2	7	3.78	46.91	
		VEN12	Respond to site microclimate	1.88	2		3.76		
		VEN11	Conserve water resources	1.99	3		5.97		
Management performance 12.12%	Control	VMA10	Able to construct to scope/cost/budget/schedule/quality	1.97	4	11	7.89	73.32	60.75
		VMA11	Completed to specification	2.04	4		8.12		
		VMA6	Produce effective plans to achieve the project objectives	2.01	3		6.03		
	Planning	VMA3	Create strategic planning	1.98	2	7	3.96	46.98	
		VMA1	Provide effective project management and delivery	2.13	3		6.39		
		VMA5	Provide cost control to achieve the project objectives	1.99	2		3.97		

Table 3: Building one risk assessment tool results.

To what extent is the value creation in the design of this project impacted by the following risk factors? 0 no impact ← 3 moderately impacted ⟶ 5 highly impacted			Weight	Scale	Total points	Scores gained	Cluster Wms (%)
	*R*11	Failure to recognise cost-value mismatches	2.789	2		5.58	
	*R*10	Failure to identify cost-value relationships	2.764	2		5.53	
	*R*8	Failure to consider the cost of losing potential revenue	2.822	3		8.47	
	*R*12	Failure to appropriately locate cost-to-function allocation	2.797	2		5.59	
	*R*9	Uncertainty about prices	2.805	2		5.61	
	*R*5	Inappropriate cost evaluation criteria	2.888	2		5.78	
Financial risks 37.09%	*R*6	Failure to consider future operational costs	2.896	2	31	5.79	47.79
	*R*3	Failure to consider implication of economic conditions	2.789	2		5.58	
	*R*1	Insufficient funding	2.995	1		2.99	
	*R*7	Failure to recognise cost as resource expenditure	2.822	1		2.82	
	*R*65	Incorrect estimated cost of maintenance	2.937	4		11.75	
	*R*63	Incorrect cost estimate	2.986	4		11.95	
	*R*66	Incorrect estimated cost of energy used	2.797	4		11.19	
	*R*20	Failure to consider construction implications during design	2.805	5		14.03	
	*R*19	Failure to design to brief/specification	2.773	4		11.09	
	*R*17	Failure to examine specifications due to unnecessary expense	2.838	4		11.35	
Functional risks 23.19%	*R*33	Failure to integrate the various systems to achieve the lowest life-cycle costs	2.797	3	28	8.39	69.68
	*R*21	Design changes	2.962	3		8.89	
	*R*22	Redesign/rework	2.962	3		8.89	
	*R*35	Failure to identify low-value, long-lead-time items	3.102	3		9.30	
	*R*36	Failure to consider design risks	2.954	3		8.86	
	*R*44	Failure to consider increase in routine maintenance	2.830	3		8.49	
Operational risks 8.50%	*R*45	Failure to consider increase in life-cycle replacement	2.797	3	9	8.39	60.00
	*R*39	Failure to consider design impact on operating efficiency	2.871	3		8.61	
	*R*38	Failure to consider obsolescence of equipment impact	2.674	4		10.70	
Environmental risks 8.00%	*R*43	Failure to consider maintainability and reparability impact	2.567	4	12	10.27	80.00
	*R*47	Failure to consider implication of environmental risks	2.756	4		11.02	
	*R*49	Poor project management	2.929	3		8.79	
	*R*50	Poor definition of the scope and objectives of projects	2.805	2		5.61	
	*R*51	Project scope unscheduled items	2.847	3		8.54	
Management risks 23.23%	*R*57	Improper project planning and budgeting	2.871	3	24	8.61	59.91
	*R*53	Lack of coordination and decision making	2.896	4		11.58	
	*R*64	Incorrect time estimate	3.060	3		9.18	
	*R*54	Poor team relationships	2.814	4		11.25	
	*R*28	Poor design that may lead to higher operation costs	3.003	2		6.01	

