Portfolio Value Optimization Model for Sustainable Construction Projects

PORTFOLIO VALUE OPTIMIZATION MODEL FOR SUSTAINABLE CONSTRUCTION PROJECTS

by

Taha Anjamrooz

A Dissertation Presented to the Faculty of
the American University of Sharjah
College of Engineering
In Partial Fulfillment of the
Requirements for the Degree of
Doctor of Philosophy
Engineering Systems Management

Sharjah, United Arab Emirates

May 2021

Declaration of Authorship

I declare that this dissertation is my own work and, to the best of my knowledge and belief, it does not contain material published or written by a third party, except where permission has been obtained and/or appropriately cited through full and accurate referencing.

Taha Anjamrooz

Signature (Taha Anjamrooz) ……………………………………………………….

15th April 2021

Date……………………..………………………………………………………

Approval Signatures

We, the undersigned, approve the PhD Dissertation written by Taha Anjamrooz:

Dissertation Title: Portfolio Value Optimization Model for Sustainable Construction Projects

Date of Defense: May 19, 2021

Name, Title and Affiliation	**Signature**
Dr. Sameh El-Sayegh Professor Department of Civil Engineering Dissertation Advisor	
Dr. Salwa Beheiry Associate Professor Department of Civil Engineering Dissertation Committee Member	
Dr. Lotfi Romdhane Professor Department of Mechanical Engineering Dissertation Committee Member	
Dr. Vian Ahmed Professor Department of Industrial Engineering Dissertation Examiner	
Dr. Issam Srour Associate Professor Department of Civil & Environmental Engineering (AUB) Dissertation Examiner	

Accepted by:
Dr. Mohamed El-Tarhuni
Vice Provost for Graduate Studies
Office of Graduate Studies

Acknowledgments

First, I would like to express my sincere gratitude to my advisor, Dr. Sameh El-Sayegh, for his continuous support, invaluable advice, and warm encouragement throughout this dissertation. With comprehensive knowledge and experience, he filled our discussion with credible ideas, which gradually guide me to achieve my project's objectives.

I also would like to express my significant appreciation to the Engineering Systems Management program's faculty at the American University of Sharjah for their guidance and support that they have given me during my course of study.

Moreover, I would like to extend my appreciation to my dissertation advisory committee members, Dr. Salwa Beheiry, Dr. Lotfi Romdhane, Dr. Vian Ahmed, and Dr. Abroon Qazi, for their valuable comments, time, and effort in evaluating my dissertation.

Most importantly, I would also like to appreciate my family, friends, and loved ones to support me every step of the way and never lose faith in me when times were difficult. My wife, Sareh Rajabi, has always been with me, giving me strength and continuous encouragement.

Thank you all!

Abstract

The continuous growth and development threaten the world's natural resources and lead to several adverse effects. The construction industry is widely blamed for its negative impact on the environment. Yet, developers/clients do not consider sustainability criteria when selecting their portfolio of projects. Instead, they rely on traditional criteria that maximize their profit. Based on the review of related literature, there is a lack of portfolio selection methods that incorporate sustainability as key criteria. This research aims at developing a new portfolio value optimization model that integrates sustainability, organization benefit realization, and project success criteria. Twenty-six selection criteria were identified based on the literature review. These criteria were classified into two groups: sustainability group and organization benefit realization, and project success group. The sustainability group consists of three pillars: environmental, social, and economical. The second group consists of two subgroups: organization benefit realization and project success. A questionnaire was then developed and distributed to key developers/clients in the United Arab Emirates (UAE) construction industry. The Analytic Hierarchy Process (AHP) was used to determine the weight of the identified selection criteria based on 34 responses. The results show that the sustainability group is more important with a weight of 0.537 compared to the organization benefits and project success criteria with a weight of 0.463. The top six selection criteria include energy use, material use, health and safety, strategic fit, profitability and organizational risk. Three portfolio value optimization models are then developed. Model A combines Project Screening Matrix (PSM) with AHP. Model B is an integrated AHP and Linear Programming (LP) model, while Model C uses Genetic Algorithms (GA). The proposed models can be used to determine the optimum solution based on the organization's constraints. A real case study is presented to demonstrate the application of the proposed models. The research is valuable as it encourages developers to consider sustainability as key criteria in their portfolio selection, and that, in turn, results in more sustainable construction industry. The research fills an identified gap in the literature and proposes new selection criteria and models.

Search Terms: Portfolio Value Optimization, Sustainability, Selection Criteria, Portfolio Selection Models, AHP, Genetic Algorithms

Table of Contents

List of Figures

List of Tables

Chapter 1. Introduction

1.1 Overview

With the current shortage of natural resources, increase in climate change, and destabilized environment, there is an increasing need for sustainable development and construction. Assessment and evaluation of sustainable construction projects are essential for stakeholders and decision-makers. Developing a new portfolio optimization model based on sustainability benefits and benefits realization became significant. Currently, decision-makers concentrate on selecting their projects, programs, and portfolios to increase benefits and advantages for stakeholders considering specific criteria [1]. Selecting the right portfolio with optimized benefits for an organization through proper portfolio selection will provide the organization with another business opportunity rather than any inappropriate investment [2]. Optimization of various project objectives and organization's goals is another significant task left to decision-makers. Optimization plays a significant role in increasing the organization's overall benefits and attaining stakeholders' satisfaction [1-2]. Presently, there is a gap in research studies regarding conceptual models in portfolio selection processes considering sustainability and project benefits. Thus, there is a need for an integrated portfolio selection method to optimize the overall organization's value while considering sustainability, organization benefit realization, and project benefits into its account [3].

Selection of sustainability criteria, rating the selected criteria, and measuring and scoring their value are challenging tasks in the current world. Thus, globally, organizations are looking for sustainable development to reduce natural resource usage to create an equilibrium between natural resources, urbanization, and growth [4]. The selection of criteria should be assessed based on three pillars of sustainability to cover all aspects of sustainable development. Therefore, the selected criteria' effectiveness will indicate the benefits obtained through sustainable practices. The concept of sustainability can be considered within each project value or as a business strategy within an organization. Sustainability can be linked to an organization's mission, vision, and objective or implemented at the project level [5]. However, suppose the viewpoint of study is from the organization's perspectives. In that case, the minimum amount of sustainability on the environment and society can be considered as the highest-ranked constraint in portfolio selection processes. Also, the monetary value of sustainable benefits should be equal or greater than its investment, so considering its stakeholders' satisfaction and positive impacts on the environment has additional value to the organization's achievements [6].

This research proposes a new portfolio value optimization model incorporating sustainability criteria. The model can be used by decision makers/ managers to select the portfolio of projects that maximizes the value to the organization.

1.2 Problem Statement

The continuous growth and development threaten the world's natural resources and lead to several adverse effects. The construction industry is widely blamed for its negative impact on the environment, which leads to the move towards sustainable construction. Yet, developers/clients do not consider sustainability criteria when selecting their portfolio of projects. Instead, they rely on traditional criteria that maximize their profit. Based on the review of related literature, there is a lack of portfolio selection methods that incorporate sustainability as key criteria. The lack of sustainability consideration in decision making leads to selecting portfolio of projects that may have negative impacts on the sustainability objectives in favor of maximizing profit. Nowadays, organizations realize the benefits of sustainability and are looking for ways to incorporate sustainability in their decision-making processes. However, there is a lack of portfolio optimization models, incorporating sustainability, that can be used. There is a need to integrate the sustainability criteria with other traditional selection criteria.

1.3 Aims and Objectives

This research aims to propose a new portfolio value optimization model for sustainable construction projects. The proposed model integrates sustainability criteria with other traditional criteria to provide optimal solution on portfolio selection for construction organizations. The detailed objectives are:

I. Identify sustainability criteria and indicators that can be used in portfolio selection.

II. Identify the organization benefit realization criteria and project success criteria currently used in portfolio selection.

III. Develop portfolio selection model that integrates sustainability, benefit realization, and project success criteria identified in objectives 1 & 2 through project screening matrix and AHP method.

IV. Develop a portfolio value optimization model using linear programming and genetic algorithm and considering the organization's constraints.

1.4 Research Questions

A review of literature review, existing gap, and challenges highlight the requirements to respond to the following questions in order to attain its research objectives:

1. What are the primary sustainability criteria in the construction industry?
2. What are benefits realization and project success criteria in line with stakeholder's requirements?
3. Can the portfolio selection process notify the stakeholders of the best opportunities among various projects and programs by integrating its sustainability benefits?
4. Can the portfolio selection process be improved by constrained optimization method to its optimum?

1.5 Research Significance

These research outcomes are significant for stakeholders and strategic decision-makers in the construction sector. The research outcomes provide organizations with portfolio value optimization models that integrate sustainability, benefit realization, and project success under one umbrella. The research model optimizes the available opportunities in line with organization constraints and strategies. The proposed model allows decision makers and managers to select the group of projects that maximizes the portfolio value to the organization while considering the constraints. This leads to organizations selecting projects that have positive impact on sustainability. Additionally, this research fills the identified gap in literature related to portfolio value optimization integrating sustainability and organization benefits.

1.6 Methodological Steps

The following steps are taken into consideration in order to attain the research objectives:

I. Literature review

- Extensive literature review is carried in order to:
  - Identify the sustainability criteria and indicators.
  - Identify the benefit realization criteria and project success criteria in the construction industry.

II. Quantitative and qualitative study

- Build sustainability and benefit realization hierarchy.
- Assess the weight of the selection criteria using AHP based on a survey sent to construction professionals.
- Develop a portfolio selection model using AHP.
- Develop a portfolio value optimization model using linear programming and genetic algorithms to select the best feasible solution considering the organization's constraints and limitations.

III. Data analysis

The model is applied to a case study to demonstrate the value of this research's decision-makers outcomes.

1.7 Content of the Dissertation

The dissertation includes eight chapters. A summary of each chapter is explained as follow:

- ***Chapter 1* – Introduction**

Chapter 1 gives an overview of this research project including the research problem, aims and objectives, the research questions and the methodological steps.

- ***Chapter 2* – Literature review**

Chapter 2 provides a review of related literature with a focus on sustainability and its beneficial indicators. It also covers the existing project selection methods and selection criteria. The use of AHP, linear programming and genetic algorithms in construction management research is also covered.

- ***Chapter 3* – Research methodology**

Chapter 3 presents the design of methodological steps to achieve the research objectives. This chapter includes technique development, proposed case study, and data analysis.

- ***Chapter 4*** **– Project selection criteria: identification and measurement**

Chapter 4 presents the identified selection criteria based on comprehensive review of related literature. The chapter covers the main criteria for sustainability, organization benefit realization, and project success along with their measurement methods.

- ***Chapter 5*** **– Criteria assessment**

Chapter 5 describes the survey design and the AHP method to measure the weight of each selected criterion for the portfolio selection process.

- ***Chapter 6*** **– Portfolio value optimization models**

Chapter 6 introduces the proposed portfolio value optimization models that can be used to select and optimize the portfolio.

- ***Chapter 7*** **– Case study**

Chapter 7 analyzes a real case study, from the UAE, to demonstrate the application and advantages of the proposed model.

- ***Chapter 8*** **– Summary and conclusion**

Chapter 8 presents a summary and conclusion derived from this research.

Chapter 2. Literature Review

2.1 Sustainability

2.1.1 Overview of sustainability. There is an increasing need for organizations worldwide to integrate sustainability measures in their portfolio decision-making process. The construction industry has an important impact on a country's economy as it is among the largest and essential industries. The management of construction projects significantly impacts a nation's environmental, societal as well as economic dynamics. Thus, it is significant to explore various methods to include sustainability and its valuable portfolio management indicators and strategies [1].

Making sustainable decisions in the management of construction projects is one of the biggest challenges facing organizations. It has become a common element in many organizations' mission statements and their business strategies. Presently, the importance of sustainability in value management is a popular research field for various scholarly studies. Value management is the most recent field that integrated the notion of sustainability [2]. Mary McKinlay [3], the World Congress of the International Project Management Association (IPMA) President - in their 22nd congress in 2008, mentioned that "the growth development of the project management profession needs project managers to be in charge for sustainability" [3]. There is a general wide-range call for the adoption of sustainability in the portfolio management processes. Project management professionals have gradually understood the growing need to develop models and methods to incorporate project management with sustainability benefits and strategies. As a result, a growing requirement of information and skills emerges to adopt sustainability into value management [4]. Indeed, Silvius and Tharp [5] summarized that "the relationship between sustainability and value management is picking up momentum."

Even as sustainability becomes popular in portfolio management, its incorporation, especially the sustainability assessment in construction projects, still is a debatable topic [6]. Therefore, there is a requirement to develop sustainability mechanisms in construction projects bearing in mind that sustainability combines index and indicators to evaluate various aspects of sustainability in portfolio management [7-9]. The construction industry's role in a community's economy, society, and environment cannot be ignored due to its significance in the construction industry and three sustainability pillars: economic, environmental, and social.

It is becoming a common practice among organizations worldwide to integrate sustainability in their value management in the wake of the challenges and opportunities related to environmental, social, and economic effects on their project activities. However, organizations incorporate sustainability into their business's strategic planning procedures by making policies and programs to avoid the challenges and minimize uncertainties. The adoption of sustainability strategies is motivated by various reasons. Some of these include gaining a competitive edge, legitimation, and accounting for ecological responsibility [10]. A considerable number of organizations have improved well in their operations by enhancing sustainability performance [10]. Nevertheless, there is an evolving perception that sustainability issues go beyond a single organization. Sustainability management of any organization must adjust to reflect the stakeholders' expectations and enlarge the performance measurement beyond such an organization's internal operations, referred to as benefits realization management [10].

The adoption of sustainability in the construction industry has led to more sustainable projects and activities. Various sustainability appraisal mechanisms and techniques help in measuring sustainability indices and indicators. The global rating systems and structures of sustainability are considered as substituting parameters in evaluating construction industry performance. The current rating systems range from assessment systems for energy savings to analyzing the life cycle and total quality evaluation systems [11]. The latest multi-dimensional approaches suggest that several project rating systems be integrated for evaluation purposes separately before being considered jointly [11].

The devastating impacts of construction processes like the generation of waste and dust, air and water pollution, and energy consumption to the society, environment, and the economy have raised many concerns recently. This has raised significant awareness of the requirement for sustainable development in the construction industry. A survey was done to the clients in the construction industry in the United States and Korea to gauge their awareness level of the sustainable construction indicators that were implementable during the construction phase. They were also surveyed on their preparedness level in implementing these indicators and parameters [12].

More attention has been paid to corporate sustainability, which has been chiefly described to mean integrating economic, environmental, social, and cultural concerns into organizational goals and strategies. Thus, there is a need for the organizations and, in particular, the ones having a worldwide presence to embrace sustainability practices and strategies as a means of expressing their support and commitment to the concept [13].

Despite the sustainability concept is widely used, no definition has yet been generally agreed upon. With the availability of substantial documentation that explains initiatives for analyzing and decreasing the sustainability effects of technical and engineering activities, questions continue as to the true definition of sustainability [14]. Likewise, the triple bottom line framework's idea of sustainability does not solve this definition question. A few authors consider this approach a simple "business reporting," which has minimal effect on achieving a more sustainable society. It has also been discussed balancing the three pillars included in the triple bottom line [15]. There are doubts about the possibility of balancing financial benefits, development of society, and preservation of the globe in parallel to intending three sustainability pillars. Thus, all these ideas may be meaningless in the end, lacking content and becoming unconnected to the reality and actual execution of projects [16]. Sustainability is also regarded as a notion representing environmental rights and associating with future generations [16].

The establishment of sustainable development, both in construction projects and urban planning, is an essential element. The introduction of Agenda 21 at the Earth Summit of 1992 led to the need to implement sustainability to construction projects at a strategic level. The idea of sustainable construction was born in 1994 at a strategic level in the construction industry. There were new target additions to the common triple objectives: time, cost, and quality. It is, therefore, essential to establish new methods and models that permit environmental, economic, and social commitments to be accomplished [17].

Above 6400 municipalities globally are currently participating in the Agenda 21 process. This translates to the facts outlined in the Agenda 21 document that it is needful to establish an indicator set that can attain sustainable benefits in construction projects and screen and control these indicators' progress over a defined timeframe [18]. Different institutions have embraced different indicator systems. The outcomes are a massive difference of dimensions and indicators with the non-existence of a worldwide consensus to choose them [19]. This group of indicators is involved in the selection process; the uncertainty of high degree exposure by the indicators [19]; the number of indicators having vast differences; and the relative significance of the environmental area compared to social and economic areas [19]. The mentioned challenges come up despite global efforts in the 1990s to start up models to produce indicators [20].

The interpretation of sustainable development involves a paradigm of different growth aspects analyzed in a complete model. According to the Bruntland Report [21], there are two main approaches in achieving sustainability objectives: The first one is the concurrent achievement of social, economic, and environmental sustainability, and the second one is intergenerational equity. The sustainability debate made a milestone with the analysis of Stiglitz, Sen, and Fitoussi [22] in 2009. Their analysis makes a practical definition of sustainable development and comprehensively discusses the field's applicable practices [22].

The international arena's value defines sustainable development in many sectors, including society, environment, economy, and awareness associated with sustainability since 1987 [23]. The prodigy of sustainability has been associated with the legislation developing from the demand to preserve natural resources and reduce economic, social, and environmental impacts associated with an organization's performance [23]. Recently, there is a need for business reporting models that offer the companies guidelines to communicate, demonstrate, understand, and improve their sustainability performance [23]. These models include Eco-Management and Audit Schema, Global Reporting Initiative (GRI), and International Standard Organization (ISO 14000 series) [23]. Despite these longstanding measures, the corporate sector still faces challenges in formulating its sustainability performance evaluation and measurement to facilitate its collection, selection, integration, and evaluation indicators in management. These policies are crucial as they act as markers for the business and organization's strategies and goals toward sustainable development for the corporate sector [23].

The corporate sustainability concept has developed in significance and recognition as organizations strive to balance their performance margins among environmental, social, and economic fields. According to Hubbard [18], the traditional shareholder-based organizational performance evaluation criteria have changed over the past two decades to a stakeholder-based measurement criterion. A multi-dimensional performance measurement system is implemented with the stakeholder-based approach in varied stakeholders' interests and different fields [24].

There are many corporate sustainability definitions developed in different literatures. The different definitions have been formed due to companies' urge to bring about corporate development sustainability into their daily business practices and strategies [25].

Corporate sustainability is a multi-dimensional concept that integrates an organization's standard operations, including financial returns, business strategies, human resources, stakeholder interest, customer satisfaction, and the internal process with the triple bottom line objectives [26]. Sustainability objectives have a broad scope in assessing organizational performance and objectivity in their focus areas [26]. The concept of sustainability also provides guidelines on how business leadership steers their companies towards success by developing effective strategies to harness the full market potential while managing the cost of sustainability and risks [27].

Business leaders in many developed countries have learned the significance of sustainability measures, are racing to implement sustainability practices initiatives in the wake of the stiff worldwide corporate competition. This change could imply that businesses strive to incorporate social and environmental bottom lines into the traditional financial-based approach [28]. Companies' actual origin to be socially and environmentally responsible occurs due to the persistent calls from various stakeholders, e.g., customers, employees, governments, communities, and shareholders [29]. Additionally, this also emerges when there is widespread awareness that businesses have a critical role to play in improving poverty, social inequality, environmental quality, and driving the society towards sustainable development [30]. Many governments today pay considerable attention to the concept of corporate sustainability in companies' operational strategies. Also, Mandelbaum [31] by using Dow Jones's perspective of corporate sustainability to define it as "a business approach that creates long term shareholder value by embracing opportunities and managing risks deriving from economic, environmental and social developments" [32].

In the construction industry, the term "sustainable construction" refers to the industry's responsibility to meet sustainable development goals. Sustainable construction is a means by which the construction industry achieves sustainable development on economic success, social welfare, and environmental protection. The main concern of sustainable development is the conservation of the environment during extraction and many construction activities, which can cause unprecedented adverse environmental effects. The social concerns include human feelings, including satisfaction, security, safety, and human efforts like health, motivation, and skills [33]. Economic sustainability concerns such as constructors, public and clients' benefits, and projects financial gains [33].

As sustainable construction is derived from sustainable development concepts, it should address the three sustainable development bottom lines. The commonly quoted sustainable development definition is one "that meets the needs of the present without compromising the ability of the future generations to meet their own needs" [34]. The three pillars of environmental, social, and economic have to be balanced [35]. Edun-Fotwe and Price [36] argue that a company's state of sustainability can be referred to as first-order, second-order, and third-order due to considering one pillar, two pillars three pillars, respectively. Thus, sustainable construction is also interpreted as first, second, and third-order states of sustainability [37]. Gilbert's [38] definition of sustainable construction focuses on a company's ability to use its resources and ecological principles in responsible development and management of a healthy environment.

Evidence shows that successful construction sustainability is driven by environmental, economic, and social constructs. This means that to achieve sustainable construction goals, a company must endeavor to integrate at least one of the drivers in its strategies. In reality, incorporation of all three sustainable construction drivers is almost impossible as challenges are always present [39]. For this reason, companies strive to implement strategies that try to incorporate most of the sustainable construction drivers. For instance, there are numerous strategies like the European Union's Performance of Building Directive (CA EPBD, 2014), whose concern is energy efficiency in the building industry [40]. However, the increased focus by construction companies on energy efficiency, especially in the operational building phase, has led to other problems like making embodied energy resulting in embodied carbon emissions. For this reason, to achieve sustainable construction, construction companies need to develop strategies that address carbon emission (CE) also [40].

The significance of construction sustainability accountability should be emphasized as these companies produce a significant environmental impact, especially in carbon emissions, due to the importance of the waste that also produces much energy for industrial and domestic purposes [41]. The Australian Bureau of Statistics (2003) noted that construction activities have massive impacts on the environment mainly due to their land, material, and energy utilization. Due to this background, construction companies need to adopt approaches that manage their adverse effects to maintain sustainability. Without such strategies to conserve the environmental, social, or economic implications, construction companies risk future reputational risks and mitigation measures [42].

Sustainability aims at achieving a more equitable and wealthy society where there is conservation of the cultural practices and environment for the benefit of future generations [42]. Thus, international companies should commit to implementing sustainable strategies to conserve the environment [43]. Companies are expected to incorporate strategies that ensure clean products and production processes that do not harm the environment. Companies have also realized the economic benefits of a clean environment. While adhering to environmentally safe strategies, companies have to protect their employees' concerns, maintain and enhance their ethical image, adhere to government directives, and develop new opportunities to maintain a competitive edge [44].

In addition to the numerous definitions, the Brundtland Report [21] gives it a general outlook: 'meeting the needs of the people now without devastating the lifesupporting ecosystems for future generations.' Further, it states that it is a 'dynamic process rather than a fixed state: "basically, sustainable development is a process of transition in which the using of resources, the control of investments, the direction of technological development, and governmental change are in harmony and improve both current and future capacity to meet human needs and aspirations" [45]. Despite widespread knowledge of the triple bottom line, the relationship, especially on the sustainability degree between the natural and human-made capital, has the intense debate on weak versus solid sustainability [46].

In determining whether sustainability is weak or strong, both human and natural capital are taken into consideration. Weak sustainability refers to an assumption that human capital (machines and infrastructure) and natural capital substitute each other unlimitedly to maintain sustainability by avoiding any chance of decreasing the number of capital stocks [47]. This means that when the natural capital is depleted or reduced in the environment, the human-made capital replaces it as a substitute. Likewise, when the ecosystem services are degraded, some equivalent forms of human capital can replace them. This concept means that sustainability can be achieved by rapid urbanization and fast economic development with a dwindling environment quality. On the contrary, for sustainability to be strong, the human-made and natural capital are complementary to one another [48], or because environmental features like uncertainty and irreversibility as well as other components that are critical for human welfare hinder the likelihood of substituting manufactured for natural capital [49]. Therefore, there is a need for the organizations in the construction industry to implement the sustainable development and practices in order to fulfill the requirements of a healthy environment and society.

This section presented an overview of sustainability, in general, and its increasing importance. Section 2.1.2 focuses on sustainability in construction. Therefore, the lack of sustainability criteria and benefits in the portfolio selection process is the main concern of the decision-makers. Moreover, the importance of sustainability criteria and their advantages in the modern construction industry is highlighted. Thus, there is a need for a new model that integrates sustainability benefits in their decision-making process along with traditional and organization advantages under one umbrella, where the top management can make their decisions while considering all aspects of benefits for the organization.

2.1.2 Sustainability in construction. The "sustainable construction" theory was discovered in the US in 1994 in the literature of sustainable construction conference held in Tampa, Florida. A detailed list of principles and conceptual models was proposed by Hill and Bowen [50] to attain sustainable construction in terms of four pillars: economic, social, biophysical, which is relevant to environmental and technical perspectives.

Construction projects' processes have significant environmental impacts, making sustainability a vital concept in the construction industry [51]. The practices and strategies of sustainable growth refer to the economy, environment, and social policies. There is a need to change the construction thoughts about the constraints related to time, quality, and cost, where the sustainability concept may involve social performance indicators and responses to the environmental issues [52].

There is evidence that various organizations originating from dissimilar economies respond differently to sustainable challenges [53]. The institutional structure of a particular environment constituted from the social, economic, and political aspects can provide organizations competitive advantages for engaging sustainability in their particular activities [53]. Organizations that get institutional support are found to perform efficiently [53].

The concept of sustainability in project development and management was initially proposed in the early 1980s. Sustainable development as a term was used by the World Commission on Environment and Development (WCED) [21] in the report to the United Nations General Assembly (UNGA). The current primarily enhanced three sustainability pillars (Social, Environmental and Economic) got implemented in the early 1990s [54]. This three-pillar framework for assessing sustainability was embraced by many current national-level sustainability assessment systems [55] mentioned previously. The literature's relevant indicators have to be utilized in the selection process to enhance sustainability in construction industries.

As per various management literature, the managers' role is to promote social change to achieve sustainable development [56]. Institutionalization and bureaucratization of sustainability concepts in companies have become a common practice. This practice is characterized by companies' public environmental and social mission statements and including a department to take care of environmental issues [57]. Welford [58] indicated a need to develop frameworks to transform the conceptual ideas into practice. It means that business leaders must develop environmental and social-conscious policies and strategies to achieve 'corporate greening' and dynamic sustainability policy [59]. Corporate greening refers to companies' ability to adopt environmental-friendly operations, referred to as adopting practices that promote environmental soundness [60].

The Brundtland Report brought the sustainability debate to the global fore when it proposed that development must not interfere with human need satisfaction (WCED, 1987). Many industrial practices have exposed human resources to potentially adverse effects on human health and their generations, resulting in efforts to change these poor practices [61]. Sustainability in the business field refers to the act of meeting the needs of an organization’s stakeholders without losing its ability to meet the needs of its future stakeholders [62]. Also, Szekely and Knirsch [63] define business sustainability as expanding the economic growth, prestige, customer satisfaction, corporate reputation, shareholder value, and the quality of products and services a business offers. This means that a business should adopt appropriate ethical practices, develop sustainable employment opportunities, attend to the overlooked needs, and build value for the stakeholder efforts.

Companies and organizations have been criticized for not paying adequate attention to their environmental and social impact due to the lack of knowledge in sustainability development [64]. Economic success is also affected as social and environmental issues affect both its costs and income [65]. Even though more research is required to confirm, companies operating in a clean environment are associated with higher financial success. King et al. [66], in their empirical study, illustrated the association between reduced pollution and higher income. They further noted that a company with good environmental performance relative to the industry is associated with higher financial success. In the same breath, other scholars confirm that firms also experience higher financial performance when adopting discretionary environmental change [67]. Epstein [68] notes that sustainability-induced international competition among firms also stimulates them to improve their production process, consequently improving the product quality, design, service quality, and efficiency in production and enhancing the environment. However, King et al. [66] argue that a firm's mere operation in a clean environment does not necessarily lead to higher financial performance [69].

Regulations have successfully propelled an organization to adopt an innovative environmental and social consciousness style and improve practice efficiency [70]. On the other hand, other researchers have argued that regulations can be detrimental to a company's financial prosperity as long as they deter financial performance [70]. Both public policy and the business sustainability debate benefit from understanding the potential link between green production, regulatory measures, and financial performance [71].

With the continued sustainability debate among business entities, organizations need to understand what it means about their operations. It is also significant to understand how best they can integrate sustainability indicators into their decision-making process to address their operations' social and environmental impacts to avoid being obsolete [72].

Before the Rio Conference, which introduced this concept into the international stage, the United Kingdom was the first to introduce a multi-criterion system for sustainability. The British Research began to plan to start the BREEAM in the 1990s and launched officially in 1993. The system has dramatically adopted the system, and the system has approved about 10,000 buildings [73]. The system has gained worldwide recognition and adapted to other criteria from other countries like Canada, Australia, and Hong Kong. The system has 11 different building typologies expressed as a percentage of the total points where; 25% is for a pass, 40% for good, 55% for very good, 70% for excellent, and 85% for outstanding. The system evaluates different categories, including water availability, transport, materials, ecology, energy, pollution, health, management, land use, and innovation [74-75].

Another system that is becoming popular is the Leadership in Energy and Environmental Design (LEED) that was developed in the year 1998. According to its six evaluation categories, the system awards points to obtain the highest points possible (69) in its second version [76]. These categories include 14 points for the sustainable site, 5 points for water efficacy, 17 points for energy and atmosphere, 13 points for materials and resources, 15 points for the indoor environment quality, and 5 points for innovation and regional specificities. For a building to be certified, it must attain a total of 26 points. Thirty-three points get silver, 39 points get gold and Platinum for 52 points and above. Over the years since its launch in the US, GBC has been adopted throughout the world. About 20,000 buildings have received GBC certifications and have received applications for new certifications from 110 countries [77].

Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) refers to a Japanese building rating system developed in 2001 and available in the English version. It employs different assessment tools based on a life-cycle evaluation fashion [78]. They go through the pre-design, new construction, existing buildings, and renovation. This design is founded on closed ecosystems where they focus on two assessment levels: the building's performance and the environmental load. While in the building performance, it covers resources and materials, energy and outdoor environment, in environmental load, it covers criteria like reuse and sustainability of materials and resources and the surrounding environment. Compared to the two previously discussed approaches, CASBEE presents its results as a measure of eco-efficiency graphically. The environmental loads are put on one axis and quality on the other axis. Sustainable buildings for CASBEE have the lowest environmental load and highest quality. Despite its immediate acknowledgment, only about 100 buildings have received the CASBEE certification [78].

Towards the end of the 1990s, the Natural Resources Canada (NRC) was mandated to lead in the internationalization of rating systems by the Sustainable Building Council [79]. A standard protocol was developed SB Method. Several countries complied and based their national rating guidelines on the SB Method, such as the ITACA in Italy, SB Method in Portugal, Verde in Spain, and SB Tool CZ in the Czech Republic [79]. The Italian ITACA was initially called SB Tool IT in 2001 before changing the name in 2011 [79]. Further, in Italy, they have modified the tool according to the specifications of its ten regions. While adapting the Canadian version of BREEAM, the Green Building Initiative (GBI) launched the Green Globes [79].

The criterion of the Green Globes involves site, project management, indoor environment, resources, water, energy, solid waste, and building materials [79].

There is a high demand for water and energy and high waste (including toxic) production. Thus, issues related to the environment dictate most of the discussion concerning industrial buildings. There is a big worry among the local dwellers of industrial building sites due to the massive degradation of the environment caused by the building activities [80]. This is among the reasons for the need to harmonize the building activities with the environment. Building activities should reduce water and energy demand and protect against environmental pollution and other environmental-related issues [81].

The economic development of a country critically depends on industrial growth. Besides the impacts of their activities on the environment, they also spend large amounts of financial resources, including the cost of building, materials and supplies, maintenance, and demolition. These items also serve as economic indicators for industrial building sustainability. They also affect regional growth, enhance competition in the industry, induce innovation, and advance technology advancements. All these should be considered before constructing a building as they enhance economic growth [82].

The city planning adopted sustainability principles in the sustainable use of resources as its primary objective in the early 21st Century [82]. Sustainability is critical in cities and urban areas because of the dense population and its adverse effects on the global environmental footprint [82]. A fundamental method of ensuring cities proceed towards sustainability is sustainable construction, whether in direct or indirect ways [83]. To assure a direct effect on sustainable construction, reducing the footprints of construction on the triple bottom lines of sustainability must be concentrated [83]. The indirect impact arises from observing construction's determination and building facilities to sustainability by people [83]. For example, a public facility with users who monitor it with sustainability can indirectly be prompted to keep its common goal. With this said, intensifying the sustainability of communities depends upon a collaborative intention [83]. The construction industry's inspirational influence will strengthen the customary determination to have more sustainable cities and communities [83]. City development presents many barriers in the implementation of sustainability despite its obvious significance. Yi, Dong, and Li [83] state that limited resources, population pressure, and high pollution rates are the main barriers to achieving sustainability in Chinese cities [65]. However, the concept of Smart Cities brought by technological advancement is a game-changer in today's efforts to bring about sustainable development in the cities [65]. Smart Cities improve the residents' quality of life by enhancing their operations performance and healthier environment [65].