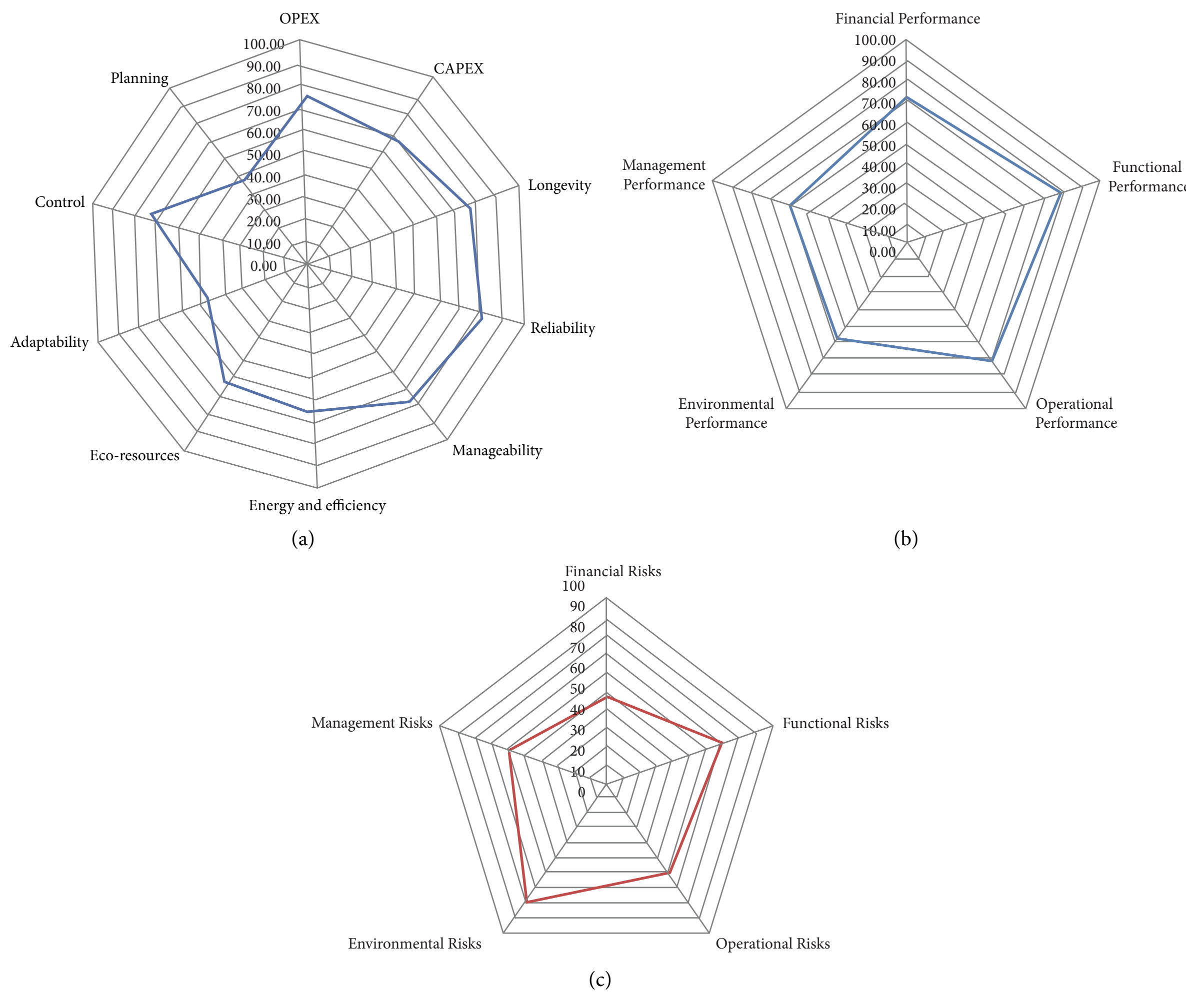

Figure 2: Results of an assessment tool for Building 1, (a) value clusters (subcriteria) plots, (b) value groups (value creation drivers) plot, and (c) risk groups plot.

Table 4: Building one final rating results.

Value creation assessment tool	Building one			
	Respondent score		Weighted respondent score	
	Points	Percentage (%)	Points	Percentage (%)
Value	181	70.98	355.28	71.06
Rating result	*Add value*		*Add value*	
Risk	104	59.43	296.48	59.3
Rating result	*Neutral impact*		*Neutral impact*	

(iv) Will the energy embodied in the building be offset by savings in operational energy over the building's lifetime?

(v) What quantity of greenhouse gas emissions will be generated?

As can be seen from the above list, the scope of the existing tools in relation to value analysis is limited. These tools neither analyse the required functions of the project from a value perspective nor do they aim to evaluate and test the ideas that are most promising for value creation. That is why cost-conscious developers are turning to value engineering analysis as a method to minimise waste and maximise functionality and profitability from building asset development [44]. Value engineering has been used to study and optimise the development of products and services for decades and has been applied successfully in construction project development. However, all project development is associated with several risks. Thus, it seems logical and obvious that a "combination of efficient value management practices and risk management is one possibility to try to avoid the most dangerous risks to realise for planned value" [45]. Thus, this research attempted to elicit VCDs that can be used to aid value engineering analysis become a useable tool

Table 5: Building two value assessment tool results.

To what extent are the following indicators considered and implemented in this design? 0 not implemented ← 3 considered ⟶ 5 highly implemented				Weight	Scale	Total points	Scores gained	Cluster Wms (%)	Group Wms (%)
Financial performance 19.07%	OPEX	VFI11	Maximise residual value	1.829	3	12	5.487	48.63	36.53
		VFI6	Increase economic lifetime	1.963	3		5.888		
		VFI15	Optimise risk-return ratio of alternative options	1.819	0		0.000		
		VFI2	Efficiency of operational expenditure (OPEX)	1.987	3		5.960		
		VFI5	Improve economic efficiency	2.001	3		6.003		
	CAPEX	VFI3	Maximise the cost efficiency to build	1.891	0	6	0.000	24.27	
		VFI1	Efficiency of capital expenditure (CAPEX)	1.991	3		5.974		
		VFI12	Minimise cost of capital	1.872	0		0.000		
		VFI4	Deliver/achieve cost certainty	1.877	0		0.000		
		VFI9	Return on investment	1.839	3		5.516		
Functional performance 35.49%	Longevity	VFU26	Provide functional ability of the foundations requirements (strength and stability)	1.915	5	29	9.575	82.71	80.03
		VFU27	Ensure substructure functional requirements meet a satisfactory level of performance	1.91	5		9.551		
		VFU28	Ensure superstructure functional requirements meet a satisfactory level of performance	1.92	3		5.759		
		VFU2	Increase life of services	2.039	3		6.117		
		VFU3	Provide function-fitness for purpose	2.044	5		10.220		
		VFU23	Configure design to enable an efficient construction process	2.006	3		6.017		
	Reliability	VFU24	Ensure construction efficiency is considered in specification	1.968	5	43	9.838	78.32	
		VFU19	Maintain security-health and safety	1.929	3		5.788		
		VFU21	Meet all statutory requirements and building regulations	1.972	5		9.862		
		VFU22	Ensure designed elements are standardised	2.053	5		10.267		
		VFU20	Suitability and maintainability of materials	2.034	3		6.103		
		VFU15	Provide durable building-last longer	1.929	5		9.647		
		VFU14	Assure convenience	1.987	3		5.960		
		VFU18	Create reliable building-safer	1.972	5		9.862		
		VFU1	Maintain adaptable building-useful to all	2.006	5		10.029		
		VFU8	Increase efficiency-add capacity	1.91	3		5.731		
		VFU13	Provide disability access	1.968	3		5.903		
		VFU16	Maintain durability	1.925	3		5.774		

Table 5: Continued.

To what extent are the following indicators considered and implemented in this design? 0 not implemented ← 3 considered ⟶ 5 highly implemented				Weight	Scale	Total points	Scores gained	Cluster Wms (%)	Group Wms (%)
		VOP8	Easy to operate	1.92	3		5.759		
		VOP6	Easy to maintain	1.905	3		5.716		
	Manageability	VOP9	Easy to inspect and maintain	1.896	3	15	5.688	60.00	
Operational performance 17.66%		VOP11	Provide building systems that are easy to operate and control	1.905	3		5.716		
		VOP15	Reduce operational risk	1.92	3		5.759		69.53
		VOP1	Reduce/minimise/save energy usage	2.087	5		10.435		
	Energy and efficiency	VOP2	Maintain efficiency in terms of energy	2.12	5	16	10.602	80.74	
		VOP3	Increase efficiency of utilities	1.944	3		5.831		
		VOP4	Increase efficiency of heating, cooling, and lighting	1.963	3		5.888		
		VEN5	Increase use of natural ventilation	1.982	0		0.000		
		VEN3	Provide indoor environmental quality	1.982	0		0.000		
	Ecoresources	VEN4	Access to natural light, management of air quality, and temperature	2.034	0	3	0.000	12.07	
Environmental performance 15.66%		VEN7	Specifying low-maintenance, durable, environmentally preferable materials, and equipment	1.991	3		5.974		29.71
		VEN10	Minimise consumption of resources	1.91	0		0.000		
		VEN8	Maximise resource reuse	1.891	3		5.673		
	Adaptability	VEN12	Respond to site microclimate	1.882	3	9	5.645	60.00	
		VEN11	Conserve water resources	1.991	3		5.974		
		VMA10	Able to construct to scope/cost/budget/schedule/quality	1.972	0		0.000		
	Control	VMA11	Completed to specification	2.039	3	3	6.117	20.32	
Management performance 12.12%		VMA6	Produce effective plans to achieve the project objectives	2.011	0		0.000		
		VMA3	Create strategic planning	1.982	0		0.000		10.09
	Planning	VMA1	Provide effective project management and delivery	2.13	0	0	0.000	0.00	
		VMA5	Provide cost control to achieve the project objectives	1.987	0		0.000		

Table 6: Building two results of the risk assessment tool.

To what extent is the value creation in the design of this project impacted by the following risk factors? 0 no impact ← 3 moderately impacted ⟶ 5 highly impacted			Weight	Scale	Total points	Scores gained	Cluster Wms (%)
	*R*11	Failure to recognise cost-value mismatches	2.789	3		8.37	
	*R*10	Failure to identify cost-value relationships	2.764	0		0.00	
	*R*8	Failure to consider the cost of losing potential revenue	2.822	0		0.00	
	*R*12	Failure to appropriately locate cost-to-function allocation	2.797	3		8.39	
	*R*9	Uncertainty about prices	2.805	5		14.03	
	*R*5	Inappropriate cost evaluation criteria	2.888	3		8.66	
Financial risks 37.09%	*R*6	Failure to consider future operational costs	2.896	0	31	0.00	47.97
	*R*3	Failure to consider implication of economic conditions	2.789	3		8.37	
	*R*1	Insufficient funding	2.995	5		14.97	
	*R*7	Failure to recognise cost as resource expenditure	2.822	0		0.00	
	*R*65	Incorrect estimated cost of maintenance	2.937	3		8.81	
	*R*63	Incorrect cost estimate	2.986	3		8.96	
	*R*66	Incorrect estimated cost of energy used	2.797	3		8.39	
	*R*20	Failure to consider construction implications during design	2.805	3		8.42	
	*R*19	Failure to design to brief/specification	2.773	3		8.32	
	*R*17	Failure to examine specifications due to unnecessary expense	2.838	3		8.52	
	*R*33	Failure to integrate the various systems to achieve the lowest life-cycle costs	2.797	0		0.00	
Functional risks 23.19%	*R*21	Design changes	2.962	3	20	8.89	50.23
	*R*22	Redesign/rework	2.962	5		14.81	
	*R*35	Failure to identify low-value, long-lead-time items	3.102	3		9.30	
	*R*36	Failure to consider design risks	2.954	0		0.00	
	*R*44	Failure to consider increase in routine maintenance	2.830	0		0.00	
Operational risks 8.50%	*R*45	Failure to consider increase in life-cycle replacement	2.797	0	3	0.00	20.27
	*R*39	Failure to consider design impact on operating efficiency	2.871	3		8.61	
	*R*38	Failure to consider obsolescence of equipment impact	2.674	0		0.00	
Environmental risks 8.00%	*R*43	Failure to consider maintainability and reparability impact	2.567	0	0	0.00	0.00
	*R*47	Failure to consider implication of environmental risks	2.756	0		0.00	
	*R*49	Poor project management	2.929	3		8.79	
	*R*50	Poor definition of the scope and objectives of projects	2.805	0		0.00	
	*R*51	Project scope unscheduled items	2.847	0		0.00	
	*R*57	Improper project planning and budgeting	2.871	5		14.36	
Management risks 23.23%	*R*53	Lack of coordination and decision making	2.896	5	24	14.48	60.60
	*R*64	Incorrect time estimate	3.060	5		15.30	
	*R*54	Poor team relationships	2.814	3		8.44	
	*R*28	Poor design that may lead to higher operation costs	3.003	3		9.01	