The vast acceptance of sustainability as the key concept in development for different communities has resulted in different discussions on the standard sustainability assessment criteria and the relevant designs to be prepared [83]. This has resulted in various assessment criteria, including product assessment tools, indices, integrated, indicators and assessment methods [83]. There are different sustainability framework indicators proposed at different levels, including local, regional, national, and global [65]. On the other hand, there has been no universal framework for assessing sustainability in its full complexity that has emerged on any of these scales [65]. However, analysis of different social and natural resources presents a problem to the interpretation of sustainability assessment [84]. In addition to that, even integrated assessment techniques are unsuitable for use in complex socio-economic systems analysis [84]. Therefore, there is a need to comprehensively measure the interactions between and within the diverse and complex systems [84].

Infrastructure sustainability for both the design and construction phases has been recognized and accepted in civil engineering projects [85].

Infrastructure projects have an essential role to play in achieving a sustainable construction environment. There is a difference between civil engineering infrastructure projects and buildings for developed sustainability assessment tools. The differences include the nature of project diversity, design standard variety, urban development impact, operational requirements, construction practice, and general management of the project, occasioned by prominent influence zones [86].

Recently, civil engineers have commenced initiating the practice of sustainability into consideration when designing and constructing projects. Infrastructure sustainability involves attracting public attention and support in building sewers, water supply, building bridges, housing, roads, electrical grids, and telecommunications [87]. The need for long-term infrastructure sustainability calls for a strong focus on the development of designs and construction. Infrastructure sustainability indicators have been proposed in the previous years [88]. The assessment indicators have been critical in evaluating issues of sustainability in engineering fields [89]. For instance, the Multiple Attribute Value Technique [90] was instrumental in choosing materials and resources to achieve sustainability in construction [91]. Mendler and Odell [92] proposed social and environmental aspects in the projects' design and construction phases [93].

There is a significant effect on the principles of sustainable development caused by the infrastructure projects. As the developing world will continue to develop infrastructure, there is a need to continue improving sustainable infrastructure. Despite various approaches for achieving infrastructure sustainability, studies have not found effective assessment indicators that limit practical assessment of infrastructure projects' sustainability [94].

The social, economic, and environmental activities, especially in the developing world, are greatly affected by infrastructure projects [89]. Before considering their implementation, a thorough assessment of their sustainability performance is vital [92]. An advantage towards general society is an infrastructure project in which the public authority strategy has a critical part in impacting the impacts of the task on the financial turn of events and social necessities [92]. Infrastructure generally refers to a wide range of services, spanning from power, water supply, sewerage and sanitation, telecommunications, railways, transport, sports, solid waste collection and disposal, piped gas, dams, canal works, water, and airports [92]. Infrastructure is the establishment for the social and financial turn of events; subsequently, foundation interests are especially significant in developing countries [93]. Between 1975 and 2005, approximately 30% of the World Bank investments were on infrastructure projects in the developing world [93]. The advancement of infrastructure projects has been making critical commitments to the improvement of developing countries [91]. For instance, in the last two decades, China's investment in power generation resulted in an improvement in power generation to approximately 718 million kilowatts in 2007 from 61.9 million kilowatts in 1978 (CPGC 2008a) [93]. Ventures in infrastructure are likewise a significant way to intensify financial exercises [93]. For instance, the Chinese government, as of late, intended to put more than RMB$2,000 billion in different infrastructure tasks to strengthen the public economy, which has experienced the world monetary emergency before the finish of 2008 [94]. These infrastructures include street, electrical force, rail lines just as rustic zones infrastructure for 2009 and 2010 (CPGC 2008b) [94].

Although investing in infrastructural projects has many advantages, it also presents other adverse effects on society and the economy. The various studies that found the infrastructure-related problems have cast doubt on infrastructure investment assessment's effectiveness and reliability. Available studies provide evidence of improvement of infrastructure investment outcome by incorporating the sustainable development attributes, generally known as triple bottom line [95].

Following the advancement of the rule of feasible turn of events, infrastructure projects ought to be created to bring benefits across all angles, including economic, social, and environmental. There are significant efforts to develop environmental-friendly methods in recent years to reduce infrastructure construction activities on the environment [96]. Despite the efforts, infrastructure's environmental and social effects are occasionally missed during assessment and identified during or after implementing the projects [97].

There are different perspectives employed by various studies in the analysis of the sustainability of infrastructure projects. For instance, Choguill [98] suggested a community-based approach in implantation and decision-making during the formulation of policies geared towards enhancing infrastructure sustainability. Rackwitz et al. [99] based his maintenance strategy for enhancing infrastructure sustainability on a cost-benefit analysis that focused on the project's performance during the operation stage. Ugwu and Haupt [86] came up with an indicator system for improving infrastructure sustainability, which focused on the operation stage. Studies have also investigated strategic environmental assessment (SEA) methods for infrastructure projects. Colonie et al. [100] used a decision support system to develop an assessment tool to assess the transport infrastructure's effect on the environment. Shen et al. [94], using a system dynamic method, developed a prototype model for construction sustainability assessment. Other scholars have developed sustainability assessment tools for various infrastructures, including transportation, energy, and wastewater.

This section provided an overview of sustainability in the construction industry. Thus, the shortage of a comprehensive standard and model that consider all three pillars of sustainability in decision-making process is highlighted. Furthermore, the significance of sustainability and sustainable development is demonstrated in the construction industry. Therefore, there is a requirement for a portfolio selection model that analyze the benefits of sustainability based on its three pillars simultaneously. In the next section, sustainability criteria and indicators in the construction industry are studied.

2.1.3 Sustainability indicators. Recently, many organizations have been including multiple stakeholders such as consumers, employees, national controllers, suppliers, local communities, and firms to use the financial indicators in tracking their business' performance [17]. Sustainability indicators are arising and becoming famous for the organization’s reporting on financial in terms of social and environmental aspects for supply-chains companies [17].

There is a model suggested by Fernández-Sánchez and Rodríguez-López [55] for identifying sustainability indicators in the construction industry. According to their report, a case application of the proposed method was simulated for Spain's infrastructure projects. The result was a list of thirty macro-indicators for sustainability valuation of an infrastructure project. The proposed approach by Fernández-Sánchez and Rodríguez-López is relatively general, which makes it possible to be utilized to other types of construction projects such as building and steel structures. Shen et al. [56] and Huang and Hsu [57] proposed similar models that helped identify construction projects' sustainability indicators using different approaches. Huang and Hsu [56] identified thirty sustainability indicators of construction engineering derived from relevant research literature and government rules. In comparison, Shen et al. [57] used the study reports of eighty-seven construction projects in China for identifying thirty-four indicators that relate to the sustainability of four types of construction projects.

The majority of the works adopted the three-pillar perspective of construction projects' environmental, social, and economic sustainability, except Hill and Bowen's first one [50]. Several important issues should be considered in developing an appropriate sustainability assessment system for a construction project. As different researchers have pointed out, these issues include; Firstly, a more thorough sustainability angle, including materials and products that are used in the execution of projects, the management process, organization, key stakeholders who are the project manager and team members, and the economy concerns [58]. Secondly, the number of indicators should be minimal for practical and cost-effective implementation [59]. Some researchers proposed very similar numbers of indicators close to thirty [60], explaining that a sustainability system with around thirty indicators is more practical and cost-effective for project performance. Thirdly was the life-cycle issue. Here the indicator system is expected to emphasize the construction project life-cycle (such as feasibility study, procurement, planning, construction, and turnover). Instead, it should also emphasize the facility life-cycle (maintenance, operation, and demolition) [61]. Lastly and most importantly is the project focus. Here, the indicators should be relevant to the project's operations and tasks for effective management since the construction objectives need to be accomplished via project execution [58].

The review focuses on the environment as a component that affects and receives effects from other components of a more extensive system—the other two pillars, which our economy and society, closely interact with the environment. Additionally, the society uses an institutional component in managing correlations between all the pillars and incorporated activities [70]. This discussion allows us to differentiate between the three significant aspects of a policy's probable outcomes or an undertaking regarding environmental, economic, and social impacts. Also, the three pillars' details represent the major themes for the sustainability assessment [64].

The Pressure-State-Response framework has been adopted by the EU Organization for Economic Co-operation and Development in the early 1990s' [65]. It is describing a reined relationship between the environment, society, and economy. It helped identify the link between the basic components, essential for integrating the environment's anthropogenic impact [66]. It helped identify the link between the basic components, essential for integrating the environment's anthropogenic impact [66].

The framework's conceptual scheme emphasizes the environment and societal aspects. Economic and societal processes impose pressure on the environment, which alters its services provides to the community [66].

The frameworks are the conceptual models for the integration of environmental evaluation of mainstreaming sustainability. The framework is applicable when it addresses issue-associated indicators. These indicators are based on the problem domain and the temporal and spatial scales of a specific investigated case. Additionally, the indicators must be coherent with the universally accepted sustainability measurement for environmental reporting [67].

Sustainability issues are converted utilizing sustainable development indicators into measures of economic, environmental, and social performance that can be quantified with the ultimate goal of addressing the key issues. The development of indicators requires identifying relevant issues that obtain the specific characteristics of each type of industry. A stakeholder analysis can demonstrate the general types of concerns; nevertheless, each industrial activity requires an in-depth analysis [101].

A sustainable development strategy comprises universal indicators utilized in evaluating and controlling overall progress against the specified goals and the specific targets. In its 46th session, the United Nations Statistical Commission (UNSC) laid down the Inter-Agency and Expert Group on SDG Indicators (IAEG-SDGs). This is mandated for the development of the universal indicator context in combination with the UNSC. The suggested indicators have gone through an inclusive, open, and transparent consultation procedure, where 300 indicators were initially chosen. Here, civil society, countries, regional and international agencies, academia, and the private sector were invited to remark and represent their opinions and thoughts. The debate brought several adjustments to the original set of indicators, which provided a foundation for the final proposal of 230 SDG indicators introduced at the 47th session of the UNSC [102].

Many of the indicators are deemed necessary in fulfilling the criteria of being useful in a management context and analyzing statistical construction capacity. Simultaneously, the many indicators strengthen the effort needed to evaluate the overall success in attaining sustainable development [103]. There is an open question that how sustainable development can be evaluated using a set of non-monetary indicators [103]. An evaluation framework necessitates selecting indicators relevant to the goal and assessing them as a means to compare a strategy or a process with its alternatives. In Agenda 21 [104], and everyday necessity describing sustainable development using quantitative indicators that measure sustainability at the international and national levels has been articulated. The initial set of sustainability indicators was introduced based on the Drivers-States-Responses framework. Here the 'drivers' indicate the activities that impacted sustainable development, 'states' describe the current situation, and 'responses' reflect societal actions towards sustainable development [105].

On the other hand, the economic perspective focuses on examining the relationship between the natural environment and economy in monetary terms. On the contrary, the System of National Accounts measures economic activities about production, foreign trade, and investment. Similar indicators used to express natural capital, and its dynamics under anthropogenic effects necessitate the assessment's integration. The only obstacle is remaining in the absence of monetary values of most environmental impacts, mainly because of the disharmony in accepting the standard impact appraisal method and lack of relevant data. Instead, the System of Integrated Environmental and Economic Accounts uses available national data to describe the physical environment [106].

The quality of human life is used as the primary indicator for the social pillar. The description of individual flows and stacks and their role in both social and economic process by the Social and Demographic Statistics System takes an accounting form reflecting "life sequences, time budgets and cost-benefit distributions" [107]. Regrettably, no understanding has been reached on the philosophy of personal satisfaction and its quantification. Unified hypotheses or statistics frameworks for environment-population collaborations are less evolved than those portraying economy-environment exchange. Subsequently, the evaluation should consider significant segment and financial attributes, for example, migration, fertility, marital status, education, labor force status, occupation, industry, and health [108].

Reviews of scientific-technical references and legislation (For example, government regulations and national sustainability white paper) and the sustainable construction project case reports generated by government agencies help identify the candidate indicators for sustainability assessment. Chang [55] suggested that a country's sustainable development assessment indicator system relies on the Taiwan government's policies and regulations, including fifty-nine environmental and twenty-three social indicators. Among these eighty-two indicators, thirty-nine of them are linked to the construction sector. A national-level sustainability indicator system was established by Hsu [109] for the construction projects of Taiwan based on an evaluation of the scientific and technical references published in the compatible literature. Hsu's indicator system constituted twenty-nine environmental indicators, eleven economic indicators, and twenty-seven social indicators. All of the 67 indicators suggested by Hsu are significant to construction projects. However, most of them are assessed by the government agency's viewpoint instead of the project manager's perspective. There is a need to redefine them to fit the need for application in construction projects. Finally, for supplementary analysis, fifty-seven candidate indicators belonging to twenty categories were classified as candidate sustainability indicators.

A more flexible conceptual structure is the theme-based framework that organizes indicators according to four sustainability dimensions (environment, economy, society, and institutions) around critical themes or policy relevance issues [110]. The theme-based framework can also be used for gauging urban sustainability on multiple scales, although it was initially designed for developing national-level sustainability indicators [110].

Economic indicators calculate a company's economic influence on its internal and external stakeholders and economic systems at the local, national, and global levels [108]. Therefore, the economic indicators must include the standard calculations of financial achievement such as shareholder returns and profits and go beyond the traditional fiscal indicators to reflect the broader contexts in which companies operate [108]. The economic indicators throughout this framework are based on the five GRI categories of performance, each including several specific indicators such as net sales, return on investments and taxes paid to the public sector. Additionally, it has been vital to add two more types of indicators related to local communities (e.g., revenue distribution) and products (e.g., value-added) [109]. The information provided under this category is made, therefore, more compatible and transparent using the environmental and social indicators [110]. The proposed economic indicators demonstrate the type of information and the stakeholders' economic issues [111]. Twenty-four economic indicators have been proposed, which has an additional six indicators proposed by the GRI [111]. The additional indicators comprise commonly relevant economic performance measures such as revenues before tax (EBIT) and interest, and the sector-specific indicators, such as total investments for mine closure and rehabilitation [111].

Environmental performance measures are most developed and have achieved the highest degree of harmony among experts regarding the three types of sustainability indicators [112]. They quantify a company's effects on ecosystems, including humans, land, water, and air. These effects can be local, regional, or global, impacting a wide range of stakeholders [112]. For instance, depletion of mineral resources has both local and global implications [112]. Locally, it will disturb the employees and their job prospects and the local communities' prospects to profit from the mining activities [112]. Globally, the reduction of mineral reserves affects both the current and future generations, as they can no longer depend on these resources to satisfy their needs [112].

The environmental indicators must reflect the critical environmental issues and the magnitude of the impacts [113]. By utilizing both the absolute measures of environmental performance (e.g., tones of mineral resources extracted per year) and normalized units (e.g., tones of a mineral resource depleted per year relative to that resource's world reserves), this can be achieved. Normalized units also allow comparisons between companies of different sizes, mainly if they are expressed per ton of product [113].

Although the economic and environmental performance is relatively easy to measure and the indicators are overall well established, measuring the level of social sustainability of a business or a sector is not straightforward. This is because social indicators have to consider both employee and communities' interests to reveal their social impacts at the local, national, and global levels. Additionally, it is impossible to quantify a company's social and ethical dimensions, such as human rights protection or cultural values, nor can they be described in physical terms. By avoiding these issues, the sustainability assessment is considered incomplete [114].

Thus, all frameworks proposing social indicators should include both quantitative and qualitative indicators. GRI proposes 53 social indicators. The GRI framework groups the social indicators into five categories related to labor practices, human rights, and broader issues that influence consumers, stakeholders, and communities. Since some of these indicators are relevant to consumer products-related companies compared to the mining companies, they can be reduced to 45 [115].

In this section, various sustainability indicator and criteria frameworks are studied and analyzed based on the three sustainability pillars. Therefore, the literature review highlights the importance of considering the benefits of all three pillars simultaneously in a comprehensive model to demonstrate the overall sustainability advantages. The deduced information from this section is developed in section 4.2 by demonstrating comprehensive sustainability selection criteria for the decision-makers. In the next section, the methods of measurement for these criteria are discussed.

2.1.4 Sustainability index and measurement. In selecting technological and alternatives in managing human activities, including policymaking, quantitative sustainability assessment becomes a crucial issue [116]. Some studies have described various appraisals for sustainability frameworks [116]. The frameworks guide the development of sustainability indicators with different granularity levels since the assessment of sustainability involves comparing and analyzing both the current and future outcomes of welfare, using models of application and mathematical tools necessitating the use of quantitative sustainability indicators [116].

Specific sets of indicators are used as helpful tools to measure sustainability. The synthetic features of the indicators make them essential in public communication and policymaking [117]. Moreover, more efforts are dedicated to developing indicators focused on sustainable development concepts comprehensively [117]. Recent research focuses on expanding the scope of sustainability and selecting appropriate indicators [116].

Despite the ‘indicators’ aggregation procedure being a controversial issue, an index is used to summarize a wide range of information. For example, the index facilitates policy design, assessment, implementation, and discovery of the relationships between indicators. In this relation, the Fondazione Enrico Mattei

(FEEM) has been developing a new tool for sustainability assessment, the FEEM Sustainability Index (FEEM SI), since 2006. A first version was released in 2009, while the updated structure for its second release was in 2011. The index summarizes and merges information derived by selecting relevant sustainability indicators offering a more comprehensive sustainability account [117].

The chief elements of sustainable development (socio-economic and environmental components) are captured by The FEEM SI, an aggregate index made of a set of indicators. The index uses a specific methodology that includes the interactions between indicators depending on subjective experts' analysis. As it is built in a circular-dynamic Computable General Equilibrium (CGE) model, the FEEM SI can be used to analyze and compare sustainability across different policy scenarios. This allows including in the analysis the intertemporal conditions of sustainability. While the macroeconomic model implies some drawbacks (e.g., the absence of indicators disconnected from economic activity), the modeling framework dispenses a coherent context for calculating indicators with comparability across countries, time, and alternative scenarios [118].

The FEEM Sustainability Index (FEEM SI) introduces an integrated methodological motion to measure sustainability performance over countries with respect to time. There are three main aspects of this approach: (1) the index takes in to account the sustainability based on the three pillars of economic, environmental, and social simultaneously; (2) the framework utilized to measure the indicators, i.e., a Computable General Equilibrium (CGE) model, permits to make predictions on the future growth of sustainability; and (3) the methodology utilized to normalize and deliver a unique and comprehensive measure of sustainability. Together with the multi-regional nature of the CGE model, these features consent to perform policy evaluations and sustainability assessments for individual countries or regions in the world [117].

Following a thorough analysis of the sustainable development literature, the list of indicators included in the FEEM SI was determined. The selection process has been further refined to consider only manageable indicators in the building's macroeconomic model framework. The specific methodology applied to define future sustainability limited the choice to indicators that can be instantly linked to economic measures present in the model [119]. The structure of the FEEM SI is illustrated by the research and includes all index construction indicators. Along with the wide definition of sustainability, it has to consider its three main pillars: social, economic, and environmental. For each of the three pillars, the FEEM SI tree covers the significant sustainability assessment areas: economic growth drivers, GDP per capita, economic exposure, population density, well-being, social vulnerability, energy, air quality, and natural endowments [119].

There is a growing concern for the global sustainability in all society sectors from the Rio Summit In the last 20 years. Organizations have to commit more toward sustainability to add value. Sustainable development has been driven mainly by the related legislation due to the need to protect natural resources and reduce impacts across economic, social, and environmental dimensions associated with an organization's performance. A structured approach for sustainability performance evaluation is recommended through the Corporate Index of Sustainability Performance (CISP) in Cuban organizations, combining different tools like ISO 14031, Sustainability Reporting Guidelines of Global Reporting Initiative, Balanced Scorecard, and multicriteria methods [120].

In sustainability research and practice, sustainability indices have highly become very important. The typology and applicability of the aggregating and weighting methods are still not yet understood, although the sustainability indices' validity relies on how they are weighted and aggregated [121].

Sustainability is a complex phenomenon of the current times, as is highlighted in the literature review [117]. It is multi-dimensional, complicated, and attached to trade-offs among many other dimensions by harmonizing environmental, economic, and social indicators [117]. Environmental sustainability includes ecological subsystems; social sustainability involves social subsystems, while economic sustainability involves the economic subsystems [118]. Nevertheless, as people strongly desire more sustainability, accurate assessment of our societies' sustainability will be more difficult [119]. To understand sustainability's complexity, it is required to integrate several indicators to form composite indices [119]. Therefore, one of the essential tools in assessing and attaining sustainability is developing sustainability indicators and indices [121]. Specifications of sustainability index formulation can radically influence the evaluated sustainability of a system [121].

A sustainability index's primary process involves selecting the selected indicators, weighing, and aggregating those indicators into a composite index. It is somehow easy to solve indicator selection disagreements since there are guidelines that exist. For example, the Bellagio framework [122] presents that the Pressure-State-Response framework, for example, can guide the selection of indicators. Selecting the best suitable weighting and aggregation methods is a challenge since the indicator incorporation process is an intrinsic subjective process [123].

Also, some sustainability assessment efforts on the urban scale have been performed, and various tools used to evaluate the impact on/caused by towns have also appeared. However, the concept of sustainability differs from one region to another. The evaluation of indictors should be appropriate to the specific conditions of the area [124].

Society has made many efforts since sustainable development emerged to assess a city and region's sustainability level through indicators. From the mid-1990s, research into the urban context has concentrated on corporate strategies and policies predominant in North America and Europe. Enormous difficulties emerged during policy implementations by local authorities. The initial indicators of sustainable development are extracted from Agenda 21 (United Nations, 1995) recommendation. This guidance suggested identifying and developing sustainable development indicators that could provide a solid basis for decision-making at regional, national, and international levels. It also recommended integrating a reliable set of these indicators into common databases that are broadly reachable and updated frequently [125].

Green City Index (GCI) was introduced in coordination between Siemens and the Economist Intelligence Unit (EIU-Siemens) for regional evaluation regarding their "environmental performance". From the year 2009, the EIU-Siemens project has assessed above one hundred twenty cities worldwide, generating a series of reports with GCI rankings of these cities by region. They chose these cities based on their eminence and size, many of which are capital cities and metropolises with many business centers and large populations [110].

GCI comprises around thirty indicators from nine categories: energy saving, CO_2 emissions, land use, transport, water and sanitation, waste management, air quality, and environmental governance [126]. Around half of the GCI indicators are quantitative and based on official sources like water consumption, air pollution, and CO_2 emissions [126]. The other half of them include information on investment in renewable energy, air quality codes, and traffic-congestion-reduction policies, which are qualitative evaluations of environmental rules [126].

Environmental Performance Index, abbreviated as EPI, was previously called the Environmental Sustainability Index (ESI). It was established based on two broad themes by the Center for Environmental Law and Policy at Yale University and Columbia University's Center for International Earth Science Information Network. This collaborated with the World Economic Forum and the European Commission's Joint Research Center [127]. These two concepts and themes' objectives were protecting ecosystems and protecting human health from environmental harm. Nine issue areas considered for this are air quality, biodiversity and habitat, fisheries, agriculture, forests, water and sanitation, climate and energy, water resources, and health impacts. Generally, twenty indicators are utilized in quantifying the nine issue areas of the two concepts. They are aggregated into one single index of EPI, whereby the weights of these indicators, the issue areas, and the policy's overall objectives are determined. This determination process considers their relevance to policy issues and the quality of data. Higher weights result from higher relevance, and lower weights have lesser data reliability [128].

EPI is used in comparing how well different nations meet goals that are set globally. Its focus is on the environmental dimension of sustainability but strongly asserts policy issues that cut across social and institutional dimensions. EPI has been in use basically at the national level. Although it is yet not done, it can also evaluate urban centers' sustainability after issues, and related indicators are correctly amended to address their problems [129].

GDP is recognized as an economic growth but not recognized as sustainable development. Since the early 1990s, demands for 'green' GDP have increased. Destabilized environment, natural resource consumption, and economic activities that are not considered in GDP are explicitly recognized in the Green GDP measures formulations. A leading indicator of the sustainability of this kind is the Genuine Progress Indicator (GPI). This comprises twenty individual indicators that cover the social, economic, and environmental aspects of sustainability. Both traditional economic transactions, nonmarket natural and social benefits are accounted for in GPI, which explicitly differentiate between positive and negative economic activities on human society and well-being [130]. GPI is the amended Index of Sustainable Economic Welfare (ISEW) version that Daly and Cobb [131] suggested. ISEW and GPI have acquired the national accounts of the transactions that are considered relevant to human well-being. GPI has lately been utilized more frequently compared to other Green GDP measures [131].

Though developed for measuring the progress nationally, the ISEW and GPI have been applied at multiple scales [132]. For instance, China was the first to implement the Green GDP at a national level. Maryland state in the USA adopted the GPI to evaluate the impact of development projects on long-term prosperity [133]. Application of GPI in cities has also become popular in Canadian, American, and Chinese cities [134].

2.2 Benefit Realization Management and Project Value Management

2.2.1 Introduction. There are varied BRM definitions in the normative literature. Farbey et al. [135], for instance, defines BRM as a process aiming at realizing and managing both the expected and unexpected benefits. Bradley [136] also defines BRM as "the process of organizing and managing, so that potential benefits arising from investment in change are achieved." BRM refers to a process used to ensure the expected returns on an investment, like BIM [137]. According to Serra and Kunc [138], BRM is defined as "a set of procedures designed to close the gap between strategy planning and implementation through ensuring the performance of the most beneficial initiatives." From another perspective, successful project implementation is highly influenced by turning visions and strategies into success. The inability or unwillingness of the stakeholders within an organization to make use of the project deliverables is frequent for zero or low generation of project benefits.

Successful accomplishment of project benefits and value are significantly affiliated with the performance of an organization. In the benefits realization management process, the first and most vital step is to formulate the project target benefits. The findings point out the significant role of project target benefits in decision-making funding [139]. There are seven criteria for their assessment: target value, realism, strategic fit, measurability, comprehensiveness, accountability, and target date [139]. Also, there are suggested constructs that enhance the developed target benefits, such as senior management leadership, senior management support, a formal benefit formulation procedure, and public service motivation [139]. The findings further provide a comprehensive understanding of the formulation and appraisal of project target benefits [139]. Minimized operational costs as one of the target benefits can contribute to long-term organizational performance improvement at the project's closure phase. It is highly relevant to set practical target benefits, which help support a portfolio's investment decisions, help the management direction, and consequently enhance its performance and the organization [140].

Benefits Realization Management (BRM), can also be referred to as project/program realization management. It is one of the various investing methods and managing time and resources to bring out desirable changes. BRM is not yet very well known in most organizations worldwide, as it is a very new discipline. Project Management Institute (PMI) has extensively researched this subject to find a link between realizing a company's maturity and its projects and programs' success. The essence of benefits realization is maximizing the real return on investment (ROI) and the achievement of non-financial gains such as customer satisfaction and reduction of risks [141].

Sigma's definition of BRM is "the organization and management process, so that prospective benefits from an investment in change are accomplished [142]." Sigma initially gave this process the name Benefit Management in 1986 [142]. However, in 2003, it was renamed Benefit Realization management as its name was more meaningful [142]. In contrast, others split the process into two components: Benefits Management and Benefits Realization, despite that it is not accessible to differentiate between these two terms. Also, Active Benefit Realization (ABR) is another term that was used [142].

Refer to the definition of BRM suggested by the office of government commerce (OGC), it is meant to be the significant and backbone process of any change initiative or program because it is an extended process that runs through the whole life-cycle. It also involves more than a few gains events that arise in the process's initial stages [143].

BRM observes drivers for change, current status, cultural factors, and stakeholders as the starting position; following through active commitment with the business, expresses and establishes the vision supported by the goals and benefits as the endpoint. This is the only point when BRM resolves on the changes necessary to attain these goal enablers and business changes [144].

This process can be applied to project portfolios, individual programs, program portfolios, or even business strategies. In the late 1980s, when BRM started to be applied, it was usually in the last stages of specific projects' life cycles and after implementing some technology or following a new system. While this still proves to be a beneficial activity, we have progressively moved our involvement to previous more strategic levels with great focus on programs, but grasping the entire spectrum from projects to business strategy [145].

A definition of a benefit has been explained as the changes result in positive outcomes by stakeholders [146]." The difference between the change and the outcome is essential because it makes us know the obtained benefits such as increased sales and staff morale improvement cannot just be made to happen [146]. Changes that should reasonably result in the achievement of the benefits must be managed. There is a requirement to track these benefits through measuring and reporting them [146]. Success lies in the identification and management of the right set of changes. Those are the ones that reasonably should bring forth the expected set of results [146]. BRM involves ‘the organization and management process, so that probable benefits or gains rising from investment in change, are attained’ [147].

The PMI operational guidelines illustrate the realization management (BRM) with particular attention to the products, services, process outcome, and improvement. BRM is responsible for daily organizational activities geared towards realizing and sustaining gains from various projects, programs, and portfolio investments. BRM makes it possible to conduct BRM even without focusing on the gains [148].

The culture and practice norms of an organization dictate its choice and the implementation of BRM practices. The practice guideline aims to understand the significance of active management of benefits/gains as a core part of project management thinking, project, activities, portfolio, accountability, and responsibilities [149].

With fast-changing technology and unprecedented market dynamics, organizations prioritize implementing only specific strategies to stay relevant in the industry [150]. There is an urgent need to look for ways of ensuring that organizations realize benefits on investment on portfolios, projects, and programs [150]. This case's benefit refers to organizational and stakeholders' gains from investment in portfolio, projects, and programs [151].

BRM practices involve strategies to bridge the gap between the planning phase of portfolio, program, or project to the stage of actual gain realization. An ideally implemented BRM will help re-align wayward strategies, boost program selection methods, and integrate outcomes with inputs to facilitate the realization of benefits [152]. Improving the existing BRM processes depends upon several conditions, such as managing portfolios of programs and projects according to the planned strategy, observing the extent of required organizational change, and creating an environment to protect alignment, evaluate progress, and course-correct as required [152].

The implementation of BRM involves an ongoing improvement process as new and better practices are introduced with the ever-changing market dynamics. Rapid and effective BRM improvement is possible with the use of incremental initiatives. Initiating quick-win measures to fasten experience development [153].

Studies in PMI acknowledge the significant value-addition role that portfolio, program, and project BRM management play. Research also acknowledges the presence of varying accounts of responsibility and accountability among organizations. These differences primarily emanate from organizations applying other management strategies other than the BRM plan [154].

Very few organizations understand the benefits realization management play in ensuring that an organization's planned benefits from a portfolio, program, and project management are aligned to the objectives [154]. Portfolio, program and project managers have unique roles to ensure rewards are awarded appropriately. Ideally, a program manager is responsible for the strategic alignment of a program's projects [154]. The portfolio manager and the beneficial owner(s) are in charge of the strategic alignments program and nonprogram projects [154]. To achieve effective BRM strategies, all the managers and stakeholders must work in a collective effort approach [154]. The finding further illustrates how many executive leaders do not fully connect portfolio, program, and project management with achieving strategic objectives [154]. It is also highlighted that BRM is a shared responsibility among portfolio, program and project managers, benefit owners, organization owners, executive sponsors (sometimes known as senior responsible owners), and other senior leaders [154].

This guide presents comprehensive information aimed at helping organizations and professionals benefit from their programs [155]. Although organizations utilize the three domains, they need to implement BRM principles effectively according to their unique needs [155]. For instance, in the medium to small businesses, where they operate on informal portfolio management, project managers should report directly to the owner(s) responsible for the gains [155].

Projects are the basic units for implementing and measuring an organization's goals [156]. Successful implementation of projects culminates in the general performance of an organization [[157]. "The flows of value resulting from a project" represent its success [158]. For instance, according to ANAO, one of Australia National Security Hotline's benefits is to increase the level of reporting suspicious behavior by public members [159]. The increased reporting leads to the success of the national security objectives [160].

A project's target benefits are set before its commencement, and the outcome is realized at the end of the project. The formulation and appraisal of target benefits is the most crucial step in achieving them [161]. The project target benefits form the foundation for funding and decision prioritization [162]. This makes the target benefits appraisal a crucial part of a project [163]. The review of project performance is based on the approved target benefits. The appraisal and formulation of such information are therefore very crucial.

Despite their significant role in choosing suitable projects, there is limited literature on the process of formulating and appraising target benefits. Moreover, the available literature on appraisal and implementation of target benefits is broad and presents a challenge in how specific they should be applied. For instance, the government of UK's Managing Successful Projects (MSP) [8] involves the following four stages in target benefit formulation: (1) benefit identification, (2) approving the target benefits, (3) collecting the baseline measurement, and (4) deciding how, when and who would collect the benefit measure [164].

The iron triangle (i.e., scope, time, and cost) strategy has helped improve project management practices compared to the target benefit achievement strategy [165]. Therefore, the funding bodies lose an opportunity to benefit from the funded projects and organizational goals. Due to this gap, the project management sector now focuses more on managing its target benefit. The currently increasing complexity, size, and inter-organizational mega projects necessitate adopting target benefit management [165]. Inability to meet the target benefits of projects significantly affects the funders and project management field negatively [165].

There are two categories of project benefits, namely "target benefits" and "fortuitous benefits [166]." The target benefits refer to the benefits set before the beginning of a project, while the fortuitous benefits refer to benefits that emerge as the project is completed [166]. Therefore, since the fortuitous benefits only result during the project, project managers focus more on the target benefits. According to researchers, "target benefits" refer to the strategic project's goals that following project completion to enhance the organizational performance" [166].

Thus, target benefits, timely project completion, and on-budget refer are sub-sets of project strategic project goals [167]. Haven has been formulated during the initiation stage of a project; target benefits are then documented to approve the project's funder [167]. Henceforth, the target benefits are used as the baseline measures for continuous project monitoring and control, including eventual evaluation of project performance [167].

Even with the increased research on target benefits, there are still no clear guidelines on what practical target benefits constitute. Aubry et al. [168] identify that the four benefit management themes include measurability, performance, organizational change, and process evaluation. Similarly, Jenner [169]] emphasizes that practical project target benefits should be both realizable and robust. However, this perspective's most significant shortfall is the limited literature on the robust and realizable target benefits. As Chih and Zwikae [170] conclude, there is limited literature and research on setting practical target benefits.

This section presented an overview of benefit realization, project value management and their increasing importance. Thus, the benefits gained through organization strategies and project deliverables are the main concern of the decision-makers. Therefore, there is a need of benefit realization and project success criteria in the portfolio selection process. Section 2.2.2 focuses on advantages and selection criteria of benefit realization in the construction industry.

2.2.2 Benefit realization management. Researchers have identified the drawbacks and the inaccurate nature of the historical output-focused project management approach [171]. In particular, this approach focuses on timely, efficient delivery of project outputs, on budget, and following the specifications, while neglecting the usefulness of project benefit realization [171]. In this stream of research, some analysts visualize projects as processes for value creation and a project's success as a multi-dimensional approach that requires various measures and focus on leadership [171]. In addition, some of them explain the challenges in the project front-end phase, pointing out how, through structured governance frameworks, project benefits can be managed [171].

There is research on the advantage and value of establishing a benefit realization program in the 1990s [154]. The benefit management concept was properly introduced for a broader audience in 2006 by two books [155] and various handbooks on project management [154]. Previously, the benefits realization topic was associated with information technology investments. Later on, it was expanded, for instance, to the public sector, although observational studies from the information technology sector are prevalent [135].

The benefit realization can be considered as goal-setting [140]. This goal-performance relationship can be explained through motivational, goal-oriented, and effort-directed [140]. Accordingly, it is expected that the practical setting of goals will improve project performance. For instance, the World Bank review discovered that 80% of projects with a rating of satisfactory "quality-at-entry" succeeded, compared to only 35% who succeeded among them that were rated unsatisfactory quality at the same level [140].

When managers are availed with high-quality information, they can make better decisions toward setting project goals that lead to the best project funding decisions [172]. A selected project's contributions to an organization's strategic goals are justified by clear goals [172]. These goals serve as support for the consequent project-planning initiatives. Project goals explained in a business scenario include monetary measures with an example of Return on Investment (ROI) or Net Present Value (NPV) [172]. Still, various projects also have goals that are non-monetary and are very difficult to capture with measures. "Reduced customer complaints" and "Improved quality of service" are examples of such non-monetary goals [172]. As per the practice and literature, it is proved that project goals are often defined ambiguously [172], favorably biased, and consciously exaggerated to increase the project approval chances. Accordingly, analysts have requested more research on practical project goal setting.

The process of target benefits setting and target benefits specifications and characteristics have been explained in the literature [172]. The goal-setting theory argues that "a goal of 'do your best' produces a lower output level than specific hard goals [172]." Likewise, Goldstein and Naor [173] discovered the projects that lacked to employ explicit and challenging goals produced a lower magnitude of improvement compared to Six Sigma projects that employed these goals. Other suggestions say that goals should be "challenging and specific" and "realizable and robust." Doran [174] advised a "SMART" approach for practical goal setting, where he points out that goals should be Specific, Measurable, Attainable, Relevant, and time targeted. In addition to these, Chih and Zwikael [140] recommended two more project-specific dimensions to the five SMART goal setting. These two were accountability and comprehensiveness [174]. Lack of clear and extensive knowledge of what entails "effective target benefits" still exists despite the previous research that describes the importance and process of project goal-setting in general and, in particular, practical target benefits [174].

Project target benefits formulation and an appraisal are very useful tasks [175]. The reason is that often, benefits are dynamic and have different meanings to different stakeholders [174]. In government, this challenge is magnified, where uncertainty and stakeholder management issues are varied and complicated [175]. Subsequently, it was discovered that many organizations poorly formulated their project target benefits [175]. Moreover, project target benefits formulation should be done before selecting project outputs as this will ensure a bold linkage with the organization's strategic goals [175]. However, many of the benefit management frameworks and industry standards that exist takes the point that benefits shall be formulated in advance to form a base for pre-determined outputs [175]. It affirms mostly getting projects authorized instead of formulating target benefits that make the basis for organizational strategic goals [175]. Therefore, target benefits for a project are often exaggerated, expenditure and complexity underestimated [175]. Such anticipation bias has caused severe delays, cost overruns, and unattained benefits and value of projects. Lastly, the most recommended projects' target benefits are ambiguous, causing difficulty in determining whether they are understood [176].

Project target benefits must be precisely analyzed to support reliable project funding decisions and assure their understanding [60]. According to the researcher's suggestion, appraisal of project target benefits can be done based on whether they fit into the organization's strategic goals and if they have target values and dates and practical and measurable [177]. These principles are consistent with the goal characteristics that the goal-setting theory proposes [177]. These include target values (Specific), measurable (Measurable), realistic (Achievable), target date (Time targeted), and strategies fit (Relevant) [177]. The other two additional principles, "accountability" and "Comprehensiveness," originated from the data as specifically vital in the public sector [177].

Projects are started in order to achieve organizational strategies. The strategic goals of an organization should be aligned with its target benefits. The necessity for project benefit formulation was discovered to be brought about either top-down direction (for example, compliance with newly authorized laws by parliament) or bottom-up direction (for example, from operations) [178]. The previous cases are outcomes from high-level strategic or critical goals. However, when it comes to the bottom-up case, attention is necessary for addressing the potential bias problem [178], under which organizational subunits may awkwardly favor their projects over others.

Target benefits must be specifically explained to avoid stakeholders' different interpretations to ensure a transparent resource allocation and responsibility for managing their realization [179]. Target benefits should have a baseline with values either in absolute or relative terms to accomplish this vital requirement [179]. It is observed that “the benefits require to be well defined and should have a baseline, as well as an interim and an end target [179].

This section presented an overview about the advantages and selection criteria of benefit realization. Thus, there is lack of a comprehensive model which integrate the benefits of sustainability and benefit realization simultaneously. Section 2.2.3 focuses on advantages and selection criteria of project success in the construction industry.

2.2.3 Project value management. In this modern construction world, the rise of sustainability reality started searching for convenient ways to aid this concept infusion into the current working environments [180]. As one of the great techniques to help in decision-making, Value Management (VM) holds a key position in integrating sustainability issues into construction projects [180]. Although VM has several underlying potentials, which strengthen its capability as a sustainability delivery mechanism, this potential has not been entirely accomplished by the practitioners [180].

Also named as architectural programming, construction briefing involves the process when clients notify participated parties of their requirements, desires, and ambitions on a facility in formal and informal ways [181]. However, a brief is an accepted manuscript that provides the clients' needs by definition. This expensive process helps the project stakeholders to establish a common perception and responsibility as a team [181].

Value management (VM) refers to a structured analytical process whose purpose is achieving value for money through ensuring the lowest cost of provision of functions at the expected level of quality performance [182]. Developed countries have used the VM to meet the challenges for several decades. It is the way toward arranging, surveying, and creating the project to settle the correct choices about the streamlined equilibrium of the advantages, risks, and expenses [183].

Value management is familiar to benefits management [184]. However, what differs between these two theories is project management. For the most part, project benefits management is about arranging expectations of the task [184]. Concurrently value arranging and management within a project aligns the expected advantages with accessible monetary assets and moderates the likelihood of hazard events that may cause project disappointment [184]. When discussing project value management, we center around cost investigation and hazard relief and search for ways to benefit the client [184].

The significance of carrying out project value management comprises empowering clients to set and accomplish their requirements through workshops and status meetings that encourage cooperation, coordinated effort, and end-client purchase. Different value management models' execution permits zeroing in capacity and an incentive for money, not reducing expense [183].

Value management is concerned with explaining what "value" means to a client by involving the project stakeholders to produce clear project objectives [183]. Many researchers use VM to elicit, clarify, and specify a client's construction briefing requirements [184]. The VM experts lead the stakeholders team through the structured job plan in workshops [185].

Value can be presented in numerous forms, including attitude, desire. The value management model has developed as found in numerous reviews of research [185]. A behavioral value management model identifies the relationships among goal specificity, conflict resolution, and participant satisfaction variables [185]. The model assumes that both the value-goal specificity and conflict resolution affect the project participants directly [185]. More specific value-goals and enhanced conflict resolutions to improve the participants' satisfaction [186].

The main aim of value management is to use a decision-making process to identify and communicate specific client and participants' values and goals through qualitative or quantitative methods [187]. Also, conflict arising from alternative proposals is expected in the decision-making process [187]. There is a need to ensure the project's value and goal specificity and conflict management to determine the best value through consensus and compromise [187].

Value exists in affective and cognitive dimensions. Affective dimension refers to the person, object, and environmental components [188]. Value is subjective, human wants, interests, and needs-related as different individuals can represent and transform needs and differ on how they determine value [188]. Different interactions between objects, persons, and the environment affects how people make value judgments [188]. Values are defined in terms of the person doing the valuing and the object that is being valued [188].

In the construction field, the object can refer to a building that affects its environment [187]. Each project participants' value-object judgment is greatly affected by personal and environmental variables [187]. The environmental factors include culture, politics, society, economics, and regulations [187]. These factors affect an individual's internalization of the shared desired value. Personal variables refer to internal factors, including experiences, wishes, fears, and current status (including knowledge, level of need, and requirements to meet the need [187].

Sustainability agenda means enhancing social prosperity, protecting the environment, and improving economic performance [189]. VM maximizes the functional value as it is problem-solving, proactive, or seeking service [189]. It performs this by managing its growth from conception to use via organized, team-oriented exercises, making it clear, and evaluating consequent decisions by referring to the needs (values) of the clients [190]. There are various scholarly publications on sustainability and VM subjects, but those explaining the relationship between sustainability and VM are minimal [190]. Several sources were extracted from international conferences organized by the IVM Australia [191] under the category of 'Balancing the Scorecard" and IVM Hong Kong [192] under the theme of 'Managing Sustainable Values.' Many papers were exhibited in these conferences that deliberated the significance of sustainability in enhancing value and the prospects of employing VM to increase sustainability. Zainul Abidin and Pasquire [193] took the initiative to take on this sphere by scrutinizing VM specialists' awareness of sustainability concerns and whether they have been incorporated in concrete practices of VM [190]. It was disclosed that the sustainability issues consideration differs from one VM study to another from preceding studies [190]. This is because it depends on the clients' requirements on construction, time constraint, and VM stakeholders' know-how [190].

Together with the clients, the industry has been broadening the interpretation of value and starting to acknowledge its intuitive nature through additions of concerns surrounding the environment and society [180]. It was argued that sustainability is enhancing the project value, for example, improvement in the quality of output, increased project profits, improved productivity, reduced life cost, and business enhancement [194]. Sustainability term has been used to promote balance between the necessity to maintain the business [194]. However, it does not look for profitability at the expenditure of the environment or society's requirements [195]. The developing pressure for sustainability raises the requirement to announce and seek efficient delivery methods [195]. It is highly motivating to highlight sustainability awareness early in the project process to optimize the project's substantial probability [194].

VM can support the imbibition of sustainability at the project process's perceptual and designing phase [195]. Working circumstances put pressure on the team to work together to accomplish sustainability requirements within the limitations of the resources available. As the approach objective at the improvement of project value, the expectation is that VM practices will abide by the highlighting interests on sustainability and considering several sustainability-related matters before critical decision-making in the process of portfolio management [195]. Sustainability issues regularly arose in VM research as parameters and criteria of the FAST diagram and value tree as value management techniques [195]. It was observed from the literature review [193] that the consideration of related issues to the sustainability concept from the VM perspective differs based on the client's requirements and desires, time constraints, and the VM stakeholders' knowledge. Accordingly, sustainability issues have not been successfully studied in different VM literature due to numerous client interferences [193]. Sustainability practices should be used with appropriate methodology into the VM procedure to diminish this variety and have more extensive coordination [193].

Evidence suggests the use of VM in projects that struggled with sustainability in the UK. The Stratfilan-based housing projects used VM to boost benefits to the community [196], build sustainable homes and Stirlingshire homes [180], as well as the Katrine Water Project at Loch Katrine, Scotland [197].

Value can be defined as the link between the fulfillment of various contradicting needs and the required resources [198]. During a VM workshop, the main concern is the identification and delivery method of project drivers [198]. By appreciating the sustainability agenda as the basis of project deliverables and drivers, the sustainability issues would be incorporated into value management [198].

Since the term sustainability may not be used regularly in VM, its related matters like energy saving, pleasant indoor environment, low running cost, minimize the amount of wastage, visual effects, and tranquility of users among society are familiar for decision-makers and stakeholders [199]. After the value tree, the recognized capacities will be exposed to the weighting examination procedure for additional appraisal of alternatives in the VM assessment arrange [200]. The UK public construction projects VM workshop reports used diagrams to illustrate how the sustainability aspects such as user comfort, environmental impact, community, accessibility, and life cost were used as part of the VM decision matrix tool [201]. Zainul Abidin and Pasquire [193] have perceived a connection between sustainability and VM through understanding what sustainability concern implies inside the ambit of VM concept on utilizing the basic rules of sustainability. The reason for these worries stays to improve the estimation of the task, other than meeting the significant needs.

The VM's unique characteristics and processes support its use for delivering sustainability. It offers the chance to include sustainability subjects at the project's initial steps, where its impact will be felt at most [195]. The concept helps in ensuring that the sustainability agenda does not disappear as projects grow into complexity. VM progression is methodical, as it employs a well-organized plan which steers the team in a coordinated manner during the problem seeking and solving process [202]. This valuable plan thus ensures that sustainability concerns are thoroughly addressed before submission of VM proposals. VM tools and techniques offer the client a way to play an active role in attaining a well-developed environment and encourage added value in the construction process [203]. Keeping in view the capability of VM to avoid high costs, it is quite possible to achieve sustainability without undue cost escalation.

Decision-makers (clients or their representatives), team members, and facilitators are the three participants in VM workshops [203]. Sustainability goals are achieved through collaborating the roles of the three participants. Leung and Liu [204] affirm that project goals influence the behavior and outcome of VM participants. For instance, when sustainability need is one of the project's goals, it affects a VM practitioner's interest and sustainability. Clients' commitment to sustainability is anchored on their interactions with VM facilitators during the pre-workshop stages. As confirmed by Dallas [205], facilitators should advise clients on sustainability. The facilitator, in turn, disseminates clients' interests and needs to the rest of the team to be considered during decision-making. The team then proceeds to work in unity to achieve its target [206].

The sustainability issues are incorporated into the final proposal. Being sustainable within the concept of VM involves a commitment to [207] the three pillars of economic sustainability (expanding productivity through proficient utilization of assets), environmental sustainability (prevention of unsafe impacts on the climate by effective utilization of natural resources), and social sustainability (reacting to society's necessities) [207].

In this section, the importance of project success and its criteria is studied. Thus, there is need to develop selection criteria based on direct benefits from the project execution and deliverables. The development of this section is shown in section 4.3 as project success selection criteria.

2.3 Project Selection

2.3.1 Introduction. Project selection could be a fundamental decision for construction organizations. For construction projects to achieve their goals in terms of budget, time, profitability, and quality, organizations need to select the most appropriate project from various projects at hand considering various selection criteria [208]. Construction project realization is often a long-term process that requires significant material, financial, human, and other resources to fulfill agreement obligations and achieve a good work quality. Therefore, one of the top conditions for attaining planned business goals and finishing the contracted time with good quality is making the right decisions following the various and best criteria [209].

Top management is supported in their decision-making by applying a proper project selection method to commit their investments in projects/ programs to be more profitable and achievable [210]. There is a need for efficient portfolio selection in the construction industry while considering numerous contradictory parameters involved in decision-making. Many parameters impact the decision to select a suitable portfolio in the construction industry. These include; resource allocation, information technology advantages, budget control, and governmental rules. In the middle of the present, models and techniques for human-made consciousness Artificial Intelligence (AI) could be recommended to accomplish superior execution slightly over conventional models inside the field [211].

Construction projects deal with complex processes, long periods, unfriendly environment, active organization structure, and financial intensity [210]. Construction clients usually find it challenging to select construction projects due to limited resources like labor, money, time, and equipment. They are not able to consider all project selection criteria simultaneously. They are supposed to select the most suitable projects to maximize effective results (for example, profits and organization reputation) and reduce any adverse outcomes (for example, environmental issues and technical deficiency). This leads them to rely on different parameters discovered to rank some potential projects and evaluate them using the highest favorable scores and priorities, such as a screening matrix [212].

In a project life-cycle, construction project selection is also referred to as the pre-investment stage. It entails crucial decisions for the profitability, growth, and survival of construction organizations in the global competitive market. The need to recognize and analyze the many different tangible and intangible parameters often complicates these crucial decisions [212].

When planning to commence on a new project, the first and probably the most challenging obstacle to face is the project's choice [213]. The project involves a mix of time, resources, capabilities, and potential returns [213]. The selection of a project has to consider the all-inclusive options of feasibility, desirability, and profitability. In outline, a project must be a profitable venture, a feasible venture, an optimal-resources venture, and a satisfactory venture [213]. A team may make a selection of decision-makers or even an individual. The team or the individual preferences determines the priorities and the weights associated with them [213].

The existence of beneficial cost/benefits parameters is the essential selection principle [208]. These costs and benefits to an organization do not necessarily require only monetary value, rates of returns attained, and economic profits generated [208]. Qualitative parameters also need to be considered in most cases in expected estimated returns selected investment in portfolio management [213]. However, the selection approach is considerable when the selected project is suitable primarily in line with its generated value from its benefits being higher than invested costs [213]. Furthermore, sustainability can be incorporated into the project selection process to evaluate the qualitative and quantitative aspects [208].

It is usually an organization's preference to select projects with the highest potential returns while requiring the minimum investment, low-level competency, and being more comfortable to be completed in the shortest time [208]. Therefore, the portfolio selection eliminates entails the advanced elimination of competing project suggestions to facilitate the selection of the most acceptable project within the framework of the optimized resource allocation, the return on investment, the technical competence of the organization, and the time aspect for the of the project implementation [213].

Project selection and project evaluation decisions are often complex since they require identifying, considering, and analyzing many tangible and intangible factors. [214]. Numerous mathematical programming models have been developed to address project-selection complications. The field has progressed from linear programming to the most recent models of multiple-criteria decision [215]. The decision problem involves tradeoffs between multiple criteria that are often qualitative. However, in recent years, multiple-criteria decision-making (MCDM) practices have gained considerable acceptance for judging different proposals [214].

The construction industry's current scenario is such that there are many projects, which makes it necessary for a client to select the most suitable projects for society and the community. It must choose the projects judiciously from the plethora of choices available to get good returns with minimum risk. Construction, like many other industries, has sizeable risk and opportunity built into it. There are currently many construction industries projects, making it necessary for a client to select the most appropriate projects for society and the community. It must choose the projects judiciously from the plethora of choices available to get good returns with minimum risk. Like many other industries, construction has sizeable risk and opportunity built into its profit structure. A construction project is complex and characterized by several uncertainties, varying from project to project, and given due consideration during the project selection process. The decision is complicated by the multitude of decision criteria and options available, along with the degree of subjectivity [215].

The construction industry is wholly involved in realizing construction projects to serve as an engine for developing the national and global economy. In realizing each construction project, particularly mega infrastructural, industrial, and public projects, many participants are included: client (owner), a contractor with subcontractors, engineer, domestic and international financial institution, producers and material suppliers, and equipment. These companies and institutions are organizationally independent. The project management team has a crucial role in their integration and orientation to reach the clients' objectives according to previously signed contracts and their own goals [210]. This process is very much exposed to the negative influence of risk, especially in the early stages. The essential decisions, which significantly matter to the mega projects, have long-term results on all angels of exploitation and realization of a project. Critical criteria for decision making in a construction project selection are actual project cost, profit, quality, duration, risk, technical, functional, technological, social, environmental factors, etc. [209].

Diversification is the reduction in risk obtained by investing in projects that are not perfectly positively correlated. When a construction organization invests in a range of projects, the combination can be viewed as a portfolio of projects. This portfolio is efficient if the clients can diversify the projects. In other words, diversification is spreading risk among several different project opportunities [216].

The literature review is conducted to study the importance of project selection and identify existing models and criteria. Accordingly, a study about the existing project selection methods and project selection criteria has been conducted.

2.3.2 Project selection methods. Mohanty's [213] study represents a real-life problem from a third-world country industrial setting, which is not specific in demonstrating this technique's transferability to similar ones. This author used the multiple-criteria method of decision-making using a real-life case study. He used three intensive-technology-based construction projects and 15 generic parameters from its internal operations and outside environment in India's economy. The study aims to incorporate the multi-criteria problems in a multiple-criteria decision-making

(MCDM) method, which could help stakeholders develop clear insights and make effective decisions. As the theoretical foundation of the analysis, the primary approach is to respond to the challenges brought forward by estimating a deterministic system value for every option (project/program). The system's value assessment by the stakeholders in the actual concentration and is the operational source for the post-implementation of cash flow and capital commitment for the project/program selection process.

Ebrahimnejad et al. [212] proposed a new Group Decision Making (GDM) approach with two phases. They designed an approach of decision-making of two phases, combining the modified Analytic network process (ANP) method and improved ranking (VIKOR) within uncertainty. A revised fuzzy ANP technique is brought out to acquire the relative weights of different parameters but not applicable to the whole assessment process.

Some researches in the last twenty years concentrated on construction project selection problems to offer positive outcomes.

Li and Chen [214] selected six essential criteria for the construction industry's project selection process: capabilities and resources, organization mission and reputation, risk and competition, and probability project completion.

Dikmen et al. [211] introduced a scientific system process (ANP) model to demonstrate how a project's decision procedure might be performed through subjective and quantitative norms in addition to their correlation instead of traditional project benefits. For instance, the Turkish government investment agenda's highway projects were their possible alternatives compared to other available projects. Tan et al. [217] used the fuzzy TOPSIS technique in assisting the clients in the project selection assessment and decision making. They also utilized linguistic parameters explained and translated into fuzzy triangular numbers for intermittent rating and weights of criteria. Shokri-Ghasabeh et al. [218] discovered the model that utilized the data in the organization's project selection process from the multiple criteria basing it on the previous projects' success level. There was a proposal from Ravanshadnia et al. [216] for a construction project selection model that examined the influences of the recent projects of an organization and also utilized a fuzzy-attribute decision making

(MADM) method in identifying benefits among available projects. They used portfolio management by also taking into account available policies.

Thirteen IS project selection methods, including scoring, ranking, mathematical programming, fuzzy logic, and Analytic Hierarchy Process (AHP), was summarized by Badri et al. [219]. Then Cheng and Li acknowledged another list of approaches that have been developed to address project-selection difficulties in the construction field [220]. Project selection evolves from the initial static methods to investigate rigid index, which utilizes cost analysis, integer programming, linear weighted, and linear programming [219]. Moreover, the project selection criteria are including quantitative index (e.g., NPV, DCF, and payback) and qualitative index [219].

Initially, project selection is mainly investigated project to economic benefit by the accurate calculation of economic index (such as NPV, DCF) [221], which reflects the project benefit to determine the project. This kind of method is overemphasized the leading role of the economic index. Moreover, it is too single without considering other indexes. Cheng and Li [214] thought that an effective project selection method is helped to ensure optimal resource utilization and more significant contribution of projects toward the company's missions and goals. Moselhi and Deb [222] reflecting the project benefit to determine the project. This kind of method overemphasis the leading role of the economic index. Also, it is too single without considering other indexes. Cheng and Li [214] thought that an effective project selection method is helped to ensure optimal resource utilization and more significant contribution of projects toward the company's missions and goals. Moselhi and Deb [222] adopt the multi-attribute utility theory. Some more researchers are introducing various technical and economic evaluation methods to the project selection decision, such as GREY [223], TOPSIS [224], ELECTREII [225]. Having contemplated the project social benefits, a value calculation method to comprehensively consider the project outflow present value, project inflow present value, and project risk, and used this total project value as the selection basis was established by Aminah Fayek [226]. Moon and Kang [227] applied the fuzzy multi-criteria evaluation method to sort dominant projects and choose the best R&D project for enterprise investment and development.

Moreover, Machacha and Bhattacharya [228] summarized that the classical project selection methods mostly ignored people's behavior in organizational settings and the project managers' different cultural and functional backgrounds. So, Fuzzy expressions are more natural for humans than rigid mathematical rules and equations. The Fuzzy logic they used is a powerful tool to handle imprecise data [228]. It can better be dealt with the project selection problem under ambiguous information situations and reducing the project risk. Cascio first introduced the AHP (The Analytic Hierarchy Process, which Thomas Saaty proposes is a mathematical decision-making method that permits the consideration of qualitative and quantitative aspects of decisions. It reduces difficult decisions to a series of head-to-head comparisons and then synthesizes the results.) to selection decision for projects bidding, and changed the unstructured decision problem into a tractable and measurable structure model by constructing the index system including cost, quality, and time [229]. Still, when there are many project variables and complex relationships in the progress of project selection, Molenaar and Songer [230] suggested using multi-attribute analyses. In addition to the applications of AHP in various fields involved in decision-making, ANP has started to be employed in project selection in construction-related fields to powerfully deal with complex decisions where interdependence exists in a decision model [231]. Cheng and Li [214] first attempted to apply the ANP process to select several plausibly undertaken projects.

Ying Chen et al. utilized factor analysis to reveal Sustainable Performance Criteria (SPC) into seven categories: quality, social parameters, health and safety, architectural parameters, long-term cost, initial cost, constructability, and environmental. They used these criteria to provide the project decision-makers with new techniques to choose the construction process through enabling sustainability factors. They designed a model to use 33 sustainable performance criteria (SPC)based on the triple bottom line to select construction methods in buildings projects [232].

Additionally, the financial portfolio problem provides tremendous importance to the tradeoff between return and risk. It is, therefore, inconsistent with the essence of project portfolio selection, which is to select the optimal portfolio from among several project proposals within resource constraints and maximize stakeholder benefits [6]. Wei et al. [233] propose two creative approaches to consider the two challenges of project portfolio selection: (i) Determining how project interactions impact the final values of project portfolios and (ii) selecting the best solution from non-dominated project portfolios. Moreover, in conclusion, all the projects are ranked according to their appearance in the ranked association rules [233].

Kumar et al. [234] designed a framework to develop a mathematical model to choose six sigma projects to maximize their maximum profit. They demonstrate the character of significant output and inputs for six sigma projects that are then evaluated using Data Envelopment Analysis (DEA) to identify projects, resulting in a maximum benefit [234]. Tan et al. Suggested the Fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method to help contractors decide on project selection and the linguistic terms defined for representing the fuzzy triangular numbers for ratings of alternatives and weights of criteria. His proposal aims to introduce a quantitative method for assisting contractors in selecting appropriate bidding projects by considering multiple attributes and integrating decision group member opinions [235]. Seydel and Olson [236] introduced a quantitative approach to solving the mark-up decision problem by merging ordinary competitive bidding optimization models with the analytical hierarchy process (AHP) technique. The determination of criteria weightings and alternative scores makes the approach somewhat complex. Still, it is well appreciated that decision-making processes implicate uncertain, incomplete, or qualitative information which is difficult to measure.

Shi Yin et al. proposed a new dynamic multi-criteria decision-making approach in construction projects under time sequence to deal with the evaluation and selection of green suppliers. The study established four main criteria and 17 sub-criteria for the selection of green suppliers in construction projects. A model that considers the interaction between criteria and the influence of the constructor's subjective preference and objective criteria information is proposed [237]. Hu et al. [238] introduced a multi-criteria group decision-making model with 2-tuple linguistic evaluations to select green suppliers under a fuzzy uncertain information environment. Tavana et al. [239] proposed an Artificial Neural Network (ANN) and Adaptive Neuro-Fuzzy Inference System (ANFIS) model to help managers in their supplier evaluation and selection process. Tsui and Wen [240] developed a hybrid multiple-criteria group decision-making (MCGDM) method based on AHP, entropy, elimination, ELECTRE III, and the linear assignment method. Qin et al. [241]

developed a new TODIM technique to select green suppliers within the context of interval type-2 Fuzzy sets. Ghadimi et al. [242] present a multi-objective Hybrid Fuzzy linear programming model for the green supplier selection problem.

Wang Wang Shun and Ma Qinhai [243] designed a partnering model to benefit clients in the construction industry. In their research paper, successful strategic partnering factors were analyzed, and eighteen indicators were selected through investigation and interview.

Nandi et al. [244] introduced a new approach for construction project selection using AHP to assist a contracting firm in evaluating the merits and demerits of a project and helping it decide whether to bid for the project or not. Thus, the AHP will provide a methodology for analysis and assessment of the risks and opportunities involved in the projects under consideration. It will allow the management team to document and communicate an explicit, familiar, and shared understanding of the degree of a project's prospects. Nydick and Hill [245] show how AHP can be utilized to structure the supplier selection process. Alhazmi and McCaffery [241] claim that AHP may be utilized to reduce construction project costs by an average of 5%. In their work, Hafeez et al. [246] provide a structured framework for evaluating a firm's competencies using AHP. Kamal [246] shows that AHP can be used as a decision-making tool to make a descending-order list of contractors and select the project's best contractor. Dey [245] uses AHP to develop a decision support system for project evaluation and selection. Topcu [232] proposes a model for contractor selection using AHP.

Chan et al. [247] used a Delphi technique to develop a multi-attribute model and four rounds of conducted Delphi surveys to overcome the project selection models' significant difficulty. Following the lack of consensus among the experts on the utility factor of the selection criteria. Abbasianjahromi and Rajaie [208] showed a hybrid model based on fuzzy case-based reasoning for prescreening projects. Natasa and Zivojin Prascevic [209] proposed another system to assure the weights of criteria in the Fuzzy analytic hierarchy model (FAHP) with trapezoidal fuzzy. They are using a new technique for computing eigenvalues and eigenvectors of the criteria according to expected values of the fuzzy numbers and their products. Local and global fuzzy weights of the alternatives are obtained using linear programming.

Ravanshadnia et al. [216] presented a construction project-selection model that notes the impacts of a company's current projects or what is known as the portfolio effect. The model applies a multistage fuzzy multi-attribute decision-making (MADM) method to determine whether one should offer or not offer a tender. Vahdani et al. [211] introduce a practical artificial intelligence (AI) model according to the modern neural networks to enhance the decision-making for the project's owners. According to the least-squares support vector machine and cross-validation technique, a hybrid AI model is proposed to predict construction projects' overall performance. Lin and Chen [231] introduced six main criteria for deciding to evaluate construction projects. Cheng and Li illustrated the main steps of the analytic network process (ANP) method in selecting construction projects through an application example. Dikmen et al. [231] Applied an ANP model to illustrate how the project selection process could be performed using quantitative and qualitative criteria by potential alternatives as highway projects.

Parvaneh and El-Sayegh [248] proposed a new model for project selection using the combined approach of Analytic Hierarchy Process (AHP) and Linear Programming (LP). The critical selection criteria for construction projects are also identified and assessed based on construction professionals' perceptions. Rezakhani [249] proposed a modified rational multi-criteria decision-making model for an effective risk factor selection in construction projects. His model is a rule-based consensus model and has the optimization property of rational models. Applying fuzzy logic to his proposed model, uncertainty factors in group decision-making, such as experts` influence weights, preference, and judgment for risk selection criteria, will be assessed. Razi et al. [250], in their research paper, aiming to identify the criteria and suitability for selecting different kinds of construction delivery methods in construction by using the multi-criteria decision making (MCDM), namely the Analytical Hierarchy Process (AHP) method.

Wang et al.'s decision-making attains scientific investment conclusions. The analyst should be conducting multi-item comparisons based on rule-based consensus valuation of the mining project and choose the best investment project to achieve rational development and utilization purpose and obtain the best economic benefits [251].

Since organizations inject much money on new projects, they must make sure that the investments they put into these projects are safe and will bring forth positive returns and benefits to them [252]. Therefore, it is essential to analyze all the new project opportunities to obtain justified decisions on the monetary investments needed. Despite an organization having several project opportunities to invest in and reap the benefits, they may not be able to invest in all of them, and hence they have to choose the best option [253].

The project/program selection methods are classified as quantitative and qualitative. The quantitative technique includes benefit measurement and constrained optimization methods. Cost benefits analysis, net present value (NPV), payback period, internal rate of return (IRR), economic added value, opportunity cost, and scoring model are various quantitative methods used in portfolio management to choose the best options among an organization's opportunities [254].

Project Screening is an initial evaluation of the portfolio appropriateness for the program/project process. It can also be an assessment methodology that examines and estimates various project/portfolio options to identify the opportunities for obtaining the best feasible solution for the organization. This method involves performing an initial evaluation of the project opportunities and applications to find the best feasible solution that fits the organization's strategy according to cost, time consumption, risk assessment, and other selection criteria for further expansion [254]. Project screening develops the initial indicators and parameters for the decision-making process of pursuing the project/program opportunities. This helps the portfolio management process in which the preferable projects/programs are identified and chosen [254].

The analytical hierarchy process (AHP) can enable the intelligent selection of projects/programs and overcome this process's challenges. A decision-making approach entails forming multi-dimensional criteria into a ranking process and examining these criteria' relative significance, contrasting alternatives for every parameter to estimate such alternatives' overall performance. It is built on mathematics and human psychology, which effectively deals with a complicated decision-making process. It also supports identifying and weighing the process of selection criteria, examining the collected information for each parameter, and accelerating the decision-making process. It is, therefore, a beneficial technique when the process of decision-making is complex for stakeholders in the clients [209].