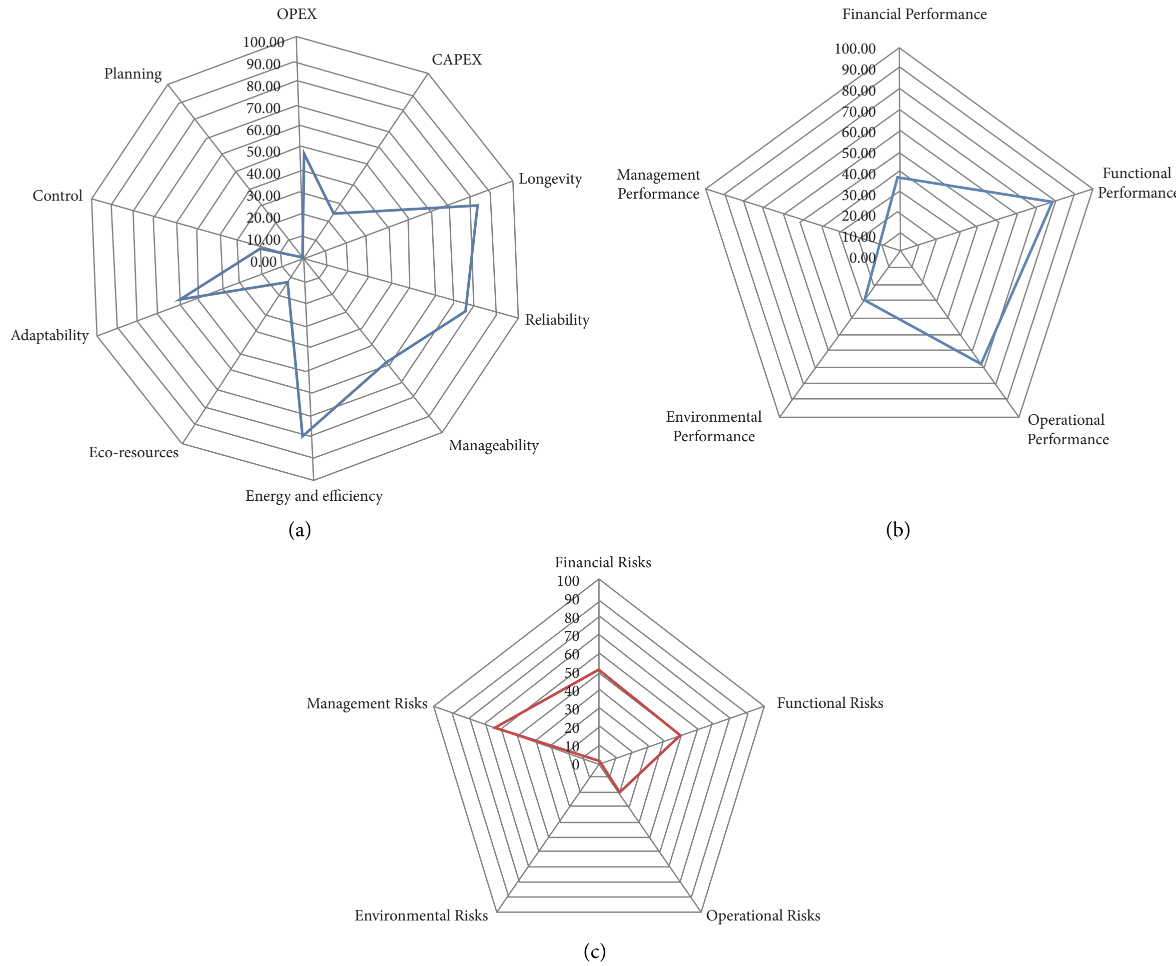

Figure 3: Assessment results for Building 2, (a) value clusters (subcriteria) plots, (b) value groups (value creation drivers) plot, and (c) risk groups plot.

that assists in unlocking value in the development of GB. The risks that challenge the destruction of value were also considered for adoption into a practical tool. This was achieved in part by defining the drivers that contribute to value creation and in part by defining the risks that may have an impact on realising the identified value.

The proposed value assessment tool consists of five main performance aspects, including financial, functional, operational, environmental, and management. Financial performance concerns with project value creation parameters to examine how to reduce the required CAPEX and OPEX in order to optimise the value of the proposed investment in green building assets. Ten value generation drivers listed in Table 2 with a cummulative weight of 19.07% contribute to the financial performance of green assets. Functional performance assessed the required functions of the asset being designed. The stakeholders need to identify what functions are important and which performance characteristics are required for these functions. The asset function is viewed as consisting of "longevity" and "reliability" value drivers. Eighteen value-generation drivers with a total weight contribution of 35.49% (see Table 2) assessed the functional performance of green assets.

The continuous increase in energy consumption has increased the need for building energy analysis worldwide [46]. Operational performance evaluated how operational value generators related to maintaining, energy use in, operating, and cleaning the green building asset once it is in use are considered and optimised in relation to other value generators during the VE analysis stages. The asset operation performance was viewed to consist of "manageability" and "energy and efficiency" value drivers. Nine value-generation drivers are used to assess the operational performance of green assets; their total weight contributes 17.66% to the overall profile of the assessed project. Environmental performance measures how to minimise the impact on the natural environment. The green building asset's environmental performance is viewed to consist of "ecoresources" and "adaptability" value drivers. In Tables 2 and 8, value creation drivers assessed the environmental performance of green assets with their total weight contributing 15.66% to the overall profile of the assessed project. Finally, management performance dealt with the management processes used and the selection of an integrated project team working throughout the life cycle of the proposed development. The management performance is viewed to consist of "control"

Table 7: Building 2 final rating results.

Value creation assessment tool	Building two			
	Respondent score		Weighted respondent score	
	Points	Percentage (%)	Points	Percentage (%)
Value	136	53.33	267.61	53.52
Rating result	*Moderate*		*Moderate*	
Risk	78	44.57	226.19	44.24
Rating result	*Neutral impact*		*Neutral impact*	

Table 8: Building three value assessment tool results.

To what extent are the following indicators considered and implemented in this design? 0 not implemented ← 3 considered ⟶ 5 highly implemented				Weight	Scale	Total points	Scores gained	Cluster Wms (%)	Group Wms (%)
Financial performance 19.07%	OPEX	VFI11	Maximise residual value	1.829	5	17	9.145	67.49	73.80
		VFI6	Increase economic lifetime	1.963	5		9.814		
		VFI15	Optimise risk-return ratio of alternative options	1.819	3		5.458		
		VFI2	Efficiency of operational expenditure (OPEX)	1.987	2		3.973		
	CAPEX	VFI5	Improve economic efficiency	2.001	2	20	4.002	80.19	
		VFI3	Maximise the cost efficiency to build	1.891	4		7.564		
		VFI1	Efficiency of capital expenditure (CAPEX)	1.991	5		9.957		
		VFI12	Minimise cost of capital	1.872	1		1.872		
		VFI4	Deliver/achieve cost certainty	1.877	5		9.384		
		VFI9	Return on investment	1.839	5		9.193		
Functional performance 35.49%	Longevity	VFU26	Provide functional ability of the foundations requirements (strength and stability)	1.915	5	34	9.575	97.04	96.62
		VFU27	Ensure substructure functional requirements meet a satisfactory level of performance	1.91	5		9.551		
		VFU28	Ensure superstructure functional requirements meet a satisfactory level of performance	1.92	5		9.599		
		VFU2	Increase life of services	2.039	4		8.157		
		VFU3	Provide function-fitness for purpose	2.044	5		10.220		
		VFU23	Configure design to enable an efficient construction process	2.006	5		10.029		
	Reliability	VFU24	Ensure construction efficiency is considered in specification	1.968	5	53	9.838	96.35	
		VFU19	Maintain security-health and safety	1.929	5		9.647		
		VFU21	Meet all statutory requirements and building regulations	1.972	5		9.862		
		VFU22	Ensure designed elements are standardised	2.053	5		10.267		
		VFU20	Suitability and maintainability of materials	2.034	4		8.138		
		VFU15	Provide durable building-last longer	1.929	5		9.647		
		VFU14	Assure convenience	1.987	5		9.933		
		VFU18	Create reliable building—safer	1.972	5		9.862		
		VFU1	Maintain adaptable building-useful to all	2.006	5		10.029		
		VFU8	Increase efficiency-add capacity	1.91	5		9.551		
		VFU13	Provide disability access	1.968	5		9.838		
		VFU16	Maintain durability	1.925	4		7.698		

Table 8: Continued.