Using AHP greatly assists in capturing both the objective and subjective estimation parameters. This offers a mechanism that supports the reliability of assessment parameters and recommended alternatives by stakeholders to reduce bias in the selection process. It is beneficial to organizations to reduce the ordinary and unnecessary costly distractions in decision-making processes, leading to improved efficient selection [239].

Another basic project management technique that relies on collecting data from traditionally industry experts is the Delphi method, in which the most valuable opinions are asked to attain a consensus [247]. Also, linear optimization and programming can be referred to as the most effective technique for achieving the best results mathematically where the stakeholders’ desires are formulated through linear relationship [246].

Luzon and El-Sayegh [255] developed a framework to identify the selection criteria for the suppliers of oil and gas projects in the United Arab Emirates. The proposed ten selection criteria were grouped into two groups of technical and commercial aspects and company-related aspects. Also, the effectiveness of these criteria is evaluated and assessed using AHP and Delphi methods.

El-Sayegh [256] suggested a framework to help the clients and decision-makers select appropriate construction management at risk. This decision-making process's selection criteria are categorized into four groups: construction management services, general contracting services, firm characteristics, technical and commercial bids. This model's core is based on the AHP technique to analyze the selection criteria and compare the alternative firms.

Therefore, there is a need for the appropriate portfolio selection method in the construction industry, where the classification of the selection criteria plays an important role.

The Analytic Hierarchy Process (AHP) is a technique for analyzing and solving complicated problems by utilizing mindset and mathematics. AHP offers a rational tool for the decision-makers by measuring the criteria importance, evaluating the alternative opportunities, and linking those parameters and criteria to the overall organization's strategies (Which is the main aim in portfolio selection process). AHP structures a complex problem into a hierarchy with an objective, selection criteria, and various options, while the ANP structures the problem as a network. Both methods utilize pair-wise comparison structures to quantify the selection criteria weights of the complex problem, and finally to rank the alternatives options for the decision-makers. The analytic network process method is a more general technique and structure of the analytic hierarchy process utilized in multi-criteria decision analysis [248].

Both techniques of AHP and ANP have the capability in assessing alternative options in multi-criteria decision-making process, however since the target audience of this research is decision-makers and top management level of the organization, then the advantage of AHP method, which is its simplicity makes it more applicable and practical in managerial practice and in the portfolio selection process in the construction industry [255].

Table 1: Methods in Portfolio Selection

Sr No.	Method	Reference
1	AHP & ANP	Aragones-Beltran et al. [261]
2	AHP	Szilagyi et al. [264], Seydel and Olson [229], Badri et al. [220], Tsui and Wen [240], Nandi et al. [244], Nandi et al. [244], Nydick and Hill [245], Alhazmi and McCaffery [241], Hafeez et al. [246], Kamal [247], Dey [245], Topcu [232], Razi et al. [250], El-Sayegh et al. [257], El-Sayegh et al. [258]
3	AHP & TOPSIS	Ahriz et al. [262], Hashemizadeh and Ju [263]
4	AHP and Linear Programming	Parvaneh and El-Sayegh [248], Seydel and Olson [236],
5	Analytic network process (ANP)	Ebrahimnejad et al. [212], Cheng and Li [214], Dikmen et al. [211], Molenaar and Songer [230]
6	Artificial neural network (ANN)	Vahdani et al. [211], Wang et al. [253], Tavana et al. [239], Hu et al. [238]
7	Delphi Technique	Chan et al. [247]
8	Fuzzy AHP & Genetic Algorithm	Wu et al. [265]
9	Fuzzy AHP & Weighted Sum, Non-linear 0-1 Programming (Genetic Algorithm),	Wu et al. [266]
10	Fuzzy AHP and Multi-Objective Linear Programming	Tavana et al. [268]
11	Fuzzy AHP and Non-linear 0-1 Programming (Genetic Algorithm)	Wu et al. [267]

12	Fuzzy AHP, Multi-Objective Nonlinear Programming	Demircan Keskin [269]
13	Fuzzy analytic hierarchy model (FAHP)	Natasa and Zivojin Prascevic [209]
14	Fuzzy TOPSIS	Tan et al. [217]
15	Fuzzy-attribute decision making (MADM)	Ravanshadnia et al. [216]
16	Interval-valued intuitionist fuzzy geometric weighted Herodian	Shi Yin et al. [237]
17	Linear Programming	Petit and Hobbs [6]

2.3.3 Project selection criteria. Selection criteria are the center of every selection technique where the most significant parameters are selected and ranked in which the right choices will be based. Thus, this part of the literature review focuses on the selection criteria for the project selection process.

Mohanty [213] proposed project selection criteria that are categorized into two groups: intrinsic and extrinsic criteria. The intrinsic parameters are the ability of project identification, project duration, the lesson learned, and experience of the organization on similar projects, resource availability and allocation, and management attitudes. The rate of return, risk assessment, government rules and policies, the market environment, information technology development, and socio-economic climate are the selected extrinsic criteria by Mohanty.

Ebrahimnejad et al. [212] suggested six main criteria for project selection: technological criteria, environmental criteria, operational criteria, legal criteria, managerial criteria, and financial criteria.

Yin et al. [237] highlighted four main criteria and seventeen sub-criteria for green supplier selection in construction projects. Their criteria are green business operation (level of green information sharing, green logistics, financial capability, emergency response capability), building materials information (materials cost, materials quality, materials flexibility, green degree of materials), green technology capability (green certifications, green production, green R&D innovation, eco-design of materials, waste materials reclamation), and potential for sustainable cooperation (compatibility of green culture, desire of green cooperation, enterprise reputation, green image).

Using a fuzzy method for project selection, Tan et al. [217] utilized the four selection criteria: project condition criteria (relationship with owner, difficulty, profitability), competition criteria (project execution risk, financial risk), firm criteria (resources and capabilities, Need for work), and risk criteria (competitors' competitiveness, keenness of competitors).

The construction selection criteria chosen by Chan et al. [247] involves quality, time predictability, client's interferences, project scope, time predictability, complication, time accessibility, price rivalry, competent contractors' availability, ability to state clear stakeholders' needs, risk assessment, knowledge (know-how), accountability, the certainty of cost and elasticity.

Natasa and Prascevic's [209] determination models are an investment, cost of misuse, security inactivity of facilities, length of construction, impact of environment on facilities, the effect of facilities on the environment, socio-logical elements, effect of the local community, optical and aesthetic impacts.

Ravanshadnia et al. [216] utilized the five criteria and sub-standards in his proposed indistinct MADM strategy for project selection technique: Organizational considerations in bidding, project characteristics, risk, financial considerations, project's synergy, correlation, and portfolio effects:

Vahdani et al. [211] suggested the construction industry's evaluation factors and hierarchical structure for project selection. The use of the hierarchical model in the construction industry helps evaluate the first level's identified project. They identified six factors: operational, managerial, financial, technological, legal, and environmental.

As indicated by the review of the related literature, selecting projects in the construction industry has not received sufficient attention from researchers. Concentration on project selection using one criterion and ignoring the decision-making nature's multi-dimensional parameters cannot make the decisions applicable in reality. Furthermore, decision-makers' judgments are rarely used in decision-making methods in which include issues of uncertainty. Furthermore, in the current developed world, there are many significant parameters and sustainability indicators that influence society and the community's environment, which are required to be taken into accounts [247].

El-Sayegh et al. [257] proposed a new model for the contractor selection process by integrating sustainable construction practices and price elements into one decision-making process. In this model, the clients incorporate twenty sustainable construction practices in their selection process as an incentive to evaluate the contractor. Therefore, two parameters of price and monetary value of sustainable construction practices are promoted in contractors' selection evaluation and process. Also, the AHP method was used to measure the effectiveness of each sustainable practice.

El-Sayegh et al. [258] suggested a selection framework for the contractor of green construction projects in the United Arab Emirates. In this framework, twenty selection criteria are categorized into five groups: environmental, socio-economic, commercial, and technical bid, firm characteristic, and strong record. The weight of criteria was calculated using pair-wise comparison and the AHP method through a survey among professionals in the United Arab Emirates. The clients can use this framework to evaluate the contractor's capabilities in performing green construction projects and green procurement before its final selection and award.

El-Sayegh et al. identified a thirty-risk criteria list to allow for appropriate risk response planning and control for the sustainable construction projects in the United Arab Emirates [259]. These risks were categorized into five groups: green material, green team, technical, management, and regulatory/economic. This research highlights the lack of insufficient sustainable design information and sustainable construction scope definition in the projects. Also, it indicates that risk criteria, in general, are one of the critical factors in the assessment of the projects.

The sustainability-related risks were identified by Qazi et al. [260] to assist and manage critical risks in construction projects. The proposed model is used to prioritize various risks that might influence sustainable construction projects. It is also used to analyze the risks on sustainable construction projects and promote the early risk assessment and its benefits towards the sustainable construction projects to minimize the related uncertainties.

2.4 Genetic Algorithms

A Genetic Algorithm (GA) is a metaheuristic influenced by the procedure of habitual selection that merges with the extended class of evolutionary algorithm (EA) within computer science together with operations research. By depending on biologically inspired mechanisms such as selection and mutation crossover. Genetic algorithms are repeatedly used to result in high-quality solutions to optimization and search problems.

Genetic Algorithm (GA) is continually used to find the best or near best solutions to challenging obstacles that otherwise would take a lifetime to decode [270]. This is a searched based optimization technique established upon Genetics and Natural Selection [270]. It is often used to solve optimization problems, in research including machine learning [270].

Every process has a set of inputs and a set of outputs [271]. The process of enhancing something is optimization [271]. Optimization indicates locating the values in a manner that allows us to achieve the "best" output values [271]. The definition of "best" refers to maximizing or minimizing one or more objective functions by varying the input parameters [272]. In mathematical terms, this varies from problem to problem, meaning that the set of all attainable solutions or values which the inputs can take forms the search space [272]. Optimization intends to find that point or set of points in the search space [271].

Genetic Algorithms (GAs) are search-based algorithms established upon natural law and genetics [273]. On every occasion, nature is an excellent source of ingenuity for all humanity. Within the large branch of Evolutionary Computation, GAs are just a variant [273].

In GAs, a population of given possible solutions to the given problem undergoes the combination and mutation (like natural genetics). This process is repeated over various generations producing new children [270]. A fitness value is assigned to each individual or (candidate solution) based on its objective function value. In line with the Darwinian Theory of "Survival of the Fittest," the fitter individuals are given a higher chance to mate and yield more "fitter" individuals [270]. This is the process of “evolving” superior individuals or solutions over generations till we attain a norm [272].

Although randomized in nature, Genetic Algorithms perform much better than random local search [274]. The advantages that have made GAs exceptionally popular include [274]:

- Being faster and more efficient as compared to the traditional methods.
- Having outstanding parallel capabilities.
- Providing a list of “good” solutions and not just a single solution.
- Providing always an answer to the problem, which gets better over time.
- Requiring no derivative information (which may not be available for many real-world problems).
- Optimizing both continuous and discrete functions as well as multi-objective problems.

What makes Genetic Algorithms captivating its potential to deliver a good and fast-enough to resolve optimization problems [275]. An extensive set of problems presents itself in computer science known as NP-Hard [275]. This indicates even the most capable computing systems take a lengthy amount of time, sometimes years, to translate that problem [276]. When presented with such an obstacle, GAs demonstrates a methodical tool to supply practical near-optimal solutions within a brief amount of time [276].

Generally, in genetic algorithms, solutions are demonstrated binary strings as 0s and 1s with other encodings achievable [270]. A population of nominees (individuals, creatures, or phenotypes) to an optimization complication is evolved, favoring a better solution [270]. Each nominee solution has a set of effects (chromosomes or genotypes) that can be mutated or altered [272].

In an iterative process, with the population in every iterative generation, the evolution generally emerges from a population of randomly bred individuals [276]. The strength of each individual within the population is evaluated in each generation [276]. The strength is customarily the value of each objective function in the optimization obstacle being translated [273]. Following the stochastic selection of the most vital individuals from the current population, each person's genome is altered to form a new generation [276]. This new generation of candidate solutions is later adapted in the next iteration of the algorithm [276].

Naturally, the algorithm ends when either a maximum number of generations has been created or an adequate fitness level had been reached for the population [273]. An array of bits is a typical depiction of every candidate solution [273]. Other varieties of arrays and structures can be used in virtually the same way [276].

Segments of these genetic representations are effortlessly aligned due to their fixed size, making them highly suited, facilitating simple crossover operations [270]. Crossover implantation is more complex when utilizing changeable length representations [272]. A mix of both linear chromosomes and tress are researched in gene expression programming [270]. As soon as the genetic representation and the fitness function are defined, a GA proceeds to initialize a population of solutions, after which to enhance it through repetitive application of mutation, crossover, inversion, and selection operators [270].

2.5 Summary and Conclusion

From the literature review, it was realized that there is lack of comprehensive models, which include the overall benefits of sustainability in terms of all three pillars simultaneously for the construction projects. Moreover, there is shortage of an appropriate model for finding and evaluating the sustainability benefits, while meeting the organizations' advantages and strategies in portfolio selection process rather than conventional methods. Thus, all above said challenges, require a unique and comprehensive model to integrate sustainability, benefits realization and organization strategies for portfolio selection process under one umbrella as a portfolio value optimization model for the construction projects.

Chapter 3. Research Methodology

3.1 Introduction

Portfolio selection and optimization play an essential role in the risky construction industry. Therefore, selecting the best portfolio of projects and programs that fit within organization strategies and promoting its objectives based on selection criteria is essential for stakeholders and decision-makers. On the other hand, integrating sustainability into construction activities got special attention from developers, government entities, and project management teams. Therefore, a decision-making model that provides the top management with the best feasible solution to select the projects/programs among all available options is needed. The literature review indicates the portfolio selection method's gap considering sustainability and benefit realization in their process. One of the difficulties is to explore suitable criteria for sustainability benefits and the way of measurement by functional units.

Moreover, the literature review highlights the requirement of advanced technology and method such as genetic algorithm. Also, decision-makers are looking for the best feasible solution to achieve sustainable development, benefits realization management, and the organization's objective. Thus, a model proposed in this research provides the stakeholders, project management team, decision-makers, and the clients with the best optimum solution by providing an integrated model that includes project success criteria, sustainability, and benefit realization value through genetic algorithm programming.

3.2 Methodology Design

The Figure 1 shows the methodology processes that was followed during research study:

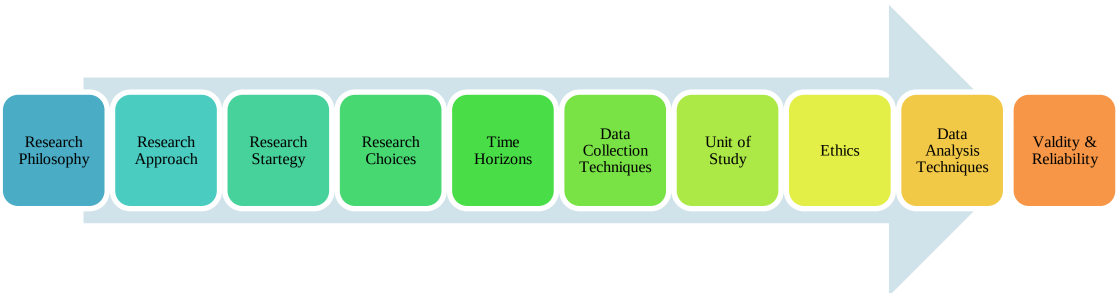

Figure 1:Methodology Process

3.2.1 Research philosophy. Development and nature of the knowledge have been referred to as research philosophy. The appropriate research philosophy for this research is “pragmatic," which covers quantitative and qualitative methods under the umbrella of "positivist" and "interpretivism" to respond to the mentioned research problems and questions. Positivist philosophy is considered due to available theory on optimization of portfolio selection, benefit realization, project success criteria, and genetic algorithm to answer research questions. It also has to be analyzed during the research process while looking for reasonable and solid knowledge gained through observations by conducting mathematical tools and case studies. On the other side, the interpretivism philosophy has taken into account analyzing and measuring the research findings of sustainability and portfolio selection methods. Sustainability criteria, benefit realization and project success criteria, and measurement methods can be developed through "interpretivism philosophy."

Moreover, the priority and importance of selected criteria can be ranked accordingly. In parallel, “positivist philosophy" can quantify the selected criteria and benefits parameters, where the quantitative data can be formulated for optimization purposes. Thus, Pragmatic philosophy is chosen for further application of this study [293].

3.2.2 Research approach. Regarding this research, it is required to derive the information and data such as sustainable indicators, selection criteria for sustainability, benefit realization, and project success from literature review to identify the main criteria for optimization processes. It is also required to collect data from the literature review to rank the most significant indicators and criteria for the portfolio selection method. The next stage is implementing a mathematical method and a structured survey among experts who know sustainability, its benefits, value, project deliverables, organization strategy, and targeted aims on optimization. Thus, this research study needs to consider "deductive" and "inductive" approaches, where the relevant term of "abductive approach" will come into the picture as an appropriate approach [293-294].

3.2.3 Research strategy. The selected research strategies are “Exploratory” and “Explanatory," which can be considered as "Mixed method" in order to fulfill various strategic requirements such as structured-survey, mathematical approaches, and case study. The required strategies and their branches in terms of proposed models are described below:

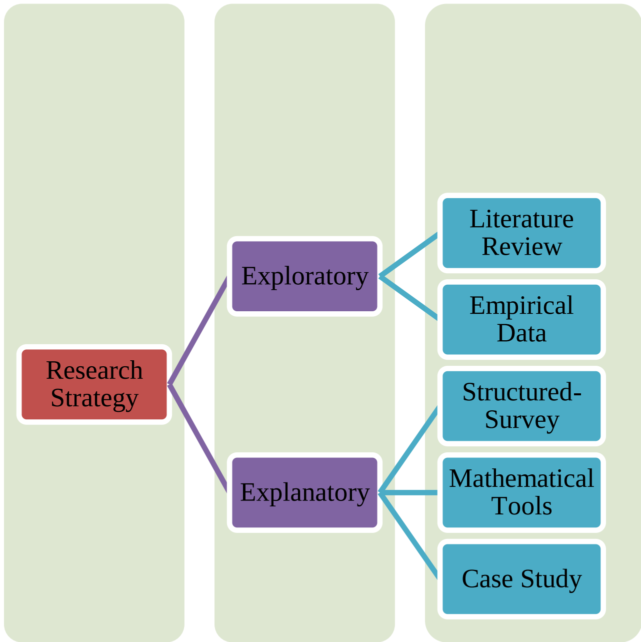

Figure 2: Research Strategy

The exploratory strategy was carried out through literature review and empirical data to identify, rank the importance of sustainability, benefit realization, and project success criteria [295]. However, this step can assist with essential criteria from the literature review and previous studies. Next step was to utilize an explanatory strategy to measure the effectiveness of selected sustainability, benefit realization, and project success criteria, and then maximize to its most possible value. A case study was analyzed to show the significance of this research and its results. This case study is about the portfolio selection of an organization in the UAE, in 2020.

3.2.4 Research methodology. A mixed-method is selected as an appropriate research choice for this research study due to quantitative and qualitative analysis requirements [293]. Qualitative analysis is applied to identify the selected criteria and parameters for sustainability, benefit realization, and project success. Simultaneously, the quantitative analysis is used to measure the criteria and parameters and maximize its overall benefits for the organization toward accomplishing its objectives.

The process to achieve each objective of this research study is described below:

I. Identify and measure sustainability criteria to evaluate each project's sustainability value, program, and portfolio for portfolio selection.

Process 1: The sustainability benefits for each project, program, and portfolio are converted into measurable value through the identified, selected, categorized criteria as follows**:**

A. Study the literature review in various construction fields such as dams, infrastructure, buildings, steel structure, etc.
B. Identify the related criteria for the construction projects
C. Extract the essential sustainability criteria from global and international standards
D. Integrate the identified and selected criteria from literature reviews and global standards into an integrated list
E. Survey experts to measure the outcomes of the literature review
F. Use a weighting system to weight and rank criteria for each pillar of sustainability
G. Identify a unit of measure for each selected criterion
H. Measure the sustainability criteria and benefits through its selected measurement units

II. Identify and evaluate the benefit realization and project success criteria that are currently used in portfolio selection. This is based on the Benefit Realization Management and Project Success Criteria of the project/program/portfolio for the organization for portfolio selection.

Process 2: Identify criteria of benefit realization and project success that are in line with organizational strategies to be measured as follows:

A. Consider the traditional project management criteria: time, cost, and scope
B. Identify benefit realization and project success criteria and outcomes expected from the projects and organization
C. Identify the related parameters to expect business outcomes in the previous step

D. Use the criteria of outcomes as constraints and objectives accordingly for the linear programming
E. Combine the traditional project selection criteria with the additional selected criteria from benefit realization and project success categories into one integrated portfolio selection criteria
F. Measure the project/program benefits and value based on the chosen significant criteria

III. Develop a portfolio selection model that integrates sustainability, benefit realization, and project success criteria established in objectives 1 & 2.

Process 3: Portfolio selection of best project/program between the opportunities available for an organization through integrated criteria which includes sustainability, benefits realization, and project success criteria (from objective one and two), using project screening matrix and AHP method.

A. Combine all aspects and criteria of sustainability, benefits realization, and project success such as cost, time, sustainable advantages, risk, resource allocation into portfolio selection criteria
B. Compute the sustainability criteria, benefit realization, and project success criteria
C. Develop a portfolio selection model (Model A) as a combination of Project Screening Matrix (PSM) and AHP methods
D. Develop the portfolio selection model using AHP as follows:
    a. Develop the AHP Hierarchy
    b. Develop pair-wise comparison matrix
    c. Data analysis for pair-wise comparisons
    d. Check consistency
    e. Determine the relative weights for the portfolio selection process
E. Develop the portfolio value optimization model using Linear Programming (LP) as follows:
    a. Define the objectives for the organization
    b. Identify the selection criteria
    c. Identify the constraints and limitation
    d. Develop the objective function

IV. Develop a portfolio value optimization model for an organization's opportunities based on its constraints using linear programming and Genetic Algorithm (GA) methods.

Process 4: Formulate the optimization model by integrating the organization's constraints and objectives (by considering its limitations, constraints, and objectives) into Portfolio Management in objective 3 using linear programming and genetic algorithm.

A. Use the selection criteria set in process 3
B. Identify the constraints from organization capabilities and resources (tangible and intangible) such as manpower, technical and financial capabilities by organization's strategies.
C. Develop a constrained optimization model, its objectives and constraints
D. Optimize the decision-making process based on constraints and objectives set by organization capabilities and resources using Linear Programming and Genetic Algorithms
E. Use genetic algorithm as an optimization method to find a most feasible solution for the portfolio selection, taking into consideration: organization objectives and sustainability value in the portfolio, in order to maximize the overall organizational benefits

3.2.5 Time horizons. The time horizon is assumed for this research study was cross-sectional and had to be accomplished within a specified timeframe as shown in the works' program, like any academic research.

3.2.6 Data collection techniques. Data collection techniques had been chosen regarding the proposed model and research strategy. The selected data collection techniques for each quantitative and qualitative methods are shown below:

- **Qualitative**
  - *Literature Review:*
    - Qualitative review of existing sustainability criteria, indicators, and index

        - Identify the project value management, and benefit realization, and project success criteria.
    - *Structured-Interviews:*
        - To ask experts in sustainability, benefit realization, and project management about the selected indicators and criteria and their perception about each criterion's effectiveness.

- **Quantitative**
    - *Survey:*
        - To weight relevant criteria of sustainability aspects and benefits realization and project success, linked to stakeholders
    - *Mathematical Tool:*
        - To measure relevant indicators and criteria of sustainability, benefit realization, and success aspects.
        - Decide about goals, constraints, and limitations of organizations' strategies.
    - *Case- study:*
        - To apply the model to the real-life scenario and analyze the outcomes

3.2.7 Unit of study. Unit of study for each data collection step is described below to have proper samples for research and experiment:

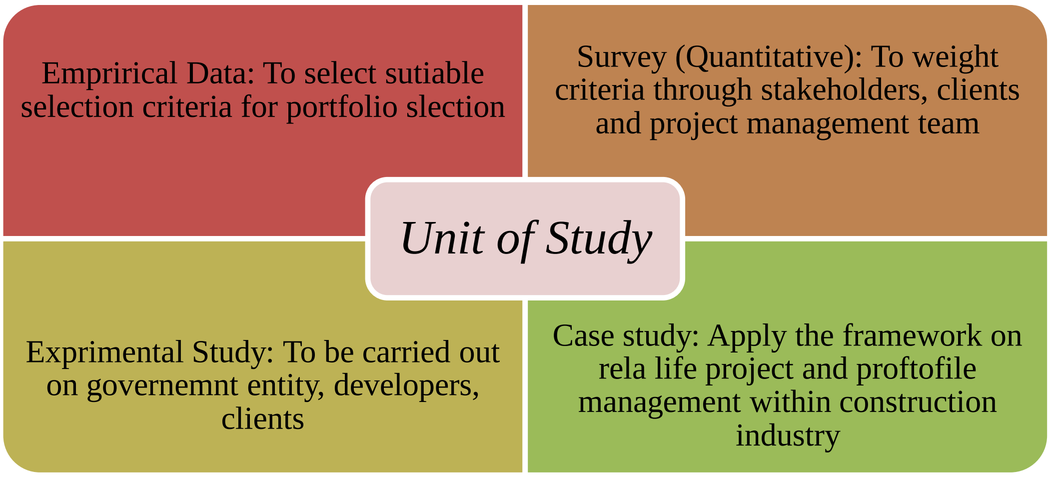

Figure 3: Unit of Study

3.2.8 Ethics. The presence of professional attitude and moral actions to be followed during data collection with ethics. Letter of consent from the participants, retaining them innocuous from any harm, elusion from stress, and securing their personal and private information as contributor's rights will be considered the ethical performance of this research. Moreover, the designed survey was reviewed and approved by the Institutional Review Board (IRB) of the American University of Sharjah (AUS).

3.2.9 Data analysis. The data analysis of this research study is developed based on its objectives as follow:

Objective 1: To develop a sustainability measurement method based on selected criteria through literature review and conducted survey with experts. Therefore, the selected criteria are measured through a defined scale for the project score for each criterion for portfolio selection.

Objective 2: To expand benefits realization and project success criteria into their value by introducing new benefits looked after by stakeholders and customers. Moreover, use the rating system to provide the stakeholders with an expected value of each criterion's benefits for each project.

Objective 3: To develop a project selection model that evaluates sustainability, benefit realization, and project success to accomplish the best choice using measurement method through a model A.

Objective 4: To provide optimum solution on portfolio selection for stakeholders by considering the constraints and limitations of organization strategies and capabilities through linear programming. It also enhances the optimization process by utilizing genetic algorithm in this research for the portfolio selection process.

Objective 5: Validating the proposed method on a case study to demonstrate the advantages of the integrated portfolio selection method to integrate sustainability, benefits realization, and project success criteria.

3.2.10 Validity and reliability. In terms of validity, the literature review's collected criteria and parameters were reviewed and validated by conducting an interview through experts specialized in the construction field prior to distributing the designed survey. Also, criterion validity was utilized to evaluate the correlation and association between criteria and portfolio selection parameters. Moreover, the reliability was carried out through statistical measures to declare the collected data's consistency (Consistency ratio in AHP method).

3.2.11 Summary and conclusion. Therefore, at the end of this section, an integrated portfolio selection method can be introduced, which takes the benefits of project value and sustainability into its account to achieve organizational strategies and objectives.

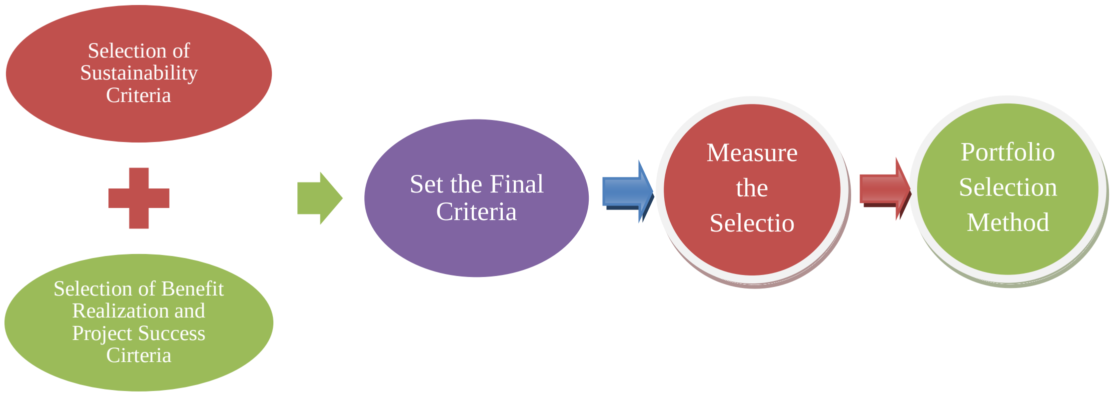

Figure 4: Conceptual Model of Research Methodology

Chapter 4. Project Selection Criteria: Identification and Measurement

4.1 Introduction

Portfolio optimization is a vital decision for clients in the construction industry. The intervallic task includes various steps such as scoring alternative options versus selection criteria, prioritizing and ranking the alternative projects and programs in the portfolio pool for any organization. This will align the organization's objectives and goals with its strategic plans and within its capabilities. Selection and optimization of the portfolio among available alternative options is a difficult task. The optimal portfolio management process complication is linked to several various and effective criteria and parameters involved in evaluating the alternative projects and programs. Proper portfolio value optimization through proper selection criteria is crucial in the construction field, where construction and development can be considered one the riskiest industry globally. Developers sometimes fail to fulfil the promises towards the communities and society for the selected portfolio due to wrong choices or not selecting the most appropriate options and projects which are not based on appropriate selection criteria. This could be due to high expectations from new development, high risks in the construction industry, and a high chance of failure for return on investment in the new project. Therefore, the need for proper study, investigation, appropriate selection criteria, evaluation of alternative options against criteria, scoring the alternatives, prioritization, ranking, and selection of the projects is increasing in the construction industry in the current world [223].

Traditionally, portfolio optimization in the construction industry was mainly focused on the budget, time, risks, resource allocation, and financial factors, where the importance of the sustainability benefits was not taken seriously into account. Due to the importance of sustainability, it becomes essential for portfolio value optimization to incorporate the sustainability value and benefits in the decision-making process to maximize the organization's overall benefits. Failure to consider the sustainability benefits as selection criteria in the decision-making process will negatively impact the construction industry's portfolio value. Clients need to assess sustainability based on environmental, social, and economic pillars in their portfolio management decision-making process to maximize the overall benefits.

Several criteria can be used in project selection. This chapter presents the identified criteria, based on the literature review, along with their measurement methods. The selection criteria are divided into two main groups: sustainability criteria group and organization benefit realization, and project selection criteria group. To facilitate the use of AHP, and the pair-wise comparisons between criteria and criteria groups, there is a need to develop the AHP hierarchy where each group/sub-group consists of small number of criteria. Although the identified criteria groups are not mutually exclusive, the chosen categorization reflects distinct categories. One of the research aims is to highlight the benefits of sustainability, therefore the AHP classification was done based on separating the sustainability benefits from the other organization's benefits.

The sustainability criteria group is divided based on three pillars: environmental, social, and economical. Sustainability generates and preserves the situation, in which nature and individuals can exist in productive harmony that allow satisfying the overall impacts on environment, the social and economic requirements, and other needs of community and society in the present and future. Therefore, the best way to consider the sustainability, is to reflect the three pillars of environmental, social and economic simultaneously, where the organizations always search for a balanced approach to maintain the all organization's goals and objectives in terms of the three pillars of sustainability as long-term strategies.

The second group is divided into organization benefit realization criteria and project success criteria. Organization benefit realization criteria are selected based on direct benefits towards the organization and its strategic plan, while the project success criteria are chosen based on project success parameters. Figure 5 presents the first three levels of the hierarchy for portfolio selection criteria.

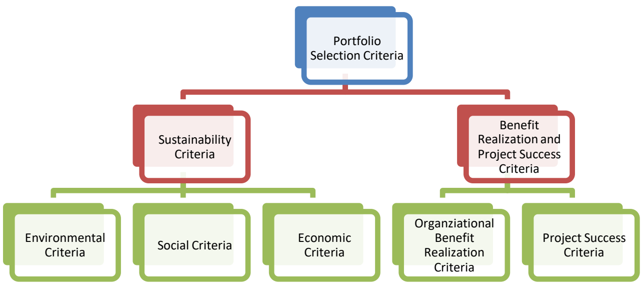

Figure 5: Top Three Levels of Hierarchy for Portfolio Selection Criteria

4.2 Sustainability Criteria

The sustainability criteria are identified through a comprehensive review of related literature and existing standards. The first step was to identify the sustainability indicators and criteria that are related to the construction industry. The selection indicators and criteria in previous researches and standards have been studied and reviewed. Therefore, as the first step, 360 indicators were extracted from these standards and research papers. These indicators were categorized into three different pillars, environmental, social, and economical, and each pillar was divided into groups/criteria. At this stage, each indicator has been assigned to a suitable and related group under the appropriate sustainability pillar: economic, social, and environmental. The first list was reviewed to combine similar indicators, which have similar meanings and represent similar sustainable practices. After this step, the total number of the indicators was dropped in the three pillars. These groups are considered as criteria with several indicators. Shortlisting of the criteria is the next step of the criteria selection process. The selection process for criteria under each pillar is based on the number of citations. The total number of criteria is reduced to sixteen groups/criteria. The selected number of criteria at this stage to be utilized in the research methodology are 16 criteria. The environmental pillar consists of 6 criteria, the social pillar consists of 5 criteria, and the economic pillar consists of 5 criteria. Table 2 shows the selected 16 criteria used in this research, along with their literature sources.

Table 2: Sustainability Criteria Citation and Frequency

List of the Sustainability Criteria for Construction Projects			
Sr No.	**Criteria**	**Citation**	**Frequency**
Environmental Criteria			
1	Energy Use	Yu et al. [57], Chen et al. [17], Eweje [13], Dabirian et al. [25], Dobrovolskienė and Tamosiunienė [1], Siew [51], Huang et al. [110], Khalili et al. [35], Gerner [28], Shultz and Peterson [49], Fernandez-Sanchez and Rodriguez-Lopez [236], Pan et al. [70], Vatalis et al. [52], Envision [277], CEEQUAL [278], Green Globes [279], BREEM [280], Global Reporting Initiative (GRI) [281], EDGE [282], LEED [283], BOMA [284],	22

		Ecodistricts[285]	
2	Material Use	Dabirian et al. [25], Siew [51], Khalili et al. [35], Yu et al. [103], Fernandez-Sanchez and Rodriguez-Lopez [236], Ugwu and Haupt [86], Azapagic [101], Heravi et al. [62], Pan et al. [70], Rickels et al. [102], Envision [277], GreenRoads [286], Green Globes [279], Ecodistricts [285], Global Reporting Initiative (GRI) [281], LEED [283]	16
3	Water Use	Dabirian et al. [25], Dobrovolskienė and Tamosiunienė [1], Siew [51], Huang et al. [110], Fernandez-Sanchez and Rodriguez-Lopez [236], Azapagic [101], Pan et al. [70], Razmjoo et al. [71], Rickels et al. [102], Vatalis et al. [52], Envision [277], CEEQUAL [278], GreenRoads [286], Green Globes [279], BREEAM [280], BOMA [284], Ecodistricts [285], Global Reporting Initiative (GRI) [281], ISO [287], LEED [283]	20
4	Land Use and Biodiversity	Chen et al. [17], Eweje [13], Martin and Assenov [40], Huang et al. [110], Khalili et al. [35], Yu et al. [103], Gerner [28], Shultz and Peterson [49], Fernandez-Sanchez and Rodriguez-Lopez [236], Ugwu and Haupt [86], Azapagic [101], Pan et al. [70], Karji et al. [64], Razmjoo et al. [71], Envision [277], CEEQUAL [278], Green Globes [279], EDGE [282], BREEAM [280], Star Communities [288], ISO [287], Global Reporting Initiative (GRI) [281]	22
5	Pollution	Chen et al. [17], Dabirian et al. [25], Huang et al. [110], Yu et al. [103], Gerner [28], Shen et al. [73], Fernandez-Sanchez and Rodriguez-Lopez [236], Ugwu and Haupt [86], Azapagic [101], Heravi et al. [62], Pan et al. [70], Karji et al. [64], Envision [277], GreenRoads [286], WELL [289], ISO [251], Green Globes [279], BREEAM [280]	18
6	Waste Management	Dabirian et al. [25], Siew [51], Huang et al. [110], Fernandez-Sanchez and Rodriguez-Lopez [236], Ugwu and Haupt [86], Rickels et al. [102], Vatalis et al. [52], Envision [277], CEEQUAL [278], GreenRoads [286], WELL [289], LEED [283], BREEAM [280], BOMA [284], Ecodistricts [285], Star Communities [288], Global Reporting Initiative (GRI) [281],	17
Social Criteria			
7	Public Health and Safety	Chen et al. [17], Martin and Assenov [40], Dobrovolskienė and Tamosiunienė [1], Siew [51], Huang et al. [110], Khalili et al. [35], Yu et al. [103], Gerner [28], Shultz and Peterson [49], Shen et al. [73], Fernandez-Sanchez and Rodriguez-Lopez [236], Ugwu and Haupt [86], Azapagic [101], Pan et al. [70], Vatalis et al. [52], Envision [277], GreenRoads [286], WELL [289], BOMA [284], CEEQUAL [278], Ecodistricts [285], Star Communities [288], Global Reporting Initiative (GRI) [281], ISO [287]	24
8	Employee Training, Education, and Skill Development	Chen et al. [17], Dobrovolskienė and Tamosiunienė [1], Siew [51], Huang et al. [110], Khalili et al. [35], Shultz and Peterson [49], Azapagic [101], Karji et al. [64], Envision [277], GreenRoads [286], WELL [289], BOMA [284], STAR Community [288], Global Reporting Initiative (GRI) [281]	14

9	Relationship with local community	R.-H. Chen et al. [17], A. Karji et al. [64], K. I. Vatalis et al. [52], Green roads [286], BOMA [281], STAR Communities [288], Global Reporting Initiative (GRI) [281], IUCN Green Standard [290]	8
10	Improvement of Infrastructure	Chen et al. [17], Huang et al. [110], Yu et al. [103], Heravi et al. [62], Envision [277], Green Roads [286], Ecodistricts [277], STAR Community [288], IUCN Green Standard [290]	9
11	Encourage Alternative Modes of Transportation	Dabirian et al. [25], Siew [51], Huang et al. [110], Karji et al. [64], Vatalis et al. [52], Envision [277], Green Roads [286], BREEAM [280], Ecodistricts [285], Star Communities [288], ISO [287]	11
Economic Criteria			
12	Life-cycle cost	Shen et al. [73], Fernandez-Sanchez and Rodriguez-Lopez [236], Ugwu and Haupt [86], Rickels et al. [102], Vatalis et al. [52], CEEQUAL [278], Green Roads [286], BREEM [280], ISO [287], ISO 15686-5 [291]	10
13	Contribution to GDP and wealth creation	Chen et al. [17], Huang et al. [110], Khalili et al. [35], Shultz and Peterson [49], Fernandez-Sanchez and Rodriguez-Lopez [236], Azapagic [101], Razmjoo et al. [71], Envision [277]	8
14	Employment creation	Dabirian et al. [25], Khalili et al. [35], Shultz and Peterson [49], Azapagic [101], Karji et al. [64]	5
15	Innovation and technological advance	Huang et al. [110], Gerner [28], Heravi et al. [62], LEED [283], BREEAM [280], STAR Community [288]	6
16	Use of National Supplier	Dabirian et al. [25], Fernandez-Sanchez and Rodriguez-Lopez [236], Vatalis et al. [52], GreenRoads [286], Star Communities [288], Global Reporting Initiative (GRI) [281]	6

The selected sixteen criteria are divided into three groups: environmental (6 criteria), social (5 criteria), and economic (5 criteria). The selected criteria in each pillar are shown in Table 2.

The environmental criteria group includes six different criteria: energy use, material use, water use, land use, pollution, and waste management. Some of these six criteria are measured based on two indicators. These six criteria include ten different sustainability indicators to be considered as portfolio selection criteria. The energy use criterion includes two indicators: reduction of energy usage and use of renewable energy. Reduction of energy usage is the indicator of reducing energy usage by utilizing suitable equipment, systems, and construction methodology during design and construction phases [25].

On the other hand, using renewable energy resources is being endorsed through renewable energy [12]. However, energy use reduction can be measured based on energy-saving through sustainable practices and efficient systems [49]. Also, the use of renewable energy can be assessed through the amount of regenerated energy using renewable resources. The water use criterion consists of using renewable water resources and reducing water consumption [81]. Reducing water consumption will be calculated according to water consumption reduction by promoting sustainable practices and water-saving devices through the design phase and control systems [14]. The amount of recycled water through sustainable machinery and practices is measured using renewable water indicators [15]. Reducing water consumption is quantified based on saving water through efficient water recycling systems, water systems, and construction methodology [82]. The use of material criterion is divided into two measurable indicators: recycled products/materials and green materials. Usage of recycled products and materials is described as utilizing the recycled material during the operation and construction [15]. Usage of harmless materials toward the environment and promoting the usage of green products is measured through the use of green materials [17]. Usage of recycled materials and products has to be quantified in each material's specific measurement unit separately, based on the recycled material generation [50].

The land use criterion includes land use and rehabilitation along with impacts on biodiversity as indicators. The avoidance of consuming the undeveloped and greenfield lands through the reuse of derelict areas, refurbishment, and brownfield, using re-development and infill sites of existing developed areas is measured through land use and rehabilitation indicator [49,76]. Impact on biodiversity is used to minimize the long-term impacts of the development on the surrounding areas and the sites [16]. Land use and rehabilitation are measured based on the saved area in m2 due to this sustainability indicator's usage. Also, the pollution criterion includes emission to air indicator. The greenhouse gas (GHG) emissions have possible negative impacts on the environment and climate, which can be evaluated through emission to air indicator [15]. Emissions to air are measured based on reducing GHG emissions from the construction's activities, equipment, and machinery [32-37]. The waste management criterion quantifies the total amount of hazardous and non-hazardous wastes that might cause a possible negative impact on the environment through the disposal of waste materials [14]. Construction waste management is measured based on reduced construction waste related to off-site manufacture or fabrication and site construction [122].

The social criteria group includes five different criteria of public health and safety, employee training and education, relationship with the local community, improvement of infrastructure, and encourage an alternative mode of transportation. These five different social criteria will be considered for the portfolio selection process. These criteria are measured differently, where health and safety criteria are evaluated through protecting consumers, employees, and the community's health and safety [21]. Public health and safety are also measured based on reducing injuries and fatalities, reducing heavy works, and impacting physical working conditions. Training of local employees and hiring national business, which is defined as educational accomplishment and opportunity, cohesion and community, social and cultural, is highlighted as employee training and education criteria [17]. Workers' training and education are measured based on total training hours for project members in sustainability and based on the percentage of improvement in the community's educational and cultural status [76]. Relationship with the local community is a criterion about caring for the environment around the development, related population, and local community [26]. Relationship with the local community is measured based on a relationship with local communities and wealth distribution [51]. Construction and new developments might improve the community's current infrastructure, measured by improving infrastructure criterion [56]. Improvement of Infrastructure is evaluated based on a percentage of infrastructure improvement compared to the existing situation [74]. Encouraging alternative modes of transportation is considered a criterion to explain transportation's total distance, including shipments, transportation of materials to the consumers, and commercial trips [67]. Encourage alternative modes of transportation is measured based on the total number of kilometres covered for moving materials and people [51-52].

The economic pillar of sustainability is evaluated based on five different life-cycle cost criteria, contribution to GDP and wealth creation, employment creation, innovation and technology, and national suppliers' use. These five different economic criteria will be considered for the portfolio selection process. The life-cycle cost criterion is described as expenses toward assets and spare parts through the whole project life cycle while satisfying the performance needs and the cost of maintenance and repair of amenities, overall expenditures [85]. Life-cycle cost and contribution to GDP and wealth creation will be estimated in the country's currency [92-94]. The contribution of the total value of services and products manufactured in a country is measured by contribution to GDP criteria [85].

In contrast, the contribution to hiring, employment, and retention of jobs are measured by the employment creation [102]. Innovation and technological advance criteria are described as benefits gained from technological growth, including the creation, technology, and invention [105]. The use of national suppliers' criterion utilizes the local suppliers who are producing and supplying the raw materials and products close to the place where the project is [104]. Figure 6 indicates level four of the hierarchy for the sustainability category.

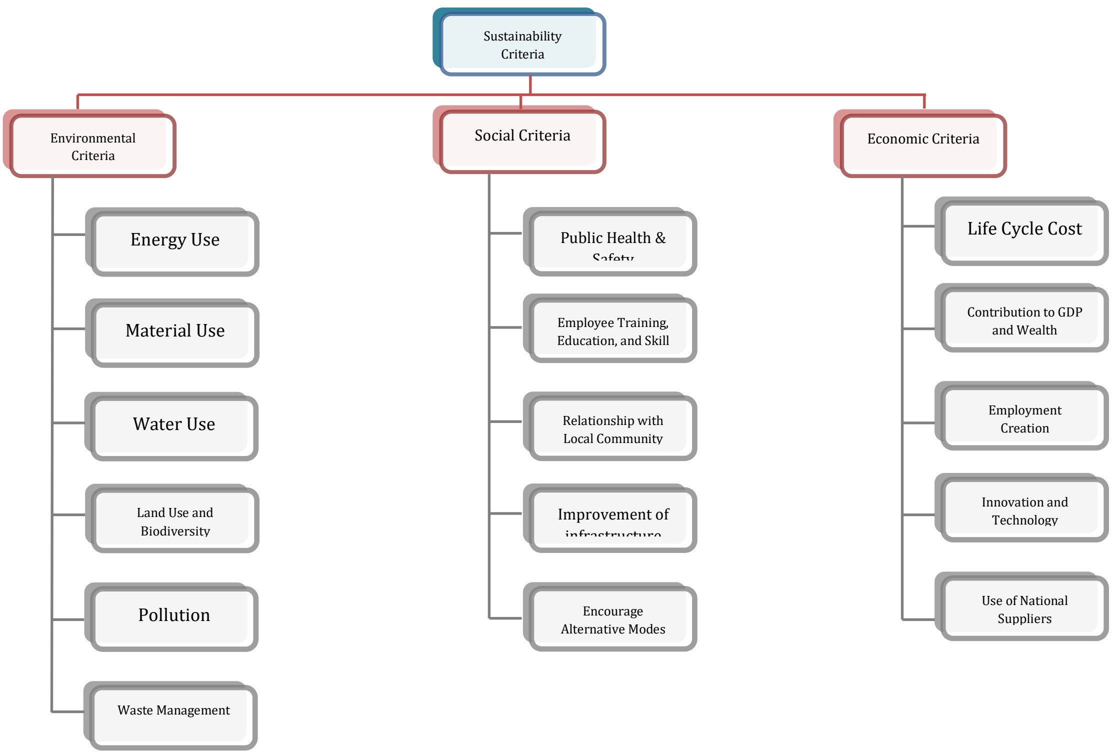

Figure 6: Sustainability Criteria

4.3 Organization Benefit Realization and Project Success Criteria

Based on the literature review, various organization’s benefit and project success criteria were studied and investigated. An analysis of the various studies found that appropriate measurement of benefits in the construction field will lead to organization and project success achievements. The selection of the organization's benefits and project success criteria plays an essential role in meeting its goals and vision and being aligned with its strategies.

The first step was to identify the organization benefit realization and project success criteria. The main aim is to identify all criteria from the organization and project perspective that influence the portfolio selection in the construction sector. The organization benefit relation criteria are the selection criteria where benefits and advantages are gained towards the organization's actions, strategies, and objectives. On the other side, the projects' benefits are measured through the project's success selection criteria. Initially, 39 criteria were extracted from 42 research papers. The first list was reviewed to combine similar criteria, which have the same meaning and represent similar sustainable practices. After this step, the total number of the criteria was dropped to 18. Shortlisting of the criteria is the next step of the criteria selection process. The selection process for criteria is based on the number of citations and repetition of each criteria [212-213]. Table 3 presents the eighteen criteria along with their citation and frequency.

Finally, ten criteria were selected based on several citations. The ten criteria are profitability, strategic fits, organizational quality (Branding and Reputation), organizational risks, resilience, project time, project cost, project quality, project risks, and project resources. The first five criteria are categorized as organization benefit realization criteria, and the second five criteria are considered project success criteria. Profitability criteria are described as predicted and planned amount of profit from the specific project, which can be named expected return on investment too [149]. Strategic fits criteria explain how the program and project accomplish its strategies and aims [156]. Organizational quality is the organization's stability and success levels in achieving the expected structure and reputation, maintaining the policies and procedures, standardizing the leadership styles, and preserving its brand name [149]. Organizational resilience criteria are an organization's skills to predict, plan, and be responsive and adaptable toward sudden change in the internal and external environment [172]. The organizational risks criterion is defined as uncertainties on an organization's strategies and objectives, which can potentially lose the organization's benefits and financial income [169].

Project quality criterion is described by meeting the stakeholder's satisfaction and expectation through fulfilling the promised deliverables [172]. Project cost is a criterion that includes the total expected expenditure and costs in execution and completing a project as per specified deliverables [198]. Project risk criterion is a set of situations or an uncertain occasion that impacts project deliverables' accomplishment when it appears [213]. In contrast, less risky projects are more beneficial for an organization. Project time criteria are defined as the timeframe to complete all project scopes and accomplish the project deliverable to meet the project completion deadline [216]. Project resources criteria are referred to non-technical and technical resources to supervise, monitor, and control the project [182].

Table 3: Organization and Project Criteria and Frequency

Sr No.	BRM Parameters	References	FrequentIy
Benefit Realization and Project Success Criteria			
Benefit Realization Criteria			
B1	Organizational Risks	Harold Kerzner [142], Ganbat et al. [171], Gillier et al. [187], Paquin et al. [163], Danesh et al. [180], Siew [51], Mohanty [213], Ebrahimnejad [212], Sanchez and Lopez [72], Wang et al. [210], Tan et al. [211], Naoum and Charles Egbu [245], Chan et al. [170], Ravanshadnia et al. [216], Vahdani et al. [211], Parvaneh and El-Sayegh [248], Rezakhani [249]	17
B2	Profitability	Siew [51], Mohanty [213], Ebrahimnejad [212], Wang et al. [210], Ying Chen et al. [231], Dinesh Kumar et al. [234], Tan et al. [211], Chan et al. [170], Ravanshadnia et al. [216], Vahdani et al. [211], Parvaneh and El-Sayegh [248], Rezakhani [249], Yang Wang et al. [251]	13
B3	Strategic fit	Chih and Zwikael [139], Gillier et al. [187], Farashah et al. [184], Leung and Liu [186], Siew [51], Mohanty [213], Ebrahimnejad [212], Wang et al. [210], Hechuan Wei et al. [233], Wang Shun and Qinhai [158], Ravanshadnia et al. [216], Vahdani et al. [211]	12

B4	Resiliance	Zhang et al. [178], Farashah et al. [184], Mohanty [213], Ebrahimnejad [212], Sanchez and Lopez [72], Tan et al. [211], Naoum and Egbu [245], Chan et al. [170], Ravanshadnia et al. [216], Vahdani et al. [211], Parvaneh and El-Sayegh [248],	11
B5	Quality	Harold Kerzner [142], Hong Kong, Tang, Cheng [70], AZAR et al. [168], Danesh et al. [180], Taylan et al. [53], Wang et al. [210], Naoum and Egbu [245], Shi Yin et al. [237], Yang Wang et al. [251]	11
B6	Competitive intelligence	Zhang et al. [178], Jin Wang et al. [210], Tan et al. [211], Yang Wang et al [251].	4
B7	R&D innovation	Zhang et al. [178], Gillier et al. [187], Naoum and Egbu [245], Shi Yin et al. [237]	4
B8	Technical ability	Parvaneh and S. El-Sayegh [248]	1
B9	Technology	Kerzner [142]	1
Project Selection Criteria			
PS1	Project Time	Harold Kerzner [142], Hong Kong, Tang, Cheng [70], Fan and Greenwood [140], Sadler [200], Perry and Barnes [155], AZAR et al. [168], Chih and Zwikael [139], Batselier and Vanhoucke [181], Danesh et al. [180], Taylan et al. [53], Mohanty [213], Ebrahimnejad [212], Ying Chen et al. [231], Kumar et al. [234], Naoum and Egbu [245], Chan et al. [170], Ravanshadnia et al. [216], Vahdani et al. [211], Parvaneh and El-Sayegh [248]	21
PS2	Project Cost (Budget)	Harold Kerzner [142], Tang, Cheng [70], AZAR et al. [168], Chih and Zwikael [139], Lipke [145], Batselier and Vanhoucke [181], Danesh et al. [180], Taylan et al. [53], Sanchez and Lopez [72], Ying Chen et al. [231], Hechuan Wei et al. [233], Kumar et al. [234], Naoum and Egbu [245], Yin et al. [237], Chan et al. [170], Ravanshadnia et al. [216], Vahdani et al. [211]	18
PS3	Project Risks	Harold Kerzner [142], Ganbat et al. [171], Gillier et al. [187], Paquin et al. [163], Danesh et al. [180], Siew [51], Mohanty [213], Ebrahimnejad [212], Sanchez and Lopez [72], Jin Wang et al. [210], Tan et al. [211], Shamil George Naoum and Charles Egbu [245], Chan et al. [170], Ravanshadnia et al. [216], Vahdani et al. [211], Parvaneh and El-Sayegh [248], Pejman Rezakhani [249]	17
PS4	Manpower and Resources	Farashah et al. [184], Mohanty [213], Ebrahimnejad [212], Jin Wang et al. [210], Ying Chen et al. [231], Hechuan Wei et al. [233], Tan et al. [211], Wang Shun and Ma Qinhai [158], Chan et al. [170], Ravanshadnia et al. [216], Vahdani et al. [211], Parvaneh and El-Sayegh [248], Pejman Rezakhani [249], Yang Wang et al. [251]	14
PS5	Project Quality	Harold Kerzner [142], Hong Kong, Tang, Cheng [70], AZAR et al. [168], Danesh et al. [180], Taylan et al. [53], Jin Wang et al. [210], Naoum and Egbu [245], Shi Yin et al. [237], Yang Wang et al. [251]	11
PS6	Project Complexity	Mohanty [213], S. Ebrahimnejad [212], Sanchez and Lopez [72], Tan et al. [211], Naoum and Egbu [245], Chan et al. [170], Parvaneh and El-Sayegh [248],	7

PS7	NPV	Jimenez and Pascual [188], Paquin et al. [163], M. Ravanshadnia [216]	3
PS8	Realism (Attainability)	Chih and Zwikael [139]	1
PS9	Political factors	Parvaneh and El-Sayegh [248]	1

The benefit realization and project success criteria for portfolio value optimization are divided into two different groups of organizational benefit realization and project success criteria. These two categories introduce ten different criteria to be considered as portfolio selection criteria. Figure 7 indicates level four of the hierarchy for benefit realization and project success criteria.

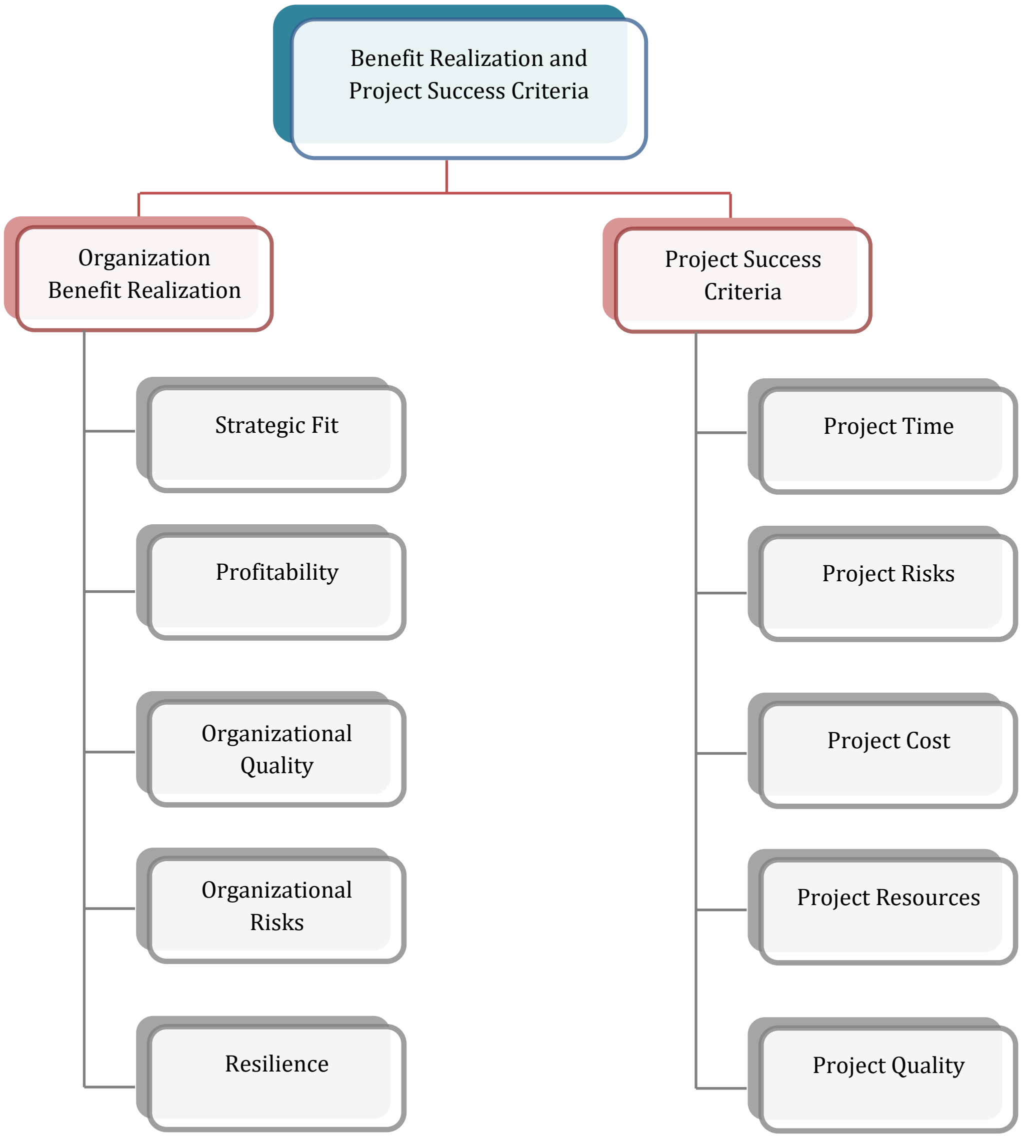

Figure 7: Benefit Realization and Project Success Criteria

4.4 Method of Measurement – Sustainability and Benefit Realization Criteria

The method of measurement should be selected after identifying the selection criteria. The measurement method for sustainability criteria, organization benefit realization and project success criteria will be done based on “10-point” rating scale, where the experts measure the score and rating of each alternative project and program with respect to each criterion. Therefore, the rating matrix between the criteria and alternative options are filled by utilizing Likert scale from “0-10”. This rating system utilizes “0” as the alternative project not complying with the selected criterion, and uses score “10” when the project is fully satisfying the maximum expectation from the selected criterion.

In the first step, a structured-survey was conducted in order to do the pair-wise comparisons using AHP method to measure the weight for the selected criteria. Then for scoring the alternative projects and programs, the decision-makers can rate the available options in the portfolio with respect to each criterion based on Likert scale from “0-10”. Also, alternatively they can utilize simple questionnaire among selected population for rating purpose. Thus, the questionnaire should not only include experts such as engineers or architects, who will underline the importance of the technical aspects, but also: the business owners (being important for economic based on investment plan); decision-makers involved in the selection process, both direct and indirect (importance of social and economic aspects); ecological organizations (environmental importance and impact on the project area); project management team (who supervise the construction and monitor the projects) and consultancy firm (who is responsible for base of sustainability and benefit realization benefits during the design phase). The questionnaire should focus on the fact that those candidates should confirm value of each alternative with respect to each criterion for the selected criteria related to sustainability, organization benefit realization and project success. Each criterion is measured using Likert-scale of “0-10” by utilizing the 16 identified criteria for sustainability and “10” criteria for organization benefit realization and project success to evaluate the alternative projects with respect to a specific criterion. The assessment step consists of distributing a 10-scale Likert points questionnaire survey to measure and score the condition of each criterion in a specific project. Based on the definition and target of each criterion, the projects will be evaluated by either developer, consultancy firms, project management team members, or experts in accordance to the type of the project. After the project evaluation is completed, a mean score of each related score for the specific project with respect to specific criterion will be calculated. The projects are assessed and evaluated based on a scaled of “0–10”, where score “10” demonstrates that the measured sustainable or benefit realization criteria is meeting the highest satisfaction level, and score “0” highlight that it is not. Table 4 presents the scoring scales for alternative options. For example, in energy use criteria, the reduction of energy usage indicator can be measured “10” if the amount of energy saving based on sustainable practices, nature of project and size of the project is meeting the highest expectation. Reduction of water consumption will be measured based on the saving on water consumption with respect to project value and scope, where score “10” indicates highest amount of saving and “0” is no saving on water consumption during the project execution. Use of material criterion is measured based on amount of expected recycled materials in the projects based on sustainable practices, where score “10” indicates that the project is fully complying with recycling process during its execution, while “0” means that there are no sustainable practices towards recycling process. Improvement of Infrastructure in social criteria can have highest score (10) when the infrastructure development with regards to new projects meeting latest technology and standards. Employment creation can score higher based on number of local recruitments compared to total project manpower and resources. The strategic fit score will be evaluated at “10” if the project is fully in line with the organization’s strategic plans and objectives. Another example can refer to risk criterion in project success group, where the less risky or risk-free project can score “10”, and highest risky project will score for “0”. Also, for project cost, the project that has higher cost and consuming more from the allocated budget scores less while the project with less project cost and required budget scores higher.

Table 4: Scales for Scoring Alternative Options

Intensity	Definition	Explanation
0	Nothing at all	Not meeting criterion satisfaction at all (Not Completely)
1	Extremely Weak	Meeting criterion satisfaction level extremely weak
2	Very Weak	Meeting criterion satisfaction level very weak

3	Weak	Meeting criterion satisfaction level weakly
4	Slightly Weak	Meeting criterion satisfaction level slightly weak
5	Moderate	Meeting criterion satisfaction level moderately
6	Slightly Strong	Meeting criterion satisfaction level slightly strong
7	Strong	Meeting criterion satisfaction level strongly
8	Very Strong	Meeting criterion satisfaction level very strong
9	Extremely Strong	Meeting criterion satisfaction level extremely strong
10	Complete	Meeting criterion satisfaction level completely

4.5 Summary and Conclusion

The selection of the evaluation criteria and development of hierarchy chart play important role in the decision-making process. Therefore, in this chapter, selection criteria for sustainability and benefit realization groups were deduced based on the literature review and existing international standards, where the most effective criteria based on empirical data and information were selected for the optimization model. Moreover, the method of measurement is developed based on rating scale from 0-10 for scoring the alternative options with respect to the selected criteria. The outcomes of this chapter are used as selection criteria in the portfolio selection model.

Chapter 5. Criteria Assessment: Data Collection, Analysis and Results

5.1 Introduction

Construction companies and clients experience complications in selecting projects and programs that provide a reasonable investment return. Moreover, they cannot consider all projects and programs within the portfolio concurrently due to restrictions on resources and capabilities. Therefore, they must choose the most reasonable projects and programs that optimize positive outcomes such as sustainability value, profits, branding, meeting stakeholders'' expectations, and minimizing organizational and project risks. This increases the requirement for relying on the onset of selection criteria that has the capability to score, rank, and select the most feasible projects and programs to optimize the portfolio value. This increases the need for criteria assessment and how effective each criterion will be in the decision-making process. After identifying critical selection criteria in Chapter 4, the next step is to evaluate the importance (weight) of the selected criteria based on the perception of qualified candidates through a survey in the United Arab Emirates (UAE). The criteria assessment is conducted through pair-wise comparison using an online portal and utilizing the AHP technique. This chapter presents the survey development, data collection, analysis, and results.

5.2 Survey Design

The survey was designed for pair-wise comparisons between criteria utilizing the AHP method through an online portal. The survey was sent to the experts in the United Arab Emirates to evaluate the selection criteria weight based on their perception. Participants were asked to compare every two criteria using the ratio scale proposed by Saaty [292], as shown in Table 5. Odd numbers from 1 to 9 are utilized to indicate the strength of significance of each criterion. Participants include developers and employers, project managers in project management companies, resident engineers in consultancy firms, staff in consultants, and other experts familiar with sustainability and project management in the construction industry. The survey was circulated to candidates in the UAE. They have experience working in international and local companies such as developers, consultants, and project management firms with comprehensive knowledge in portfolio selection in the construction business. The sample of pair-wise comparison between two criteria is shown in Figure 8.

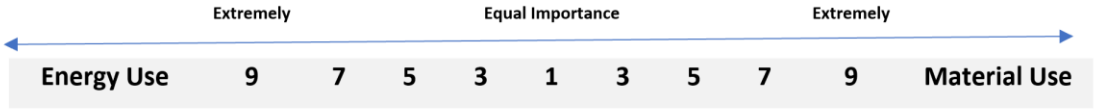

Figure 8: Sample of Pair-wise Comparison Between Two Criteria

Table 5: Ratio Scales of AHP [292]

Intensity	Definition	Explanation
1	Equal importance	Two criteria contribute equally
3	Moderate importance	Experience and judgement slightly favor one criterion over another
5	Strong importance	Experience and judgement strongly favor one criterion over another
7	Very strong importance	A criterion is strongly favored and its dominance is demonstrated in practice
9	Extreme importance	The evidence favoring one criterion over another is of the highest possible order of affirmation

5.3 Data Collection

Forty-one surveys were forwarded to construction experts, of which thirty-four positive responses were received. This demonstrates a response rate of 87.18%. About 24 participants (70.58%) are from the local companies, and 10 participants (29.42%) from international companies. About 41.18% of the participants have experience of more than twenty years, and 29.41% of the participants have experience between 11 to 20 years. The majority of the participants are clients and employers with higher participation percentage of 38.32%, while the participation percentage of consultant and project management team is 29.41% and 20.58%, respectively. 41.18% of the participants having experience executing the projects with a budget above 500 million, 17.65% of participants' projects range from 201 to 500 million, 23.53% of the participants execute the projects between 50 to 200 million. In comparison, 17.66% of the participants have a project with a budget of below 50 million. This highlights that the involved population has experience performing various types of projects, from mega projects to small types of projects. Table 6 presents the summary of respondents' profiles of the conducted survey.