To what extent are the following indicators considered and implemented in this design? 0 not implemented ← 3 considered ⟶ 5 highly implemented				Weight	Scale	Total points	Scores gained	Cluster Wms (%)	Group Wms (%)
Operational performance 17.66%	Manageability	VOP8	Easy to operate	1.92	5	21	9.599	83.91	79.89
		VOP6	Easy to maintain	1.905	5		9.527		
		VOP9	Easy to inspect and maintain	1.896	5		9.479		
		VOP11	Provide building systems that are easy to operate and control	1.905	5		9.527		
		VOP15	Reduce operational risk	1.92	1		1.920		
	Energy and efficiency	VOP1	Reduce/minimise/save energy usage	2.087	4	15	8.348	75.16	
		VOP2	Maintain efficiency in terms of energy	2.12	4		8.481		
		VOP3	Increase efficiency of utilities	1.944	4		7.775		
		VOP4	Increase efficiency of heating, cooling, and lighting	1.963	3		5.888		
Environmental performance 15.66%	Ecoresources	VEN5	Increase use of natural ventilation	1.982	2	14	3.964	55.98	42.87
		VEN3	Provide indoor environmental quality	1.982	4		7.927		
		VEN4	Access to natural light, management of air quality, and temperature	2.034	3		6.103		
		VEN7	Specifying low-maintenance, durable, environmentally preferable materials, and equipment	1.991	2		3.983		
		VEN10	Minimise consumption of resources	1.91	3		5.731		
	Adaptability	VEN8	Maximise resource reuse	1.891	0	3	0.000	20.35	
		VEN12	Respond to site microclimate	1.882	1		1.882		
		VEN11	Conserve water resources	1.991	2		3.983		
Management performance 12.12%	Control	VMA10	Able to construct to scope/cost/budget/schedule/quality	1.972	3	12	5.917	80.13	76.78
		VMA11	Completed to specification	2.039	4		8.157		
		VMA6	Produce effective plans to achieve the project objectives	2.011	5		10.053		
	Planning	VMA3	Create strategic planning	1.982	5	11	9.909	73.47	
		VMA1	Provide effective project management and delivery	2.13	4		8.520		
		VMA5	Provide cost control to achieve the project objectives	1.987	2		3.973		

and "planning" value drivers. Six VCDs assessed the management performance of green assets. Their total weight contributes 12.12% to the overall profile of the assessed project.

Figure 5 presents a comparison of the overall results of the assessment tool for the three buildings evaluated in the present study. The commercial building is the best performer with the highest percentage of value addition and lowest risk impacts during the design process. The multistorey hotel performance can be considered moderate as it obtained around 70% score for value addition but around 60% risk impact simultaneously during its design phase. Office building attained the lowest performance scores in value addition; however, the risk impacted the value was also low. These results clearly show that the concept of value creation has been more implemented in high-value projects (i.e., *B*1 and *B*3) as compared to conventional buildings (*B*2). Nevertheless, the design process is susceptible to being impacted by various types of risks if not adequately addressed during the design process.

The results from the assessment tool in the form of aggregated scores (ranging between 0 and 100) for each main VCD and risk categories are based on the evaluation of the project design parameters by concerned stakeholders. The spider charts display and inform stakeholders about which of the value drivers need to be optimised to add value to the

Table 9: Building three risk assessment tool results.

To what extent is the value creation in the design of this project impacted by the following risk factors? 0 no impact ← 3 moderately impacted ⟶ 5 highly impacted			Weight	Scale	Total points	Scores gained	Cluster Wms (%)
	*R*11	Failure to recognise cost-value mismatches	2.789	0		0.00	
	*R*10	Failure to identify cost-value relationships	2.764	0		0.00	
	*R*8	Failure to consider the cost of losing potential revenue	2.822	3		8.47	
	*R*12	Failure to appropriately locate cost-to-function allocation	2.797	0		0.00	
	*R*9	Uncertainty about prices	2.805	0		0.00	
	*R*5	Inappropriate cost evaluation criteria	2.888	3		8.66	
Financial risks 37.09%	*R*6	Failure to consider future operational costs	2.896	1	26	2.90	40.49
	*R*3	Failure to consider implication of economic conditions	2.789	3		8.37	
	*R*1	Insufficient funding	2.995	3		8.98	
	*R*7	Failure to recognise cost as resource expenditure	2.822	1		2.82	
	*R*65	Incorrect estimated cost of maintenance	2.937	4		11.75	
	*R*63	Incorrect cost estimate	2.986	4		11.95	
	*R*66	Incorrect estimated cost of energy used	2.797	4		11.19	
	*R*20	Failure to consider construction implications during design	2.805	3		8.42	
	*R*19	Failure to design to brief/specification	2.773	0		0.00	
	*R*17	Failure to examine specifications due to unnecessary expense	2.838	0		0.00	
Functional risks 23.19%	*R*33	Failure to integrate the various systems to achieve the lowest life-cycle costs	2.797	0	8	0.00	20.39
	*R*21	Design changes	2.962	1		2.96	
	*R*22	Redesign/rework	2.962	1		2.96	
	*R*35	Failure to identify low-value, long-lead-time items	3.102	3		9.30	
	*R*36	Failure to consider design risks	2.954	0		0.00	
	*R*44	Failure to consider increase in routine maintenance	2.830	2		5.66	
Operational risks 8.50%	*R*45	Failure to consider increase in life-cycle replacement	2.797	2	7	5.59	46.76
	*R*39	Failure to consider design impact on operating efficiency	2.871	3		8.61	
	*R*38	Failure to consider obsolescence of equipment impact	2.674	1		2.67	
Environmental risks 8.00%	*R*43	Failure to consider maintainability and, reparability impact	2.567	1	7	2.57	47.57
	*R*47	Failure to consider implication of environmental risks	2.756	5		13.78	
	*R*49	Poor project management	2.929	5		14.64	
	*R*50	Poor definition of the scope and objectives of projects	2.805	5		14.03	
	*R*51	Project scope unscheduled items	2.847	1		2.85	
Management risks 23.23%	*R*57	Improper project planning and budgeting	2.871	3	25	8.61	62.79
	*R*53	Lack of coordination and decision making	2.896	5		14.48	
	*R*64	Incorrect time estimate	3.060	5		15.30	
	*R*54	Poor team relationships	2.814	0		0.00	
	*R*28	Poor design that may lead to higher operation costs	3.003	1		3.00	

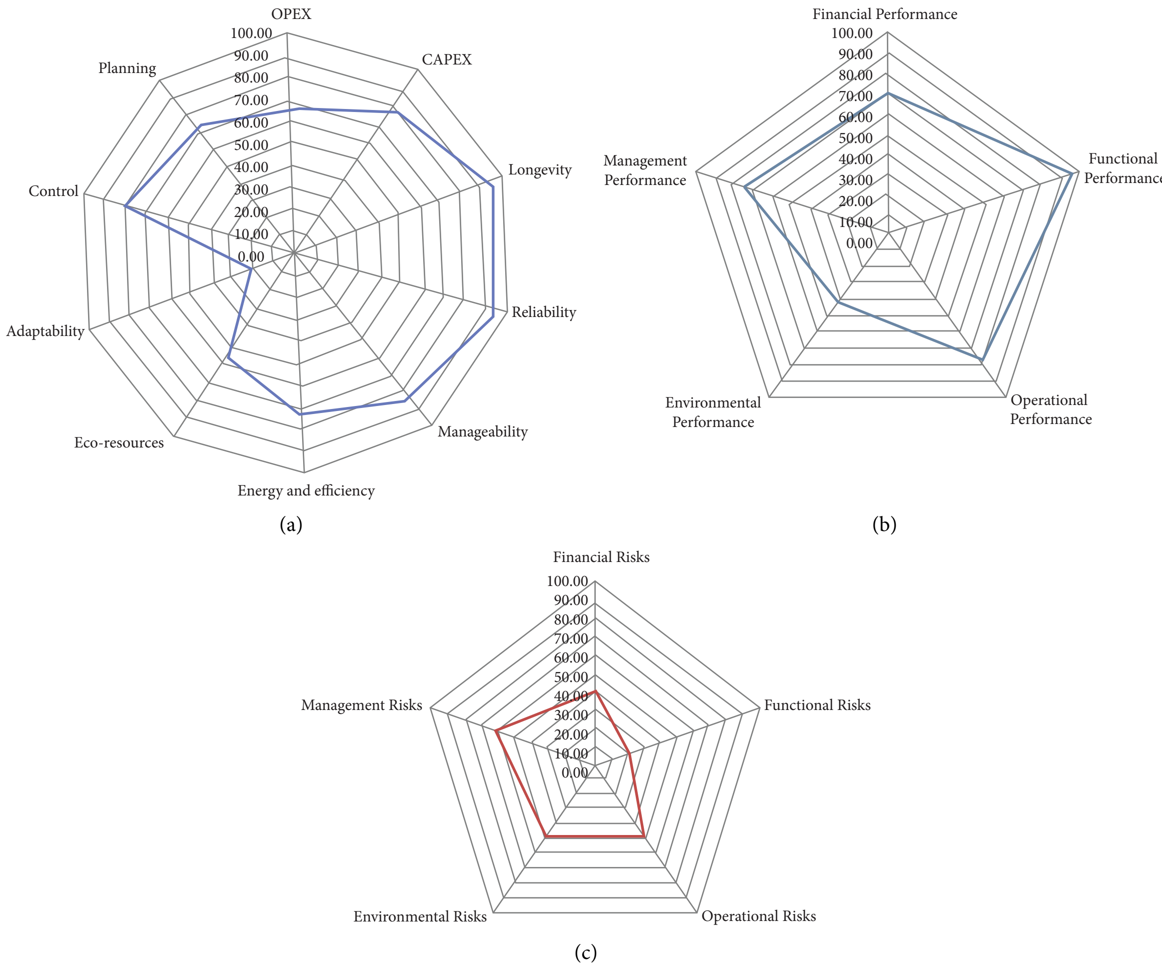

Figure 4: Assessment results for Building 3, (a) value clusters (subcriteria) plots, (b) value groups (value creation drivers) plot, and (c) risk groups plot.

Table 10: Building three final rating results.