Table 6: Respondents Profile

Category		Respondents (Total 41) Number	%
Type of Organization			
	Local	24	70.58%
	International	10	29.42%
Years of experience			
	<5	2	5.88%
	5 to 10	8	23.53%
	11 to 20	10	29.41%
	>20	14	41.18%
Company Role			
	Client/Employer	13	38.24%
	Consultant	10	29.41%
	Project Management	7	20.59%
	Others	4	11.76%
Average project size			
	<50M	6	17.65%
	50 to 200M	8	23.53%
	201 to 500M	6	17.65%
	>500M	14	41.17%

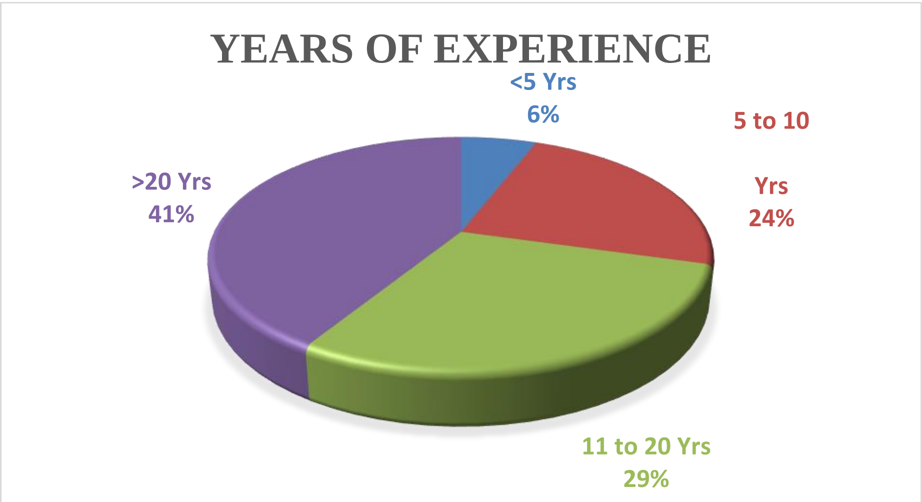

Figure 9: Respondents’ Years of Experience

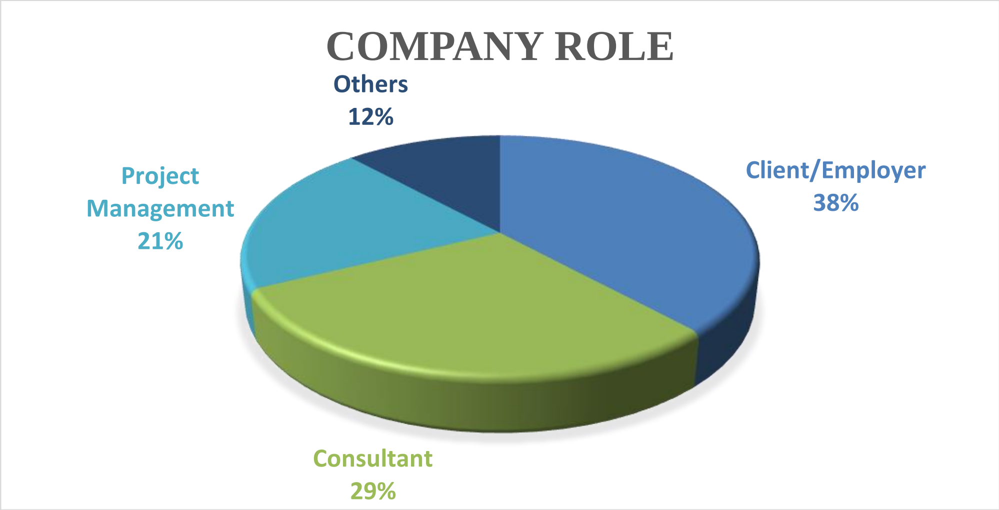

Figure 10: Respondents' Company Role

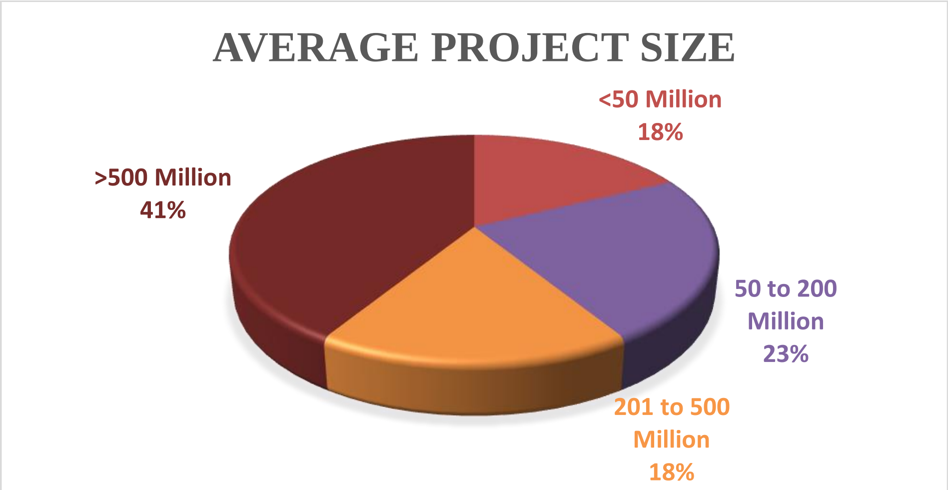

Figure 11: Respondents' Average Project Size

5.4 Data Analysis and Results

The next step was to calculate the weight for each criterion and each category by using excel software. The local and global priorities are computed through the excel software. The local priority is the weight of the selection criteria in its group, while the global priority is to the weight of the selection criteria relative to overall selection criteria [265]. Inconsistency was also computed from the collected data. The inconsistency for the collected data is 0.03. The inconsistency to be acceptable should be less than 0.1. This is a decent indicator to evaluate the level of consistency among all the participants regarding the weight of selection criteria. It is dynamic especially, when numerous decision-makers are involved, as various personalities may evaluate the problem from different perspectives. To recognize the most effective criteria, it is significant to measure each criterion's effectiveness based on the perception of experts in the construction industry. The survey's comprehensive analysis is shown in Table 7, which demonstrates the main selection classifications and criteria along with their local, global priorities and ranking.

Table 7: Portfolio Selection Criteria Weights

Criteria			***Local Weight***			***Global Weight***	***Rank***
Sustainability			0.537				
	Environmental			0.520			
		Energy Use			0.317	0.089	1
		Material Use			0.178	0.050	5
		Water Use			0.170	0.047	9
		Land Use			0.127	0.035	13
		Pollution			0.120	0.034	14
		Waste Management			0.088	0.025	18
	Social			0.214			
		Health & Safety			0.426	0.049	6
		Employee Training & Education			0.200	0.023	21
		Relation with Local Community			0.117	0.013	25
		Improvement of Infrastructure			0.173	0.020	22
		Alternative Transportation			0.084	0.010	26
	Economic			0.266			
		Life-cycle Cost			0.324	0.046	10
		Contribution to GDP			0.220	0.031	16
		Employment Creation			0.177	0.025	18
		Innovation & Technology			0.171	0.024	20
		Use of National Suppliers			0.108	0.015	24
Benefit Realization and Project Success			0.463				
	Organizational Benefits			0.599			
		Strategic Fit			0.225	0.062	3
		Profitability			0.305	0.084	2
		Organizational Quality			0.157	0.045	11
		Organizational Risk			0.194	0.054	4

	Resilience		0.119	0.033	15
Project Success		0.401			
	Project Time		0.265	0.049	6
	Project Risk		0.258	0.048	8
	Project Cost		0.220	0.041	12
	Project Quality		0.161	0.030	17
	Project Resources		0.096	0.018	23

There are two main groups, sustainability criteria group, benefit realization, and project success criteria group with criteria weight of 0.537 and 0.463, respectively. Also, three sustainability pillars got a local weight of 0.520, 0.214, and 0.266 respectively for environmental, social, and economic pillars. The organizational benefit realization criteria obtained a local weight of 0.599 compared to project success criteria with a local weight of 0.401. The energy use has the highest local weight (0.317) among environmental pillar, while Health & Safety is the most weighted criterion (local weight: 0.426) among the social category. On the other side, the life-cycle has been ranked as the highest criterion (local weight: 0.324) among economic pillars. Strategic fit and profitability are the most influential criteria in organizational benefit realization criteria with the local weight of 0.225 and 0.305, respectively. Moreover, Project time is the highest-ranked criterion in the project success criteria group.

The geometric mean equation (*Eq. 1*) was used to calculate each criterion average from the received respondents.

$$\left(\prod_{i}^{n} r_i\right)^{1/n} = \sqrt[n]{r_1\, r_{2\ldots\ldots\ldots} r_n} \qquad (1)$$

In Table 8 and Table 9, the details of criteria weight calculation are demonstrated. In Table 8, a pair-wise comparison was developed between the selection criteria. The normalization process was carried on the resulting matrix and finally averaged each row's values to get the corresponding rating (Table 9).

In the first step, the pair-wise comparison between two criteria is based on the Ratio Scales of AHP suggested by Saaty [292]. Then, each column's sum will be calculated, for example, for strategic fit (Sum= 1.00+1.40+0.60+0.79+0.64= 4.42) as shown in Table 8. Therefore, each element of the resulting matrix is divided by the column sum to generate a normalized matrix, as shown in Table 9 (Example: Strategic Fit: normalized element a_{11}=1/4.42 =0.2262). Finally, the average of each row will be calculated to obtain the weight of each corresponding criterion. For example, the weight for strategic fit will be:

(0.2262+0.2204+0.2502+0.2409+0.1877) / 5= 0.2250 as Local Weight

Also, below equations were used to calculate the overall inconsistency and inconsistency among each group:

$$Consistency\ Index\ (CI) = (\lambda_{max} - n) / (n-1) \qquad (2)$$

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI}\ \text{, where RI is a random index} \qquad (3)$$

MMULT function in Excel, which is a matrix multiplication function was used to calculate the consistency measure. In this function, each column in the pairwise comparison matrix was multiplied by the corresponding weight. The result of this function was divided by the corresponding weight of each criterion. Then, the average of results from MMULT function within a selection criteria group was taken, referred to λmax in Eq. 2. Therefore, equation Eq. 2 and Eq. 3 were used to compute inconsistency ratio. For Example, the result of MMULT function between strategic fit criterion raw by the selection criteria weight is 1.139. Then, this result was divided by the corresponding weight for strategic fit criterion:

1.139/0.2251 = 5.060

Finally, the average of all MMULT function was calculated, referred to λmax= 5.049. Therefore, the consistency ratio was calculated by using Eq. 2 and Eq. 3.

$$CI_{Organziation\ Benefit\ Realziation} = \frac{(5.049 - 5)}{(5 - 1)} = 0.01225$$

$$CR_{Organziation\ Benefit\ Realziation} = \frac{0.01225}{1.12} = 0.10$$

Table 8: Pairwise Comparison Matrix

Analytic Hierarchy Process (AHP) - Weightage						
	Organizational Benefit Realization					
	Strategic Fit	Profitability	Org. Quality	Org. Risk	Resilience	
Strategic Fit	1.00	0.72	1.68	1.26	1.57	
Profitability	1.40	1.00	2.27	1.63	2.08	
Organizational Quality	0.60	0.44	1.00	0.86	1.70	
Organizational Risk	0.79	0.62	1.17	1.00	2.00	
Resilience	0.64	0.48	0.59	0.50	1.00	
Sum	4.42	3.25	6.71	5.25	8.34	

Table 9: Calculation of Criteria Weight

Analytic Hierarchy Process (AHP) - Pairwise Comparison (Normalized Score)						
	Organizational Benefit Realization					
	Strategic Fit	Profitability	Org. Quality	Org. Risk	Resilience	Criteria Weight
Strategic Fit	0.2262	0.2204	0.2502	0.2409	0.1877	0.2250682
Profitability	0.3157	0.3076	0.3389	0.3098	0.2498	0.3043499
Organizational Quality	0.1347	0.1353	0.1491	0.1633	0.2032	0.1571209
Organizational Risk	0.1789	0.1892	0.1739	0.1906	0.2394	0.1943934
Resilience	0.1445	0.1476	0.0879	0.0954	0.1199	0.1190676

Table 10: Values of the Random Index (RI)

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.46	1.49

Table 11: Consistency Ratio for each Group

Overall			0.03		
	Sustainability			0.03	
		Environmental			0.06
		Social			0.01
		Economic			0.04
	Benefit Realization & Project Success			0.01	
		Organization Benefit Realization			0.01
		Project Success			0.01

5.5 Discussion of the Results

The comparison between the criteria weight of the sustainability criteria group and the benefit realization and project success criteria group indicates that the sustainability group has higher effective weight compared to benefit realization and project success criteria. This indicates the recent attention towards sustainability and sustainable practices in the UAE and how the sustainability practices and standards have been promoted recently. On the other side, the comparison between the three pillars of sustainability demonstrates that the environmental criteria got greater attention than others. This is due to the recycling of material, using renewable energy, environmental impacts, and the threat of water scarcity. Also, it should be considered that employees' and the community's health and safety is the most significant criterion in social criteria based on the survey results. Moreover, one of the main client's concerns on the economic criteria is the life-cycle cost, due to high operations and maintenance cost after the project completion during the defined project life cycle and involved cost.

For the benefit realization and project success criteria, the organizational benefits criteria have more effectiveness than the project success criteria. This reveals that the client is looking for a competitive advantage and long-term relationship in the market rather than limiting its decision only on the project's benefits. As expected, within the organizational benefits criteria, the strategic fit and profitability are the most effective criteria. The strategic fit is essential due to aligning the portfolio selection process to its goals and objectives. Profitability is another significant criterion in the organizational benefits category due to its pure financial aspect. Project cost, project risk, and project time are the three main components of the project success criteria triangle.

To find the most critical criteria, it was significant to measure the importance of the selected criteria based on construction experts' insight and awareness. The completed survey was analyzed, and the outcomes are demonstrated in Figure 12-Figure 16. These figures show the outcomes in terms of local weight for the five main selection categories and criteria.

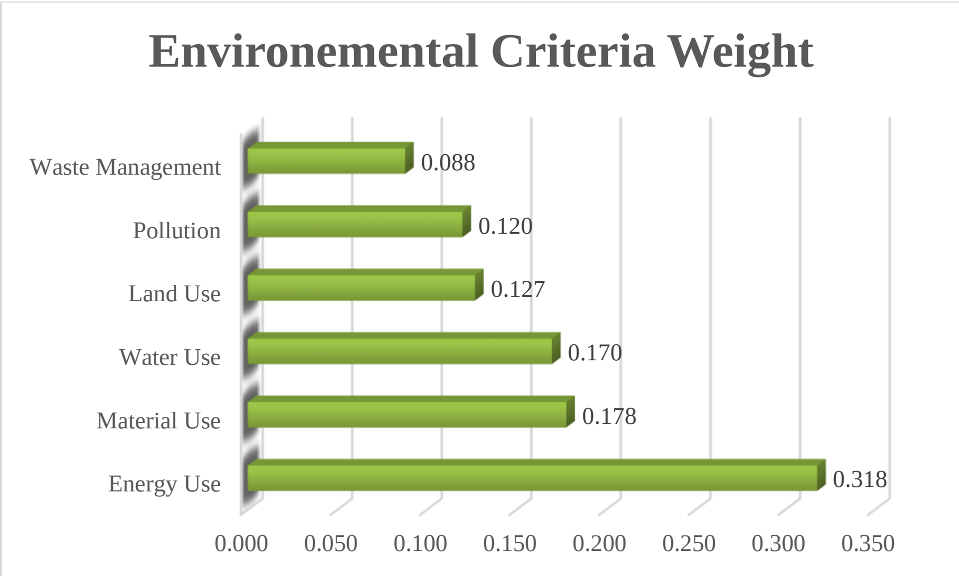

Figure 12: Environmental Criteria Weight (Local Weight)

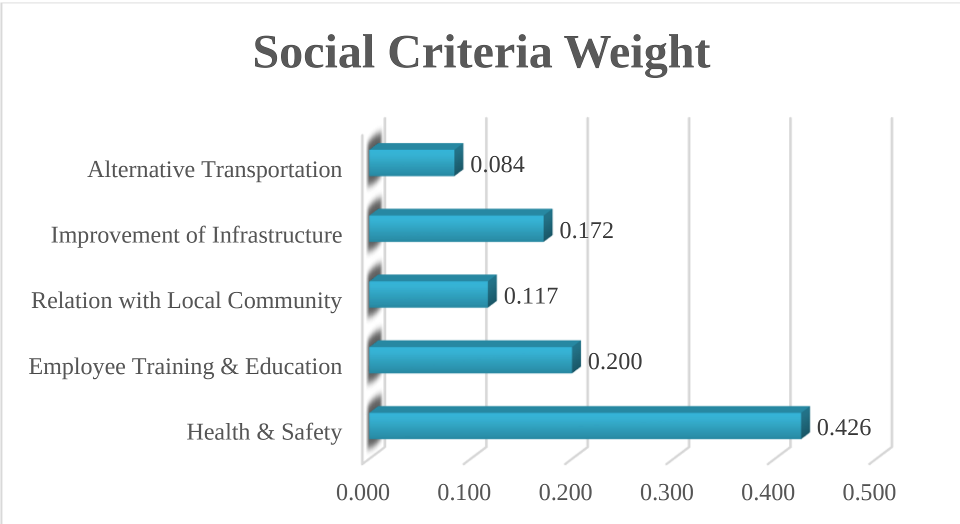

Figure 13: Social Criteria Weight (Local Weight)

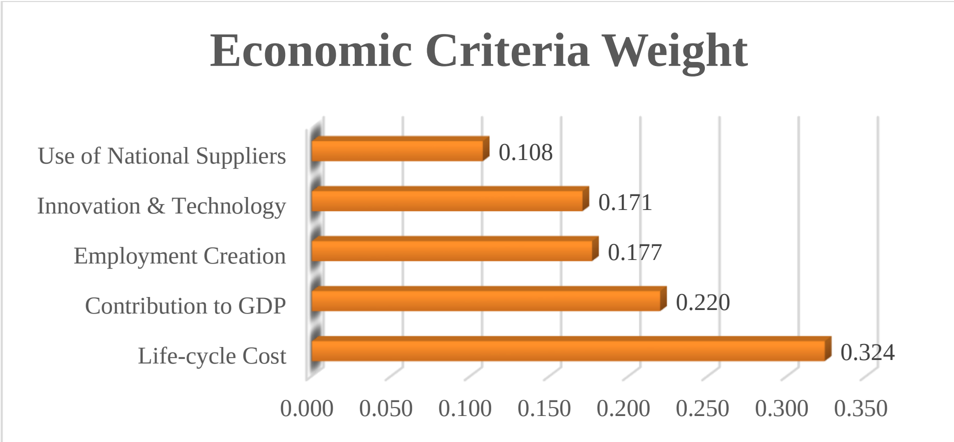

Figure 14: Economic Criteria Weight (Local Weight)

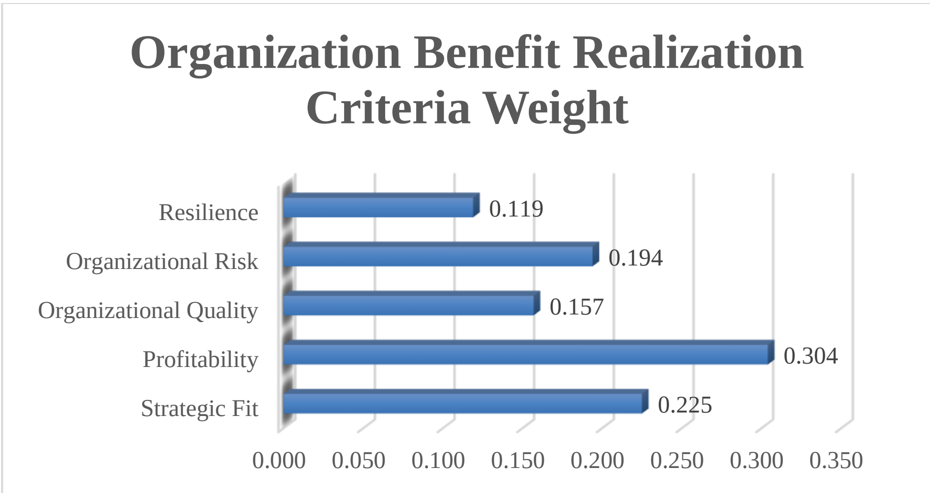

Figure 15: Organization Benefit Realization Criteria Weight (Local Weight)

Figure 16: Project Success Criteria Weight (Local Weight)

5.6 Summary and Conclusion

In summary, the importance of sustainability value was realized in the portfolio selection process and models. Therefore, the decision-makers have to integrate their decision-making process into one comprehensive model that includes all overall benefits such as sustainability value, organization benefits, and projects success value. Therefore, when the selection criteria are chosen, and alternatives are recognized, the decision-makers must compare the alternative programs and projects against each other to meet each selection criterion. Each program and project's score should be computed, where the weighted score of each project is computed by multiplying the score of each project with respect to each criterion by its global weight and then adding them to discover the overall score of each project.

Chapter 6. Portfolio Value Optimization Models

6.1 Introduction

The portfolio selection process within a pool of available projects and programs is a complex and challenging decision due to the incorporation of various targets, which are the prioritized goals by the organization and the significant number of criteria to consider such as sustainability value, benefit realization advantages, project success criteria like manpower resources and project risks.

After reviewing the literature, it is realized that there are various methods utilized for portfolio selection. These methods use quantitative and qualitative criteria without considering the budget restriction, optimizing portfolio value, and incorporating the sustainability value into their decision-making process. Consequently, there is a requirement to propose a technique that integrates both tactics to consider both types of criteria and include limitations on the organization's capabilities. In this dissertation, three new models are developed for portfolio selection to combine two AHP and linear programming methods by considering the sustainability criteria, benefit realization, and project success criteria along with the client's limitations and capabilities. However, for simplicity in the scoring model, the project screening matrix is proposed too.

On the other hand, the proposed linear programming method is enhanced using the genetic algorithm method. Therefore, there are four selection methods suggested in this research: project screening matrix, AHP method, linear programming, and genetic algorithm. These four selected methods form three different models in this research: Model A, Model B, and Model C that are explained accordingly in this chapter.

The project screening matrix, AHP, linear programming, and genetic algorithm methods have been variously used in the portfolio selection process. The main aim is to select the project or program that optimizes the overall organizational benefits. There are four different methods that are proposed in this research. The first method is the project screening matrix, which is selected based on its humble framework and simplicity, and mainly to score the alternative options with respect to each criterion. Secondly, the AHP technique is used to compute each criterion's weight from the collected data through the survey and rank the projects based on their value by being evaluated through the AHP method for Model B.

Finally, the criteria weight calculated from the AHP model is utilized as the coefficients of the LP model's decision variables to meet the available capital optimally. That is in order to optimize the client's benefit. Finally, the linear programming model is applied in Matlab using a genetic algorithm.

6.2 Defining Variables and Methods for the Research Methodology

The portfolio selection method's main task is defining the variables, where defining the standard variables play the primary role. Moreover, in the following sections, this research study's variables have been defined for each method separately: project screening matrix, AHP, and linear programming. Also, the objective function is described as the final project value in terms of criteria weightage and project/program score with respect to each criterion.

<u>Common Variables:</u>

n: number of projects and programs

j: Project or Program Number

V: Portfolio Value

v_j: Project value

x_j: Binary decision variable for Project j (can be either 0 or 1)

C: Available capital for investment in the portfolio

c_j: Required Budget for each Project or Program j

Portfolio Selection Criteria:

Sustainability Criteria:

ENV_i = Environmental Criteria where i=1-6

SOC_i = Social Criteria where i=1-5

ECO_i = Economic Criteria where i=1-5

Organization benefit realization and project success Criteria

BRC_i = BRM Criteria where i=1-5

PSC_i = TPS Criteria where i=1-5

Weightage: i=1,2,3,… Criteria # and j=1,2,3,…. Project number

$Wenv_i$ ➔Weight for Environmental Criteria from AHP survey

$Wsoc_i$ ➔Weight for Social Criteria from AHP survey

$Weco_i$ ➔Weight for Economic Criteria from AHP survey

$Wbrm_i$ ➔Weight for BRM Criteria from AHP survey

$Wtps_i$ ➔Weight for TPS Criteria from AHP survey

Score:

$Senv_{ij}$ ➔Score for Project j with respect to Environmental Criteria

$Ssoc_{ij}$ ➔Score for Project j with respect to Social Criteria

$Seco_{ij}$ ➔Score for Project j with respect to Economic Criteria

$Sbrm_{ij}$ ➔Score for Project j with respect to BRM Criteria

$Stps_{ij}$ ➔Score for Project j with respect to TPS Criteria

Objective function:

To select the most valuable projects/program for the portfolio:

A. Objective:

To maximize the Portfolio Value (V):

$$V = \sum_{j=1}^{n} x_j * v_j \quad (4)$$

where each v_j:

$$v_j = stainability\ Value + Overall\ Benefit\ Relaization\ Value \quad (5)$$

$$= \sum_{i=1} Wsus_i * Ssus_{ij} + \sum_{i=1} Wobrm_i * Sobrm_{ij}$$

$$v_j = \sum_{i=1}^{6} Wenv_i * Senv_{ij} + \sum_{i=1}^{5} Wsoc_i * Ssoc_{ij} + \sum_{i=1}^{5} Weco_i * Seco_{ij} + \sum_{i=1}^{5} Wbrm_i * Sbrm_{ij} + \sum_{i=1}^{5} Wtps_i * Stps_{ij} \quad (6)$$

B. Constraints:

Budget Constraint:

$$\sum_{j=1}^{n} x_j * c_j \leq C \quad (7)$$

Score of any criteria category to meet minimum expectation and requirement:

$$\sum_{i,j=1} S\,xxx_{ij} \geq Min\,(req) \quad (8)$$

Exclusivity Constraint between 2 projects:

$$x_j + x_k \leq 1 \quad (9)$$

Contingent projects:

$$x_j - x_k \leq 0 \quad (10)$$

Therefore, the project and program with higher v_j will be selected for the portfolio in sequence until the client's satisfaction level has been reached.

6.2.1 Project screening matrix (PSM). A project screening matrix can be used as a simple way to score and evaluate the alternative options in the portfolio pool to succeed in the project and program. It can also be considered an evaluation technique that analyzes and evaluates the different project and program choices to support identifying the occasions for gaining the best possible result for the company and organization. This method can evaluate the reasonability of various criteria for new project/portfolio development. This method may be carried out through different measures and procedures while comparing the strengths and weaknesses of different portfolio opportunities.

Project Screening Matrix (PSM) will be conducted through the following steps:

1. Determine the criteria.

2. Give each of your criteria a weighted value.
3. Prepare the matrix.
4. Score each option.
5. Calculate weighted scores for each option.
6. Compare your results.

6.2.2 Analytic hierarchy process (AHP). AHP method was developed in 1970 with the ability to solve quantitative and qualitative problems. This technique uses multi-criteria structure into its specified hierarchy format to assess each criterion's significance through pairwise comparison among the selected criteria with the capability of evaluating the alternative options and scenarios with respect to the selected criteria to demonstrate the most reasonable and practical solution. The researchers use the AHP method to assess, score the alternatives, rank, and choose the best options among portfolio baskets to enhance portfolio value optimization.

AHP method can improve the portfolio selection process, enhance its overall value and resolve the selection process challenges and complications. AHP is considered a decision-making model that involves creating multi-dimensional criteria into an assessment and scoring model by the relative importance of the selected criteria, comparing the options for each criterion to evaluate such options' overall results. This model is developed over mathematics and human perceptions, which provides a valuable tool to solve complicated decision-making problems [244]. Moreover, the AHP method helps identify and evaluate the portfolio selection criteria' effectiveness by gathering data for each criterion and enhancing the decision-making process. Then, AHP is one of the most valuable and efficient techniques for the decision-making process and complicated portfolio problems in the organization.

The AHP method can be utilized in the simple successive steps:

1. Design the AHP Hierarchy
2. Develop a pairwise comparison survey to accomplish measuring the effectiveness of the selected criteria
3. Analyze the collected information and data
4. Compute the weights of the selected criteria
5. Calculate the vector of criteria weights

6. Determine the matrix of alternative option scores
7. Ranking the alternative options

6.2.3 Linear programming (LP). Linear programming is a mathematical technique that is utilized to calculate the best possible results from the selected criteria as the portfolio and organization's requirements in the form of the linear relationship between the criteria and the goals. Moreover, it is also called linear optimization due to the nature of the linear programming technique.

The linear programming method is utilized to optimize the overall organization benefits such as sustainability, benefit realization, project success, and financial criteria. In this technique, the organization's constraints and restrictions are considered while searching for the best optimal solution to satisfy the organization's aim and objective within its capabilities. One of the latest trends in the construction industry to be taken into account while conducting an optimization model is the benefits of sustainability practices and their advantages to society and the public. On the other side, the limitations and constraints that authorities and government implement on the projects should be considered while utilizing portfolio value optimization.

Linear Programming (LP) will be processed through the following stages:

1. Identify the selection criteria
2. Outline the objective function for the company
3. Define the limitations and constraints
4. Consider the non-negatively of restriction

6.2.4 Genetic algorithm. Charles Darwin's theory of natural evolution influenced a search heuristic known as the genetic algorithm. This algorithm resembles natural selection, where the most competent individuals are selected for reproduction to create offspring of the following generation. Genetic algorithms follow the conventional iteration steps as evolutionary algorithms and are based on natural selection. To do this, binary or floating genes are used to represent design variables with fixed lengths. At each repetition, the pairs of two genes with the highest competence are then used to produce new genes by crossover and mutation. The following population is decided in parent and children's genes according to fitness.

In the late 1970s, when genetic algorithms came into discussion, the most popular practice was to use binary numbers to represent genes. Genes are defined, in biology, as a sequence of DNA that represents specific characteristics. Each binary number can be seen as the equivalent of one chromosome of the gene, as called in biology. The 1 and 0 sequence in the GA gene represents a unique solution. Mutation and crossover are both applied in Genetic algorithms.

The separation of the fittest individuals from a population commences the process of natural selection. They will then produce offspring that acquire the parents' characteristics and will continue to the next generation. If parents have superior fitness, their offspring will be more superior than their parents and have a greater chance of surviving. This practice keeps on iterating, and in the end, a generation with the fittest individuals will be established. This notion can be adapted for a search problem. Experts examine a set of solutions for the problem and choose the set of most beneficial ones out of them.

There are five phases considered in a genetic algorithm:

1. Initial population
2. Fitness function
3. Selection
4. Crossover
5. Mutation

Genetic Algorithm (GA) initiates its process through generating a set of individuals. This set of individuals is called population. Characteristic of each individual is recognized by series of parameters, called Genes. Each individual is considered as a feasible solution to solve the problem. The individual is represented using the string in terms of binary codes in the genetic algorithm method. Also, this set of strings are referred to as Chromosomes as solutions to the problem. Compared to others, each individual's fitness and ability are computed through the fitness function by generating a string for each individual. This provides the fitness score for each feasible solution (Individual). The fitness score of each individual defines the probability of an individual to be selected for reproduction. The individuals with higher fitness scores are selected through the selection process. Therefore, the chance of selection will be measured based on fitness score and fitness probability. The next critical stage is crossover in the process of genetic algorithm.

Parents are a combination of two pairs of the selected individuals. A crossover point is selected randomly from the string for each pair of parents. Transferring of genes between parents to reach the crossover point is called offspring. Some genes are subject to mutation with very low probability during the offspring process. This process is done by flipping the binary digit of the string. The new individual will be eliminated if it does not make a reasonable difference from its original string. At this stage, a set of solutions are created by a genetic algorithm for the defined problem. Again, the individuals with low fitness are eliminated while providing chances for new individuals to be created during the reproduction process. The exact process is repeated to generate individuals for each new population with higher fitness scores and probabilities during the regeneration process.

The population size is always the same and constant during reproduction and offspring steps. The feasible solution with high probability will remain in the transaction until the final selection is completed. The fitness function is the decision-making tool to differentiate between feasible solutions and inadequate ones. The individuals with a higher fitness score (value) computed by fitness function have a higher chance and probability of existing and remaining as a solution.

The generated individuals' selection process can be categorized into two groups: elite group and non-elite group. The elite group ensures that the qualified individual as a feasible solution, which is having a good fitness score and meeting the constraints, goes to the next stage. This process ranks the individuals with higher fitness scores, while the non-elite process is the roulette wheel selection process. Each individual’s fitness score will be assigned to a fitness probability according to its fitness value in this process. At each selection step, the non-elite process shuffles the population randomly and breaks them into smaller groups. Half of the individuals are eliminated in each process and iteration.

The generation eliminates the old individuals and creates the individuals into the new population in the genetic algorithm during each iteration. During reproduction and generating the new population, the population's size always remains the same.

The number of iteration and generations in the genetic algorithm will decide the running time and its capability to find the optimal solution.

Figure 17 explains the genetic algorithm optimization steps for the described problem to select the portfolio's most feasible solution.

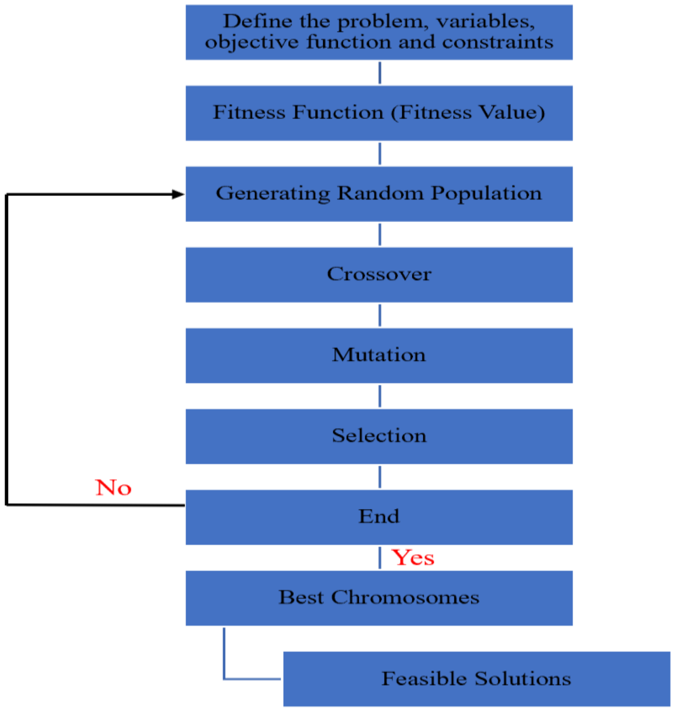

Figure 17: Genetic Algorithm based on Optimization Model

Step 1: Commence the generation of a random population: In this step, GA will generate a random population (sets of values), which might be the optimal solution. These random populations are called "Chromosomes," and this process is referred to as "Generation of Random Population."

Step 2: Assess the fitness function of the population: The fitness function is a significant aspect in GA learning by determining what to be optimized in the GA model. Typically, the fitness function will provide each chromosome's fitness score, giving the chromosome's probability and chance to be selected as the optimal solution. Sometimes, the fineness score is obtained through the objective function.

Step 3: Implement elitist selection: This step will select and send forward the best feasible solution and individuals to the next step from reproduction, crossover, and mutation processes.

Step 4: Replace the existing population with the newly generated population: A new population is generated after crossover and mutation. The selection process chooses the best chromosome with the highest fitness value by using the roulette wheel approach.

Step 5: Feasible Solution: If the selected chromosomes meet the limitation and constraint conditions, then the GA will provide us with a list of a potential solution; otherwise, the chromosome will be sent back to step #2 for reproduction, crossover, nutation, and optimization until a certain number of feasible solutions with a defined fitness goal are achieved.

6.3 Portfolio Selection Models

After identifying the selection criteria and portfolio selection methods, it is crucial to develop a model and model to describe the proposed methodology. In this section, three different models are suggested regarding the four proposed portfolio selection methods in the previous section: project screening matrix, AHP method, linear programming, and genetic algorithm technique. The three models are Model A, Model B, and Model C, where model A combines the project screening matrix and AHP method. In model A, the project screening matrix is used to score each option with respect to each criterion and do the first shortlisting of the projects based on their values. Then, the AHP method is utilized to make the final portfolio selection for the projects and programs selected in the first stage.

Moreover, this model can be used as the initial screening stage, having various and multiple projects, where applying the AHP technique will consume huge time. Model B is a kind of combination of Model A with Linear Programming. In this model, in one stage evaluation, the project screening matrix is used to rate each project versus each criterion. The AHP method is used to measure the importance of each criterion based on the conducted survey. Finally, linear programming is utilized to make the final portfolio selection by considering the organization's capabilities and limitations. Model C will follow the same workflow sequence in model B except using a genetic algorithm instead of linear programming for optimization.

6.3.1 Model A – combination method of project screening matrix and AHP. In this model, the combination of the project screening matrix and the AHP technique is used to solve the portfolio selection problem. As the first step, the selection criteria are chosen based on sustainability, benefit realization, and project success categories. Therefore, each project or program value is rated based on the selected criteria to obtain potential portfolio value using a project screening matrix through the scoring scale of 0-10. Moreover, each criterion's weight is measured through the AHP technique for the conducted survey among experts. Each project and program's overall value is then calculated to compare individual project/program benefits to the organization. Next, the ranking system is used to order the project/program from the highest overall value to the lowest. At this stage, the decision-makers will select the highest project/program to increase overall portfolio value. After developing the selected projects' list in the first screening stage, the AHP method will be used for final portfolio selection. The framework for model A is shown in Figure 18.

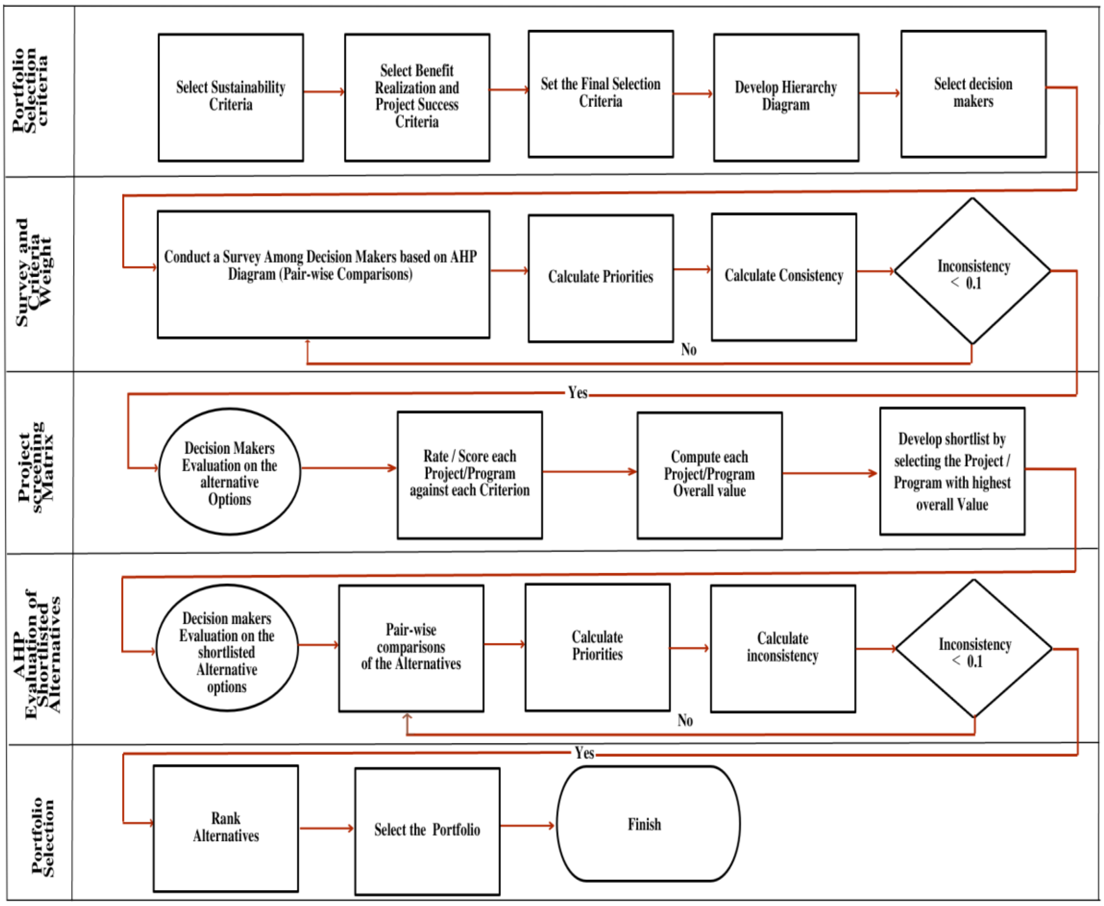

Figure 18: Framework for Model A

6.3.2 Model B – linear programming. Model B is considered an improved version of model A, where the organization's limitations and capabilities are taken into account while selecting the portfolio. In this model, the selection criteria are addressed in the initial stage. Each project's rating will be evaluated based on the project screening matrix with respect to the selection criteria. Also, the weight of each criterion is measured through the survey by the decision-makers. In this model, linear programming is used to select the optimal solution instead of developing a shortlist and using AHP to evaluate the portfolio's shortlisted alternative options. The optimal portfolio selection is made considering the developed formula in section 6.2 for linear programming. The framework for this model B is shown in Figure 19:

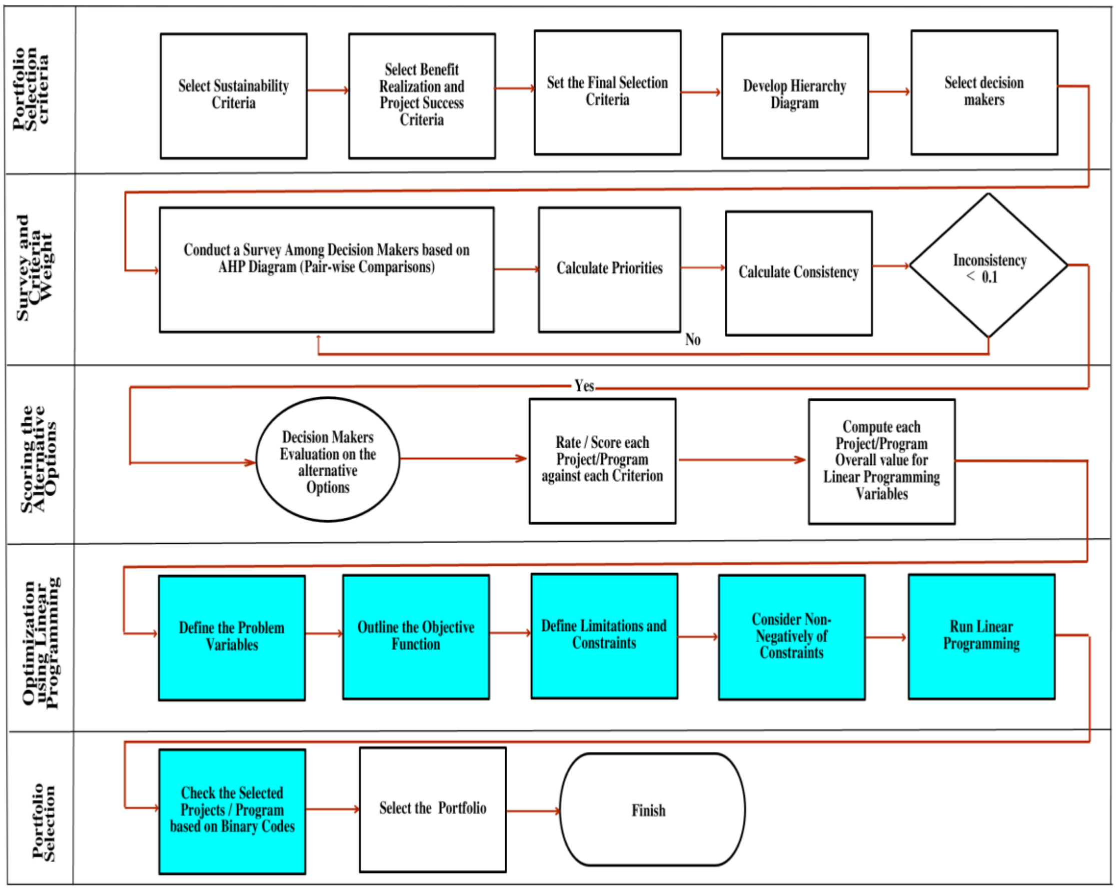

Figure 19: Framework for Model B

6.3.3 Model C – genetic algorithm. Model C will enhance Model B by utilizing the genetic algorithm method as an AI technique to compute the best feasible solution for the defined problem. The initial process of selection criteria, rating each alternative option versus each criterion, computation of the criteria weight will follow the same defined steps in Model B, except optimization technique that has been replaced by genetic algorithm instead of linear programming.

The formulation of a genetic algorithm utilizes the same objective function used in linear programming. The genetic algorithm technique has been stated to be efficient and effective in optimization applications. This method is easy to be set up and implemented by the users. The GA technique utilizes the data and constraints to support the multi-objective optimization model, where GA uses probabilistic transition rules instead of deterministic ones.

Therefore, the framework of model C, which includes optimization of portfolio value using Artificial Intelligence, is shown in Figure 20.

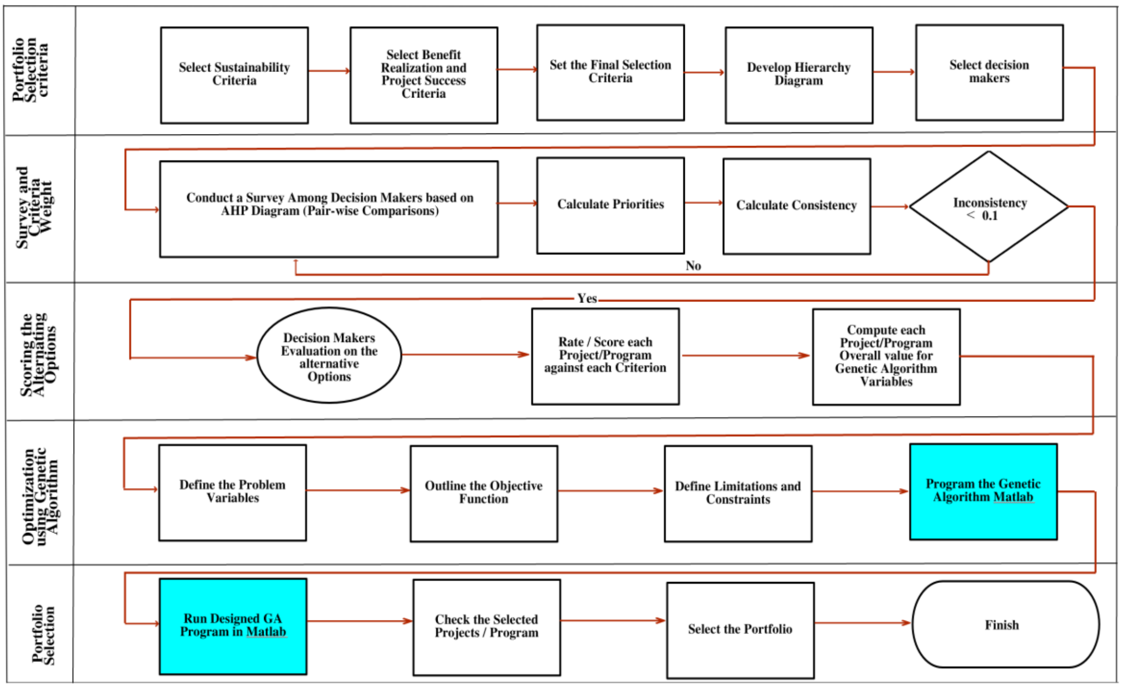

Figure 20: Framework for Model C using Genetic Algorithm

The design of genetic algorithm variables and objective function will be similar to linear programming, except the portfolio's selection process for the genetic algorithm explained in Figure 17.

The genetic algorithm method has capability of solving linear and nonlinear problems with inaccurate data that can be used in portfolio selection process and portfolio management fields. The genetic algorithm method has been used in decision-making process because it is effective, robust, and has capability to find the optimal or closest solution to optimal in less time compared to the traditional methods. The proposed model C integrates the AHP method and genetic algorithm to locate the neighborhood of the optimal solution for portfolio selection process, in which the genetic algorithm has ability to substitute the criteria weights measured by traditional pair-wise comparison of AHP method to the alternatives with regards to one or more of the criteria. The GA model may also be used for sensitivity analysis purposes.

6.4 Summary and Conclusion

These models are applicable for the organization with various alternative projects and programs, such as developers, private investments companies and governments entities, where the right portfolio selection has direct impact on present and future of the society and community in direct and indirect traditions. The decision-makers and top management can use this model in their decision-making and portfolio selection process. Model A provides simple portfolio selection method for the decision-makers, where the final selection and number of selected projects will be decided by the top management. Model B and Model C, are optimization models, where the outcomes of the linear programming and genetic algorithm is the optimal solution to the complex problem. However, the selection criteria can be customized for these three models based on geographical area and type of the projects for the decision-makers and the organizations.

Chapter 7. Models' Applications: Case Study

7.1 Case Study for a Developer in the UAE

To demonstrate the use and advantage of the proposed optimization model in portfolio value which incorporates the sustainability benefits of the construction projects for the developers and clients, a case study is selected to be analyzed in this section. In this case study, the client has various investment options with different advantages and budgets. The selected criteria in the proposed model and the portfolio selection technique are used to evaluate and assess the alternative projects for the client. Later, the selected criteria, the client's limitations, and constraints are used in the linear programming model to optimize the client’s investment benefits through objective function. Finally, the same problem is solved using a genetic algorithm through mono and multi-objective functions. Thus, the client's portfolio selection problem is solved through three different proposed models: model A, model B, and model C.

The firm is a private holding company with headquarter in Dubai and assets and operations in the United Arab Emirates. The company was founded in 2007, who has executed various projects in numerous segments such as retail, food and beverage, hospitality, healthcare, entertainment, and real estate. The solid real estate portfolio includes asset management and property development across various locations in Dubai. The entertainment department functions leisure venues, and the retail sector operates retail outlets. The hospitality section handled the hotel operation for the firm, which is in partnership with famous and big hotel operators worldwide. Also, the firm has a range of more than twenty concepts in 40 different locations around Dubai as part of its food and beverage segment.

At the end of 2020, and considering the pandemic situation, the firm restricted its budget to limited projects. Therefore, the firm is carefully reviewing its portfolio to maximize its overall benefits towards the considered criteria. The firm's new investment is restricted to a budget of AED 600 million. The development team and market analyst team suggested seven different investment opportunities with various specifications and characters. Table 12 illustrates the seven projects' explanations, while Table 13 indicates the projects' requirements with respect to their constraints and budget. Regarding the employer's knowledge and past investment, the client has performed various similar projects in different locations across Dubai in the United Arab Emirates.

- The firm has AED 600 million available to invest in new opportunities
- The minimum cumulative energy use score for the selected projects shall not be less than 23

Table 12: Projects' Description

Project Description	
Project#1	Landscaping Project – Residential Area (P1)
Project#2	Labor Accommodation (P2)
Project#3	Landscaping project around the airport area (P3)
Project#4	Roads development with Road and Transport Authority (P4)
Project#5	Infrastructure project in Logistic Complex (P5)
Project#6	New Building and office for the partner - Bank (P6)
Project#7	A New connecting Bridge (P7)

Table 13: Projects' Required Budget

Project Budget	
Project Name	***Required Budget***
Project#1	AED 130,000,000
Project#2	AED 260,000,000
Project#3	AED 95,000,000
Project#4	AED 180,000,000
Project#5	AED 350,000,000
Project#6	AED 150,000,000
Project#7	AED 140,000,000

The example is shown below consists of seven projects. The firm analyzed the portfolio based on 26 criteria categorized into two groups: sustainability criteria and benefit realization and project success criteria. Sustainability criteria are studied based on energy use, material use, water use, land use, pollution and waste management, public health and safety, employee training and education, relationship with the local community, improvement of infrastructure, and encourage an alternative mode of transportation, life-cycle cost, contribution to GDP and wealth creation, employment creation, innovation and technology, and use of national suppliers. On the other hand, the analysis of benefit realization and project success is conducted based on profitability, strategic fits, organizational quality (Branding and Reputation), organizational risks, resilience, project time, project cost, project quality, project risks, and project resources. The portfolio selection process is analyzed and studied through three different models: a combination of Project Screening Matrix (PSM) and Analytic Hierarchy Process (AHP), secondly the linear programming where the obtained weights of the criteria from the AHP method will be used as a coefficient in the objective function of the linear programming model, and finally enhancing the second model by using genetic algorithm.

Each project's score with respect to each criterion is obtained through a rating system and survey conducted by the developer procurement and tendering team, using a Likert scale from 0 to 10. The weight of each criteria for the AHP method is obtained through a survey responded to by experts in the construction field (Using the AHP method, the pairwise comparison is made using odd numbers such as 1, 3, 5, 7, and 9).

7.2 Model A – Project Screening Matrix and AHP Methods

For the combination model of project screening matrix and AHP, each project's score with respect to each criterion is analyzed and done by procurement and tendering teams. The weight of each criterion is taken from the conducted survey, pairwise comparison, and AHP method. Table 14 is showing the scores of all projects with respect to all criteria. As a result of this table, each project's total score is demonstrated with the purpose of portfolio selection. As shown, project 6, project 2, and project 4 have achieved the highest overall project value and score among other projects.

Moreover, evaluating the environmental criteria individually, project 6, project 4, and project 2 have the highest positive environmental impacts on the community. After shortlisting the three projects with the highest value, the AHP method will be used for pairwise comparison between these three projects. The results of the AHP analysis are demonstrated in Table 15. As a result, project 6 is still the highest-ranked project amongst others to be selected for the portfolio, following project 4 and then project 2.

Table 14: Results of Project Screening Matrix Method

Portfolio Value Optimization Model for Sustainable Construction Projects																
		Project #	Project 1		Project 2		Project 3		Project 4		Project 5		Project 6		Project 7	
	Selection Criteria	**Criteria Weight**	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Environment																
ENV-1	Energy Use	0.089	6	0.534	7	0.623	5	0.445	8	0.712	6	0.534	9	0.801	6	0.534
ENV-2	Material Use	0.05	7	0.35	8	0.4	7	0.35	7	0.35	7	0.35	7	0.35	7	0.35
ENV-3	Water Use	0.047	8	0.376	8	0.376	6	0.282	7	0.329	5	0.235	8	0.376	8	0.376
ENV-4	Land Use and Biodiversity	0.035	7	0.245	6	0.21	7	0.245	6	0.21	5	0.175	8	0.28	7	0.245
ENV-5	Pollution	0.034	6	0.204	7	0.238	7	0.238	8	0.272	7	0.238	6	0.204	7	0.238
ENV-6	Waste Management	0.025	7	0.175	8	0.2	5	0.125	7	0.175	6	0.15	7	0.175	7	0.175
Total Environmental Scores for each Prog/Proj			**Project 1**	1.884	**Project 2**	2.047	**Project 3**	1.685	**Project 4**	2.048	**Project 5**	1.682	**Project 6**	2.186	**Project 7**	1.918
Social																
SOC-1	Public Health and Safety	0.049	7	0.343	8	0.392	7	0.343	8	0.392	7	0.343	7	0.343	8	0.392
SOC-2	Employee Training, Education, and Skill Development	0.023	5	0.115	6	0.138	7	0.161	8	0.184	7	0.161	7	0.161	7	0.161
SOC-3	Relationship with local community	0.013	6	0.078	7	0.091	6	0.078	7	0.091	5	0.065	8	0.104	6	0.078
SOC-4	Improvement of Infrastructure	0.02	6	0.12	8	0.16	6	0.12	9	0.18	7	0.14	6	0.12	7	0.14
SOC-5	Encourage Alternative Modes of Transportation	0.01	7	0.07	7	0.07	6	0.06	8	0.08	5	0.05	8	0.08	8	0.08
Total Social Scores for each Prog/Proj			**Project 1**	0.726	**Project 2**	0.851	**Project 3**	0.762	**Project 4**	0.927	**Project 5**	0.759	**Project 6**	0.808	**Project 7**	0.851
Economic																
ECO-1	Life-cycle cost	0.046	6	0.276	8	0.368	6	0.276	7	0.322	6	0.276	8	0.368	7	0.322
ECO-2	Contribution to GDP and wealth creation	0.031	5	0.155	6	0.186	6	0.186	5	0.155	6	0.186	7	0.217	6	0.186
ECO-3	Employment creation	0.025	6	0.15	7	0.175	7	0.175	6	0.15	5	0.125	8	0.2	7	0.175
ECO-4	Innovation and technological advance	0.024	8	0.192	7	0.168	4	0.096	6	0.144	5	0.12	7	0.168	5	0.12
ECO-5	Use of National Supplier	0.015	5	0.075	8	0.12	5	0.075	7	0.105	6	0.09	7	0.105	8	0.12
Total Economic Scores for each Prog/Proj			**Project 1**	0.848	**Project 2**	1.017	**Project 3**	0.808	**Project 4**	0.876	**Project 5**	0.797	**Project 6**	1.058	**Project 7**	0.923
Organziation Benefit Realization																
BRC-1	Strategic fit	0.062	6	0.372	7	0.434	7	0.434	8	0.496	6	0.372	9	0.558	7	0.434
BRC-2	Profitability	0.084	6	0.504	8	0.672	7	0.588	8	0.672	6	0.504	8	0.672	7	0.588
BRC-3	Organizational Risks	0.045	5	0.225	9	0.405	7	0.315	7	0.315	8	0.36	8	0.36	8	0.36
BRC-4	Organizational Quality	0.054	6	0.324	8	0.432	5	0.27	6	0.324	6	0.324	7	0.378	6	0.324
BRC-5	Resilience	0.033	7	0.231	6	0.198	6	0.198	6	0.198	7	0.231	7	0.231	6	0.198
Total BRM & PSC Scores for each Prog/Proj			**Project 1**	1.656	**Project 2**	2.141	**Project 3**	1.805	**Project 4**	2.005	**Project 5**	1.791	**Project 6**	2.199	**Project 7**	1.904
Project Success Criteria																
PSC-1	Project Cost (Budget)	0.049	7	0.343	6	0.294	8	0.392	7	0.343	5	0.245	6	0.294	7	0.343
PSC-2	Project Time	0.048	7	0.336	8	0.384	8	0.384	6	0.288	7	0.336	8	0.384	5	0.24
PSC-3	Project Risks	0.041	7	0.287	7	0.287	7	0.287	7	0.287	6	0.246	7	0.287	6	0.246
PSC-4	Project Quality	0.03	6	0.18	8	0.24	7	0.21	6	0.18	6	0.18	7	0.21	7	0.21
PSC-5	Project Resources	0.018	8	0.144	7	0.126	8	0.144	6	0.108	7	0.126	6	0.108	6	0.108
Total BRM & PSC Scores for each Prog/Proj			**Project 1**	1.29	**Project 2**	1.331	**Project 3**	1.417	**Project 4**	1.206	**Project 5**	1.133	**Project 6**	1.283	**Project 7**	1.147
Aggregate Project/Program Score			**Project 1**	6.404	**Project 2**	7.387	**Project 3**	6.477	**Project 4**	7.062	**Project 5**	6.162	**Project 6**	7.534	**Project 7**	6.743

Also, in order to demonstrate the difference between portfolio selection results including sustainability and without sustainability, the case study was analyzed by using model A without sustainability criteria. The result of model A without sustainability is shown in Table 16. As shown, project 6, project 2, and project 3 have achieved the highest overall project value and score among other projects for the client's portfolio. Therefore, project 4 in the portfolio selection process including sustainability is replaced by project 3 in the portfolio selection process without sustainability criteria. This highlights the importance of sustainability criteria in the decision-making process.

Table 15: Results of AHP Analysis for Model A

Portfolio Value Optimization Model for Sustainable Construction Projects								
		Project #	Project 2		Project 4		Project 6	
Selection Criteria		**Criteria Weight**	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Environment								
ENV-1	Energy Use	0.089	0.1932	0.017	0.0833	0.007	0.7235	0.064
ENV-2	Material Use	0.05	0.6	0.03	0.2	0.01	0.2	0.01
ENV-3	Water Use	0.047	0.6333	0.03	0.2605	0.012	0.1062	0.005
ENV-4	Land Use and Biodiversity	0.035	0.1429	0.005	0.4286	0.015	0.4286	0.015
ENV-5	Pollution	0.034	0.6333	0.022	0.2605	0.009	0.1062	0.004
ENV-6	Waste Management	0.025	0.3333	0.008	0.3333	0.008	0.3333	0.008
Total Environmental Scores for each Prog/Proj			**Project 2**	0.112	**Project 4**	0.062	**Project 6**	0.106
Social								
SOC-1	Public Health and Safety	0.049	0.2605	0.013	0.1062	0.005	0.6333	0.031
SOC-2	Employee Training, Education, and Skill Development	0.023	0.0599	0.001	0.1897	0.004	0.7504	0.017
SOC-3	Relationship with local community	0.013	0.2605	0.003	0.6333	0.008	0.1062	0.001
SOC-4	Improvement of Infrastructure	0.02	0.2605	0.005	0.1062	0.002	0.6333	0.013
SOC-5	Encourage Alternative Modes of Transportation	0.01	0.0599	6E-04	0.1897	0.002	0.7504	0.008
Total Social Scores for each Prog/Proj			**Project 2**	0.023	**Project 4**	0.022	**Project 6**	0.07
Economic								
ECO-1	Life-cycle cost	0.046	0.2605	0.012	0.6333	0.029	0.1062	0.005
ECO-2	Contribution to GDP and wealth creation	0.031	0.2605	0.008	0.1062	0.003	0.6333	0.02
ECO-3	Employment creation	0.025	0.0599	0.001	0.1897	0.005	0.7504	0.019
ECO-4	Innovation and technological advance	0.024	0.2605	0.006	0.6333	0.015	0.1062	0.003
ECO-5	Use of National Supplier	0.015	0.2605	0.004	0.1062	0.002	0.6333	0.01
Total Economic Scores for each Prog/Proj			**Project 2**	0.032	**Project 4**	0.054	**Project 6**	0.055
Organziation Benefit Realization								
BRC-1	Strategic fit	0.062	0.0599	0.004	0.1897	0.012	0.7504	0.047
BRC-2	Profitability	0.084	0.2605	0.022	0.6333	0.053	0.1062	0.009
BRC-3	Organizational Risks	0.045	0.2605	0.012	0.1062	0.005	0.6333	0.029
BRC-4	Organizational Quality	0.054	0.0599	0.003	0.1897	0.01	0.7504	0.041
BRC-5	Resilience	0.033	0.2605	0.009	0.6333	0.021	0.1062	0.004
Total BRM & PSC Scores for each Prog/Proj			**Project 2**	0.049	**Project 4**	0.101	**Project 6**	0.128
Project Success Criteria								
PSC-1	Project Cost (Budget)	0.049	0.2605	0.013	0.1062	0.005	0.6333	0.031
PSC-2	Project Time	0.048	0.0599	0.003	0.1897	0.009	0.7504	0.036
PSC-3	Project Risks	0.041	0.2605	0.011	0.6333	0.026	0.1062	0.004
PSC-4	Project Quality	0.03	0.2605	0.008	0.1062	0.003	0.6333	0.019
PSC-5	Project Resources	0.018	0.0599	0.001	0.1897	0.003	0.7504	0.014
Total BRM & PSC Scores for each Prog/Proj			**Project 2**	0.035	**Project 4**	0.047	**Project 6**	0.104
Aggregate Project/Program Score			**Project 2**	0.251	**Project 4**	0.285	**Project 6**	0.463

Table 16: Results of Project Screening Matrix Method

Portfolio Value Optimization Model for Sustainable Construction Projects																
		Project #	Project 1		Project 2		Project 3		Project 4		Project 5		Project 6		Project 7	
Selection Criteria		**Criteria Weight**	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score	Score	Weighted Score
Organziation Benefit Realization																
BRC-1	Strategic fit	0.136	6	0.816	7	0.952	7	0.952	8	1.088	6	0.816	9	1.224	7	0.952
BRC-2	Profitability	0.182	6	1.092	8	1.456	7	1.274	8	1.456	6	1.092	8	1.456	7	1.274
BRC-3	Organizational Risks	0.094	5	0.47	9	0.846	7	0.658	7	0.658	8	0.752	8	0.752	8	0.752
BRC-4	Organizational Quality	0.116	6	0.696	8	0.928	5	0.58	6	0.696	6	0.696	7	0.812	6	0.696
BRC-5	Resilience	0.071	7	0.497	6	0.426	6	0.426	6	0.426	7	0.497	7	0.497	6	0.426
Total BRM & PSC Scores for each Prog/Proj			**Project 1**	3.571	**Project 2**	4.608	**Project 3**	3.89	**Project 4**	4.324	**Project 5**	3.853	**Project 6**	4.741	**Project 7**	4.1
Project Success Criteria																
PSC-1	Project Cost (Budget)	0.106	7	0.742	6	0.636	8	0.848	7	0.742	5	0.53	6	0.636	7	0.742
PSC-2	Project Time	0.103	7	0.721	8	0.824	8	0.824	6	0.618	7	0.721	8	0.824	5	0.515
PSC-3	Project Risks	0.089	7	0.623	7	0.623	7	0.623	7	0.623	6	0.534	7	0.623	6	0.534
PSC-4	Project Quality	0.065	6	0.39	8	0.52	7	0.455	6	0.39	6	0.39	7	0.455	7	0.455
PSC-5	Project Resources	0.038	8	0.304	7	0.266	8	0.304	6	0.228	7	0.266	6	0.228	6	0.228
Total BRM & PSC Scores for each Prog/Proj			**Project 1**	2.78	**Project 2**	2.869	**Project 3**	3.054	**Project 4**	2.601	**Project 5**	2.441	**Project 6**	2.766	**Project 7**	2.474
Aggregate Project/Program Score			**Project 1**	6.351	**Project 2**	7.477	**Project 3**	6.944	**Project 4**	6.925	**Project 5**	6.294	**Project 6**	7.507	**Project 7**	6.574

7.3 Model B – Linear Programming

Accordingly, for the second model, the individual project value taken from the project screening matrix in Table 14 is used in the linear programming model to optimize the client's benefits while considering the organization's limitations, which is mainly the budget constraint. In addition to the client's budget limitation of AED 600 million, the client's primary concern is renewable energy and reduction of energy measured through the energy use criterion. Therefore, the client set another limitation while selecting its portfolio: the minimum cumulative energy use score to be 23.