Value creation assessment tool	Building three			
	Respondent score		Weighted respondent score	
	Points	Percentage (%)	Points	Percentage (%)
Value	200	78.43	392.445	78.49
Rating result	*Add value*		*Add value*	
Risk	73	41.71	210.53	42.11
Rating result	*Neutral impact*		*Neutral impact*	

green asset. However, the assessment tool's ability to capture data and results of each assessment needs to be further enhanced. These should then be used as feedback for learning purposes. In order to take into account of the variability, the following challenges will need to be considered:

(i) Representation of the sensitivity associated with evaluator opinions with highly subjective scoring of value drivers

(ii) The need to improve the range of value drivers to reflect different contexts

(iii) The need to integrate and synchronise the assessment with value engineering processes

In general, the tool will assist the value engineering studies to deal with the following issues concerning green building development:

(i) Understanding project criteria

(ii) Identifying appropriate project scope

(iii) Validating project initial cost and budget

(iv) Ascertaining best value alternatives

(v) Evaluating life-cycle costs

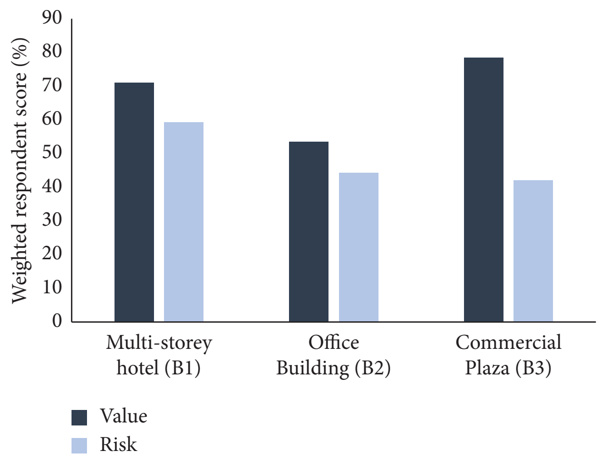

Figure 5: Comparison of three different types of buildings in terms of value-added and risk impacts in the design process.

(vi) Identifying and evaluating risk

The proposed assessment tool can be globally used in green building development, providing the scoring system can be changed to reflect the context of a specific regional application outside KSA.

There is an increasing endeavour in the industry to maximise value from investment in green development. Hence, further knowledge about value creation and risks will consolidate the theory of value creation in the development of GB. Further work needs to be carried out to refine the extracted value drivers and risks. If this can be performed according to building type, it will increase the accuracy of the tools. Additional research can test the proposed framework on case studies to verify the correlation between risks and the value creation drivers and to demonstrate the implementation and use of the prosed tools and gather feedback from the users for further improvements. Uncertainties associated with the vagueness of expert opinion while using subjective rating can also be addressed in the future [47, 48].

5. Conclusion

The developed value creation and associated risk assessment tool is useable at the early stages of preparing a business case and design for developing GB. The overall framework, including the selection of PVDs and risk factors, and the tool presented in the present study can be used to assist in sustainability and value-for-money analysis. The value generated from investment in GB will hinge on the level of value-creation strategies inducted into the project brief and on the perceived risks from not including some of the value-generating strategies. In addition, the proposed approach provides appropriate opportunities for the stakeholders to assess value and risk impacts before the actual construction starts. It will provide a cheap alternative simulation environment for testing what-if scenarios. Although value drivers and risks are mainly derived from green building assets, as commonalities across similar building projects exist, this will provide appropriate opportunities for this study to be utilised in other building types as well.

Although the developed tool is based on specific population data collected from the KSA context, the framework is robust enough to be applied anywhere with different conditions and associated feedbacks. Although the number of respondents is comparable to other studies, it is not possible to claim that their views represent the views of the majority of value experts in KSA. Due to the lack of professional databases in KSA, it was an impossible task to define the exact population. Consequently, the extraction of value drivers and risk factors was not from a specific type of building.

The proposed tool's in this research potential for use in value-creating assessment are demonstrated in the three case studies in KSA. The test results demonstrated how some aspects of value creation were not taken into consideration during the design of the test buildings. This was carried out based on the work of three projects, including multistorey hotel, office building, and commercial plaza. Each of these projects was scored by the value engineering professionals (who were involved in the value engineering of these buildings) and then calculations were carried out to obtain the final results. An excellent project that includes most of the features that contribute to value creation should have a 100% score in each of the five VCDs. The results of the assessment tool revealed that the environmental driver was given less importance in the design process with Wms of less than 60% for all three types of buildings. All the buildings gave the highest importance to functional performance driver with Wms of 80% or more.

At the same time, such a project should have the lowest risk scores for each of the five categories so that the value created is preserved. Overall, all the buildings showed moderate financial risks ranging between 40 and 50% and a higher potential of management risks with scores around 60% or higher. A wide variation between 20 and 60% was observed for operational risks. Interestingly, the largest commercial building reported the lowest functional risk with Wms of around 20%.

By using this type of information, designers and consultants would be able to optimise the design to improve the building's performance, leading to value creation and preservation. Value can be improved and optimised by taking into consideration the performance value drivers while reducing or mitigating the risks that destroy value creation. The proposed assessment tools are not limited to the Saudi context; however, they can be globally used in green building development with a change in the scoring system to reflect the context of the application.

The proposed value assessment tool has not been tested or presented to a different set of experts to validate. However, the framework has been developed based on integrating several current best practices. Although the robustness of the tool has been demonstrated through case studies, its validation can be considered as a further research recommendation.

Data Availability

All the shareable data are included in the manuscript.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Authors' Contributions

Wael Alattyih conceptualized the model, developed a detailed methodology, performed analysis, and prepared the main draft of the manuscript. Husnain Haider was involved in the conceptualization, presentation, and writing of the main manuscript.

Supplementary Materials

Supplementary Material 1. The overall weights for each value indicator. Supplementary Material 2. The overall weights of each risk factor. (*Supplementary Materials*)

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