As the next step, the overall score of each project will be used in the objective function of linear programming along with the client's limitations in order to obtain the optimal solution:

Maximize Portfolio Value:

$$\boldsymbol{v = 6.404x_1 + 7.387x_2 + 6.477x_3 + 7.062x_4 + 6.162x_5 + 7.734x_6 + 6.743x_7}$$

Subject to the following constraints and limitations:

$$\textbf{Budget Constraint: } \boldsymbol{130x_1 + 260x_2 + 95x_3 + 180x_4 + 350x_5 + 150x_6 + 140x_7 \leq 600}$$

$$\textbf{Energy Use Constraint: } \boldsymbol{6x_1 + 7x_2 + 5x_3 + 8x_4 + 6x_5 + 9x_6 + 6x_7 \geq 23}$$

After running the linear programming in excel sheet using solver, the result of linear programming, indicates that the clients should select project 3, project 4, project 6 and project 7 with an overall benefit score of 27.816, total allocated budget of 565 million, and cumulative energy use score of 28 (Appendix III).

7.4 Model C – Genetic Algorithm

Model C enhances Model B by utilizing the genetic algorithm method as an AI technique to compute the best feasible solution for the defined problem. The initial process of selection criteria, rating each alternative option versus each criterion, computation of the criteria weight will follow the same defined steps in Model B, except optimization technique that has been replaced by genetic algorithm instead of linear programming.

The formulation of genetic algorithm formulation utilized the same objective function used in the linear programming:

Maximize Portfolio Value:

$$\boldsymbol{v = 6.404x_1 + 7.387x_2 + 6.477x_3 + 7.062x_4 + 6.162x_5 + 7.734x_6 + 6.743x_7}$$

Subject to the following constraints and limitations:

Budget Constraint: $\boldsymbol{130x_1 + 260x_2 + 95x_3 + 180x_4 + 350x_5 + 150x_6 + 140x_7 \leq 600}$

Energy Use Constraint: $\boldsymbol{6x_1 + 7x_2 + 5x_3 + 8x_4 + 6x_5 + 9x_6 + 6x_7 \geq 23}$

The process of genetic algorithm goes through five steps of initial population, fitness function, selection, crossover, mutation to select the feasible solution. The results of this model are shown in Table 17:

Table 17: Feasible Solutions for Mono Objective Genetic Algorithm for Model B

Feasible Solution	Max Portfolio Value	Budget (AED – Million)	Energy Use
1 0 1 0 0 1 1	27.158	515	26
1 0 0 1 0 1 0	21.00	460	23
0 0 1 1 0 1 1	27.816	565	28
1 0 1 1 0 1 0	27.477	555	28
0 0 1 1 0 1 1	27.816	565	28
1 0 0 1 0 1 1	27.743	600	29
1 0 0 1 0 1 1	27.743	600	29
1 0 0 1 0 1 0	21.00	460	23
1 0 1 0 0 1 1	27.158	515	26
1 0 1 1 0 1 0	27.477	555	28

The genetic algorithm's optimal solution is the same as linear programming, where project 3, project 4, project 6, and project 7 are selected. In this optimal solution, the portfolio value is 27.816, the consumed budget is 565 million, and the achieved energy use constraint is 28. The optimal solution is 0011011, where the 0 indicates the project which is not selected and 1 demonstrates the selected projects by genetic algorithm. The selected solution in Table 16 is the accepted solution in genetic algorithm through programming and coding.

Model C promotes advantage of genetic algorithm through the graphical user interface (GUI), which is form of user interface that permits the clients to interact with created user-friendly window in Matlab. In this GUI, the clients as end users can substitute the criteria weights measured by traditional pair-wise comparison of AHP method to the alternatives with regards to one or more of the criteria, as shown in Figure 21 and Figure 22. Therefore, the end user has an option to enter range for the selection criteria weights, where the selection will be done through programmed GA.

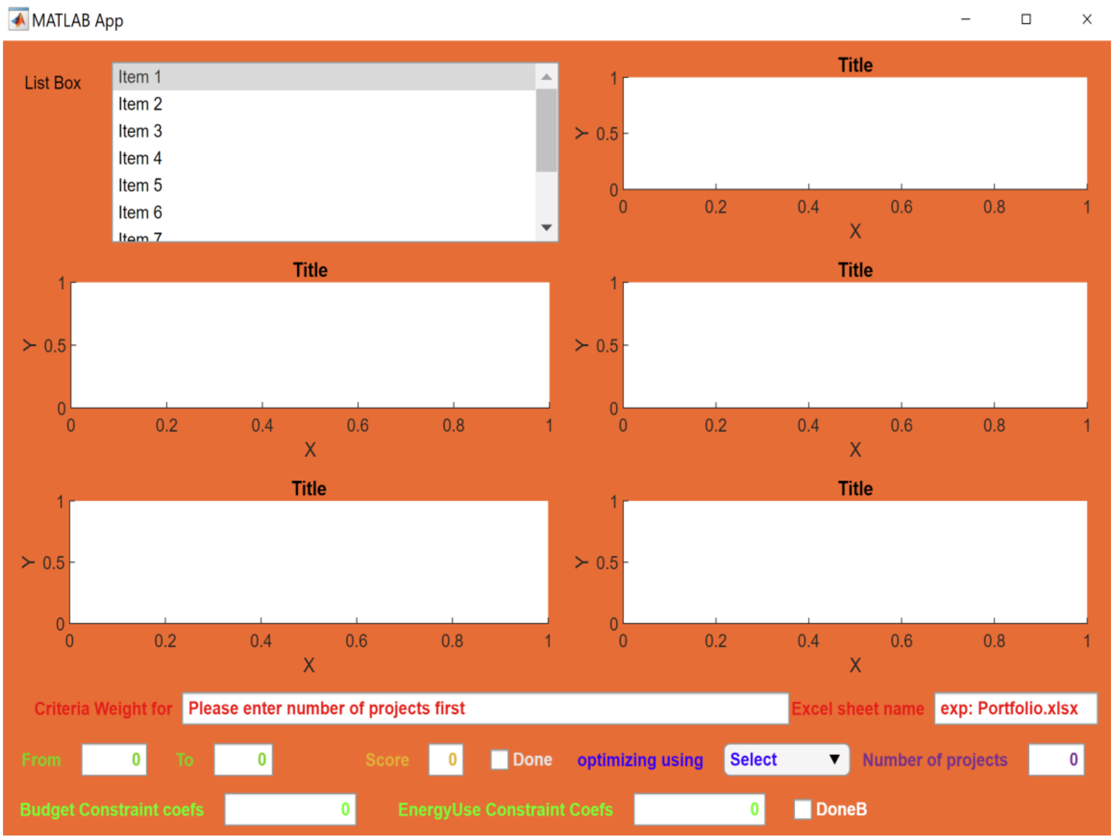

Figure 21: GUI Window for Users' Interface

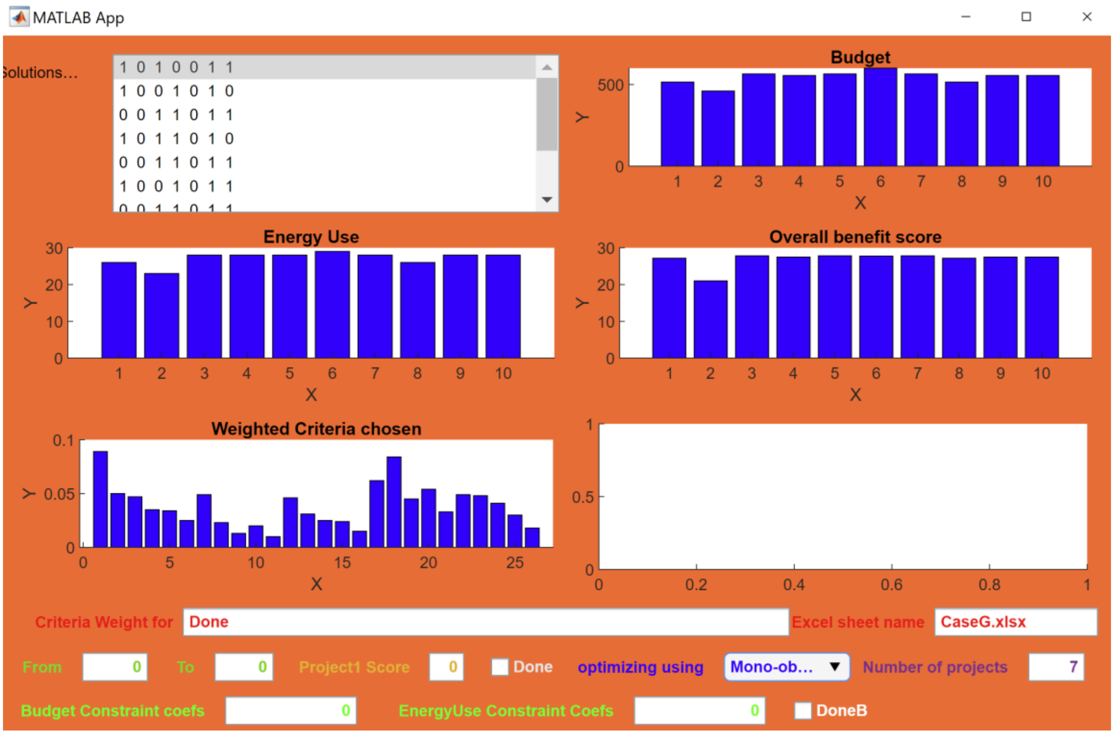

Figure 22: Example of outputs for GUI Application in Matlab

Chapter 8. Conclusion

8.1 Summary

The portfolio selection criteria are divided into two groups: sustainability criteria group, benefit realization, and project success criteria group with criteria weight of 0.537 and 0.463, respectively. Sustainability criteria consist of environmental, social, and economic pillars with the local weight of 0.52, 0.214, and 0.266, respectively, which demonstrates the importance of environmental pillar among sustainability group. The data also highlights the significance of reducing energy usage and renewable energy use through energy use criteria with the highest local weight of (0.317) among environmental criteria. Moreover, the collected data confirms that one of the highest concerns in the construction industry is Health and Safety selection criteria by obtaining the highest local weight (0.426) in the social category. Also, it was found that the life-cycle is ranked as the most important criterion among the economy category.

Another finding of this research is the importance of the organization benefit realization criteria with the local weight of 0.599 compared to project success criteria with the local weight of 0.401, which indicates that the client is looking for a competitive advantage and long-term relationship in the market rather than limiting its decision only on the project's benefits. Strategic fit and profitability were identified as the most effective criteria in organization benefit realization criteria, while project time was the most effective criteria in the project success criteria group.

The sustainability group has higher effective weight than benefit realization and project success criteria, which are shown by comparing the criteria weight of these two groups. This highlights the importance of sustainability and sustainable practices in the current world and specifically in the United Arab Emirates. In summary, the significance of sustainability value was realized in the portfolio selection and decision-making process. Thus, it highlights one comprehensive model's requirement to evaluate overall benefits such as sustainability value, organization benefits and projects success value simultaneously.

8.2 Conclusions

Economic growth and development create threats for natural resources and climate change, result in a destabilized environment. Such implications highlight the importance of sustainability in future development and mainly in the construction industry. Moreover, organization strategies and objectives might change stakeholders' views on how the portfolio selection process has taken place. The organization strategy will customize traditional project management into benefits realization management to link the project deliverables and outputs to its mission and objectives. Therefore, the experts will look for an integrated method to combine the advantages of sustainability and benefit realization management in the portfolio selection process. Moreover, human interferences and errors inquire about a computerized technology that can enhance the optimization and portfolio selection process. A genetic algorithm can sound like a solution to minimize such errors and save time-consumption of human intervention.

Therefore, this dissertation's outcomes provide a comprehensive model and solution for the portfolio selection process, which fulfill the needs for sustainability in the construction industry and raise the attention of government entities and clients to include sustainability benefits in their decision-making process. This process includes promoting benefits that incorporate sustainability, benefit realization, project success, inputs of experts' opinion, prioritizing the benefits and advantages, obtaining stakeholders' opinion through survey, portfolio selection through benefits measurement and constrained optimization methods, usage of Genetic Algorithm, and finally prepare a conceptual model that enhance the decision-making process for the organization and stakeholders. Thus, this dissertation outcome will provide the stakeholders with a precise global solution for portfolio selection, which has taken all construction industry requirements such as benefits realization management, organization strategy, project success, and sustainability into its account and calculations through a comprehensive model that ease management-level decisions.

In this research, the selection criteria were categorized into two groups: sustainability group, and organization benefit realization, and project success group. The sustainability group consists of the three pillars: environmental, social, and economical, while the other group consists of two sub-categories: organization benefit realization and project success. A survey was designed and distributed to professionals in the United Arab Emirates (UAE) construction industry to measure selection criteria' weight by using the Analytic Hierarchy Process (AHP) method. The results show that the sustainability group is more important compared to the organization benefits and project success criteria. The top six selection criteria include energy use, material use, water use, health and safety, strategic fit, and profitability. Three models are proposed to determine the optimum solution based on the organization's constraints. Model A combines Project Screening Matrix (PSM) with AHP. Model B is an integrated AHP and Linear Programming (LP) model, while Model C uses Genetic Algorithms (GA). The research is valuable to inspire the clients and authorities to consider sustainability as key criteria in their portfolio selection which results in more sustainable construction industry.

8.3 Recommendations

This research is important to identify the significant selection criteria and the selection models due to the lack of research conducted worldwide, and in the United Arab Emirates, on the optimization of portfolio value by integrating all three aspects of sustainability, organization benefit, and project success. This research is significant due to verifying the relationship between the identified selection criteria and project selection methods in the literature review on optimizing the portfolio value. This study will add significant value to the optimization of portfolio value and portfolio selection process by promoting sustainability value based on the conducted survey and literature review results. The proposed model is helpful for the portfolio selection process and optimization worldwide and specifically in the UAE.

The results of this research will be supportive for the management and decision-makers in developers and clients, particularly in the construction industry. The results and analysis advise that organizations use an integrated model that promotes sustainability value and considers organization benefit and project success criteria simultaneously. Also, it highlights government sectors and authorities to implement sustainability value in their decision-making process, applied standards, guidelines, and procedures. On the other side, the education and training on sustainability and sustainable practices should be a continuous exercise to keep the organization updated in the sustainable construction industry and its competitive advantage upgraded to the developed and modern world. Local and international companies should take the lead in promoting and implementing sustainability in their decision-making process and project execution.

8.4 Future Research

This research can be expanded to the larger geographical area by including different continental and enlarging the target audience to calculate a global criteria weight developed in various countries. Therefore, such developed research can be introduced as one of the first portfolio selection standards for clients and developers worldwide. Also, a user-friendly program can be introduced with a decision-making model that incorporates sustainability value into the optimization of the portfolio value model. Likewise, this user-friendly program can turn into a mobile application to be used by managers in order not only to select the projects and programs but to monitor and supervise the projects during execution based on decision-making parameters used at the time of portfolio selection.

References

1. N. Dobrovolskiene and R. Tamosiuniene. "An Index to Measure Sustainability of a Business Project in the Construction Industry: Lithuanian Case." *Sustainable Development Journal*, vol. 8, no. 1, pp. 14 - 19, 2015.
2. R. Gareis, M. Heumann, and A. Martinuzzi. “Relating sustainable development and project management.” *In Proceedings of the IRNOP IX*, 2009, pp. 11–13.
3. M. McKinley. “Where Is Project Management Running to?” *In Proceedings of the 22nd World Congress of the International Project Management*, 2008, pp. 9–11.
4. J.B. Ebbesen, and A.J. Hope. “Re-imagining the Iron Triangle: Embedding Sustainability into Project Constrains.” *PM World Journal*, vol. 3, pp. 1-13, 2013.
5. A.J.G. Silvius, and J. Tharp. “Sustainability Integration for Effective Project Management.” *IGI Global Publishing: Hershey*, PA, USA, 2013.
6. A.J.G. Silvius, and R. Schipper. “Sustainability in the Business Case.” *In Proceedings of the 26th IPMA World Congress*, Crete, Greece, October 2012, pp. 29–3.
7. C. Bohringer, and P. Jochem. “Measuring the immeasurable: A survey of sustainability indices.” *Ecol. Econ*. Vol. 63, pp.1–8, 2007.
8. Y. Chen, G.E. Okudan, and D.R. Riley. “Sustainable performance criteria for construction method selection in concrete buildings.” *Autom. Constr.*, Vol. 19, pp. 235–244, 2010.
9. A. Kemmler, D. Spreng. “Energy indicators for tracking sustainability in developing countries.” Energy Policy, Vol. 35, pp. 2466–2480, 2006.
10. D. Searcy. "Measuring Enterprise Sustainability." *Business Strategy and the Environment*, vol. 25, no. 2, pp. 120-133, 2016.
11. U. Berardi. "Sustainability Assessment in the Construction Sector: Rating Systems and Rated Buildings." *Sustainable Development*, vol. 20, no. 6, pp. 411-424, 2012.
12. A. Son, C. Kim, W. K. Chong, and J.-S. Chou. "Implementing sustainable development in the construction industry: constructors' perspectives in the US and Korea." *Sustainable Development*, vol. 19, no. 5, pp. 337-347, 2011.

13. A. Eweje. "A Shift in corporate practice? Facilitating sustainability strategy in companies." *Corporate Social Responsibility and Environmental Management*, vol. 18, no. 3, pp. 125-136, 2011.
14. P. Simoes and R.C. Marques. “On the economic performance of the waste sector.” A literature reviews. J. Environ. Manag. vol. 106, pp. 40-47, 2012.
15. Z. N. Ansari and R. Kant. "Exploring the Framework Development Status for Sustainability in Supply Chain Management: A Systematic Literature Synthesis and Future Research Directions." *Business Strategy and the Environme*nt, vol. 26, no. 7, pp. 873-892, 2017.
16. M. Bastons and J. Armengou. "Realism and Impartiality: Making Sustainability Effective in Decision-Making." *Science and Engineering Ethics*, vol. 23, no. 4, pp. 969-987, 2017.
17. R.-H. Chen, Y. Lin, and M.-L. Tseng. "Multicriteria analysis of sustainable development indicators in the construction minerals industry in China." Resources Policy, vol. 46, no. Part 1, pp. 123-133, 2015.
18. D. M. Aspen, M. Sparrevik, and A. M. Fet. "Review of methods for sustainability appraisals in ship acquisition." *Environment Systems and Decisions: Formerly the Environmentalist*, vol. 35, no. 3, pp. 323-333, 2015.
19. T. K. Biswas and K. Zaman. "A Fuzzy-Based Risk Assessment Methodology for Construction Projects Under Epistemic Uncertainty." *International Journal of Fuzzy Systems*, vol. 21, no. 4, pp. 1221-1240, 2019.
20. L. Boyle and K. Michell. "A Management Concept for Driving Sustainability in Marginalised Communities in South Africa." *Urban Forum*, vol. 29, no. 2, pp. 185-204, 2018.
21. "The Bruntland report," The Globe and Mail (Index-only), pp. A8-A9, 1987.
22. I. R. Cantalapiedra, M. Bosch, and F. Lopez. “Sustainability in Higher Education: What is involvement of final architecture diploma projects in the analysis of the UPC buildings energy performance as a way of teaching practical sustainability." *Journal of Cleaner Production*, vol. 14, no. 9-11, pp. 958-962, 2006.
23. G. Coombs and B. Dollery, "An Analysis of the Debate on Intergenerational Equity and Fiscal Sustainability in Australia." *Australian Journal of Social Issues*, vol. 37, no. 4, pp. 363-381, 2002.

24. T. M. Cracknell and B. Abu-Hijleh. "Measuring LEED-NC applicability in design for hospitality." *Frontiers of Architectural Research*, vol. 4, no. 4, pp. 308-317, 2015.
25. S. Dabirian, M. Khanzadi, and R. Taheriattar. "Qualitative Modeling of Sustainability Performance in Construction Projects Considering Productivity Approach." *International Journal of Civil Engineering*, vol. 15, no. 8, pp. 1143-1158, 2017.
26. M. Del Baldo and M.-G. Baldarell. "Renewing and improving the business model toward sustainability in theory and practice." *International Journal of Corporate Social Responsibility*, vol. 2, no. 1, pp. 1-13, 2017.
27. B. D. Amico and F. Pomponi. "Sustainability Tool to Optimise Material Quantities of Steel in the Construction Industry." *Procedia CIRP*, vol. 69, pp. 184-188, 2018.
28. M. Gerner. "Assessing and managing sustainability in international perspective: corporate sustainability across cultures - towards a strategic framework implementation approach." *International Journal of Corporate Social Responsibility*, vol. 4, no. 1, pp. 1-34, 2019.
29. C. Harley, L. Metcalf, and J. Irwin. "An Exploratory Study in Community Perspectives of Sustainability Leadership in the Murray Darling Basin." *Journal of Business Ethics*, vol. 124, no. 3, pp. 413-433, 2014.
30. A.-I. Horcea-Milcu et al. "Values in transformational sustainability science: four perspectives for change." *Sustainability Science*, vol. 14, no. 5, pp. 1425-1437, 2019.
31. L. Hsu, V. B. Hutchison, and M. L. Langseth. "Measuring sustainability of seed-funded earth science informatics projects," *Plos one*, vol. 14, no. 10, pp. 87-96, 2019.
32. G. I. Idoro. "Sustainability of Mechanisation in the Nigerian Construction Industry." *Journal of Civil Engineering and Management*, vol. 18, no. 1, pp. 91-105, 2012.
33. N. Zainul Abidin. "Investigating the awareness and application of sustainable construction concept by Malaysian developers." *Habitat Int*, vol. 34, no. 4, pp. 421–426, 2010.

34. R. Karpurapu. "The Geosynthetics for Sustainable Construction of Infrastructure Projects." *Indian Geotechnical* Journal, vol. 47, no. 1, pp. 2-34, 2017.
35. N. R. Khalili, W. Cheng, and A. McWilliams. "A methodological approach for the design of sustainability initiatives: in pursuit of sustainable transition in China." *Sustainability Science*, vol. 12, no. 6, pp. 933-956, 2017.
36. F. T. Edum-Fotwe and A. D. F. Price. "A social ontology for appraising sustainability of construction projects and developments." *International Journal of Project Management*, vol. 27, no. 4, pp. 313-318, 2009.
37. N. Kibwami and A. Tutesigensi. "Enhancing sustainable construction in the building sector in Uganda." *Habitat International*, vol. 57, pp. 64-73, 2016.
38. Kibert and Bosch. "Research Information: Green Building Materials '96." *Building research and information*, vol. 26/3, no. 3, pp. 190-198, 1998.
39. Z. Luo, R. Dubey, T. Papadopoulos, B. Hazen, and D. Roubaud. "Explaining Environmental Sustainability in Supply Chains Using Graph Theory." *Computational Economics*, vol. 52, no. 4, pp. 1257-1275, 2018.
40. S. A. Martin and I. Assenov. "Measuring the Conservation Aptitude of Surf Beaches in Phuket, Thailand: An Application of the Surf Resource Sustainability Index." *International Journal of Tourism Research*, vol. 17, no. 2, pp. 105-117, 2015.
41. O. T. Oladinrin and C. M.-F. Ho. "Enabling Ethical Code Embeddedness in Construction Organizations: A Review of Process Assessment Approach." *Science and Engineering Ethics*, vol. 22, no. 4, pp. 1193-1215, 2016.
42. J.-A. S. Polanco. "Exploring governance for sustainability in contexts of violence: the case of the hydropower industry in Colombia." *Energy, Sustainability and Society*, vol. 8, no. 1, pp. 1-15, 2018.
43. B. Purvis, Y. Mao, and D. Robinson. "Three pillars of sustainability: in search of conceptual origins." *Sustainability Science*, vol. 14, no. 3, pp. 681-695, 2019.
44. N. Raynsford. "The UK's approach to sustainable development in construction." *Building Research & Information*, vol. 27, no. 6, pp. 419-423, 1999.
45. I. Reychav, R. Maskil Leitan, and R. McHaney. "Sociocultural sustainability in green building information modeling." *Clean Technologies and Environmental Policy: Focusing on Technology Research, Innovation, Demonstration, Insights*

and Policy Issues for Sustainable Technologies, vol. 19, no. 9, pp. 2245-2254, 2017.

46. M. G. Rietbergen, I. J. Opstelten, and K. Blok. "Improving energy and carbon management in construction and civil engineering companies—evaluating the impacts of the CO_2 Performance Ladder." *Energy Efficiency*, vol. 10, no. 1, pp. 55-79, 2017.
47. C. Ritz and T. Scheurer. "Sustainability in a Time of Global Change: The Challenge for Research." *Mountain Research and Development*, vol. 21, no. 2, pp. 104-108, 2001.
48. R. Seidl. "A functional-dynamic reflection on participatory processes in modeling projects." *Ambio: A Journal of the Human Environment*, vol. 44, no. 8, pp. 750-765, 2015.
49. C. J. Shultz and M. Peterson. "A Macromarketing View of Sustainable Development in Vietnam." *Environmental Management*, vol. 63, no. 4, pp. 507-519, 2019.
50. R.C. Hilland P. Bowen "Sustainable construction: Principles and a framework for attainment." *Constr. Manag. Econ.*, vol. 15, pp. 223–239, 1997.
51. R. Y. J. Siew. "Integrating sustainability into construction project portfolio management." *KSCE Journal of Civil Engineering*, vol. 20, no. 1, pp. 101-108, 2016.
52. K. I. Vatalis, O. G. Manoliadis, and D. G. Mavridis. "Project Performance Indicators as an Innovative Tool for Identifying Sustainability Perspectives in Green Public Procurement." *Procedia Economics and Finance,* vol. 1, pp. 401-410, 2012.
53. O. Taylan, A. O. Bafail, R. M. S. Abdulaal, and M. R. Kabli. "Construction projects selection and risk assessment by fuzzy AHP and fuzzy TOPSIS methodologies." *Applied Soft Computing Journal*, vol. 17, pp. 105-116, 2014.
54. M. Munasinghe. *Environmental Economics and Sustainable Development*. World Bank Publications: Washington, DC, USA, 1993.
55. I.C Chang. *Application of Factor Analysis in Establishing the National Sustainable Development Evaluation Indicator System for Taiwan. Ph.D. Thesis,*

Graduate Institute of Environmental Engineering, National Taiwan University, Taiwan, 2000.

56. D. Yu and J. Yang. "Knowledge Management Research in the Construction Industry: a Review." *Journal of the Knowledge Economy*, vol. 9, no. 3, pp. 782-803, 2018.
57. M. Yu, C. Wang, Y. Liu, G. Olsson, and C. Wang. "Sustainability of mega water diversion projects: Experience and lessons from China." *Science of the Total Environment*, vol. 619-620, pp. 721-731, 2018.
58. T. Yu et al. "Evaluating different stakeholder impacts on the occurrence of quality defects in offsite construction projects: A Bayesian-network-based model." *Journal of Cleaner Production*, vol. 241, pp. 102-115, 2019.
59. N. Zhang, X. Deng, X. Zhao, and T. Chang. "Exploring the Sources of Contractors' Competitive Advantage on International HSR Construction Projects." *International Journal of Civil Engineering*, vol. 17, no. 7, pp. 1115-1129, 2019.
60. K.A. Tutu, and Y.A. Tuffour. "Warm-Mix Asphalt and Pavement Sustainability: A Review." *Sci. Res.,* vol. 6, pp. 84-93, 2016.
61. C. Labuschagne and A.C. Brent. "Sustainable Project Life Cycle Management: Aligning project management methodologies with the principles of sustainable development." *In Proceedings of the 2004 PMSA International Conference, Johannesburg, South Africa*, vol. 10–12, pp. 104–115, May 2004.
62. G. Heravi, M. Fathi, and S. Faegh. "Evaluation of sustainability indicators of industrial buildings focused on petrochemical projects." *Journal of Cleaner Production*, vol. 109, pp. 92-107, 2015.
63. F. Szekely and M. Knirsch. "Responsible Leadership and Corporate Social Responsibility: Metrics for Sustainable Performance." *European Management Journal*, vol. 23, no. 6, pp. 628-647, 2005.
64. A. Karji, A. Woldesenbet, M. Khanzadi, and M. Tafazzoli. "Assessment of Social Sustainability Indicators in Mass Housing Construction: A Case Study of Mehr Housing Project." *Sustainable Cities and Society*, vol. 50, pp. 54-65, 2019.

65. A. Azapagic and S. Perdan S. “Indicators of sustainable development for industry: A general framework.” *Trans IChemE (Proc Safety Envir Prot) Part B*, vol. 78, no. B4, pp. 243-61, 2000.
66. A. A. King and M. J. Lenox. "Does It Really Pay to Be Green? An Empirical Study of Firm Environmental and Financial Performance: An Empirical Study of Firm Environmental and Financial Performance." *Journal of Industrial Ecology*, vol. 5, no. 1, pp. 105-116, 2001.
67. H. Mata-Lima. "Measuring an Organization's Performance: The Road to Defining Sustainability Indicators." *Environmental Quality Management*, vol. 26, no. 2, pp. 89-104, 2016.
68. M. J. Epstein, J. Elkington, and H. B. Leonard. "Making sustainability work: best practices in managing and measuring corporate social, environmental and economic impacts," Choice Reviews Online, vol. 46, no. 02, pp. 46-0995, 2008, doi: 10.5860/CHOICE.46-0995.
69. T. Myllyviita, K. Lähtinen, T. Hujala, L. A. Leskinen, L. Sikanen, and P. Leskinen. "Identifying and rating cultural sustainability indicators: a case study of wood-based bioenergy systems in eastern Finland." *Environment, Development and Sustainability: A Multidisciplinary Approach to the Theory and Practice of Sustainable Development*, vol. 16, no. 2, pp. 287-304, 2014.
70. M. Pan, T. Linner, W. Pan, H. Cheng, and T. Bock. "A framework of indicators for assessing construction automation and robotics in the sustainability context." *Journal of Cleaner Production*, vol. 182, pp. 82-95, 2018.
71. A. Razmjoo, A. Sumper, M. Marzband, A. Davarpanah, A. Shahhoseini, and S. Sarlak. "Energy sustainability analyses using feasible indicators for urban areas." *International Journal of Energy and Water Resources*, vol. 3, no. 2, pp. 127-140, 2019.
72. F. Rodrilguez Lopez and G. Fernandez Sanchez. "Challenges for sustainability assessment by indicators." *Leadership and Management in Engineering*, vol. 11, no. 4, pp. 321-325, 2011.
73. L. Shen, Y. Wu, and X. Zhang. "Key assessment indicators for the sustainability of infrastructure projects." *Journal of Construction Engineering and Management*, vol. 137, no. 6, pp. 441-451, 2011.

74. L. Shen, Y. Wu, and X. Zhang. "Erratum for 'Key Assessment Indicators for the Sustainability of Infrastructure Projects' by Liyin Shen, Yuzhe Wu, and Xiaoling Zhang." *Journal of Construction Engineering & Management*, vol. 139, no. 5, pp. 412-423, 2013.
75. S. Perdan and A. Azapagic. “Sustainable development and industry: Ethical indicators.” *Environ Prot Bulletin, IChemE, Rugby*, Issue 066, May 2000.
76. Azapagic A. *Life cycle assessment: A tool for identification of more sustainable products and processes*. *In: Clark J, Macquarrie D, editors. Handbook of Green Chemistry and Technology*. Oxford: Blackwell Science; 2002. pp. 62–85.
77. BREEAM (Building Research Establishment Environmental Assessment Method), URL: http://products.bre.co.uk/breeam/index.html, 2008.
78. CERT. HK-BEAM (New Offices)—*An environmental assessment for new office designs*, Version 1/96R, ISBN: 962-85076-2-1, Centre of Environmental Technology, Limited (CERT), Hong Kong, 1999.
79. JP Brins and P. Vinke. “A preference ranking organization method.” *Management Science*, vol 31, pp. 647-469, 2002.
80. RM Fisher. “Applying ISO 14001 as a business tool for campus sustainability: a case study from New Zealand.” *International Journal of Sustainability in Higher Education*, Vol. 4, no. 2, pp. 138-150, 2003.
81. P. Ryan “Sustainability partnerships: eco-stragtegy theory in practice” *Management of Environmental Quality: An International Journal*, vol 14, no. 2, pp. 256-265, 2003.
82. J. Hokkanen, R. Lahdelma, and P. Salminen. “Multicriteria decision support in a technology competition for cleaning polluted soil in Helsinki.” *Journal of Environmental Management*, vol. 60, no. 4, pp. 339-485, 2000.
83. P. Yi, Q. Dong, and W. Li. "Evaluation of city sustainability using the deviation maximization method." *Sustainable Cities and Society*, vol. 50, pp. 164-178, 2019.
84. S. Smetana, C. Tamásy, A. Mathys, and V. Heinz. "Measuring Relative Sustainability of Regions Using Regional Sustainability Assessment Methodology." *Geographical Analysis*, vol. 48, no. 4, pp. 391-410, 2016.

85. H.-J. Shau, T.-Y. Liu, P.-H. Chen, and N. N. S. Chou. "Sustainability Practices for the Suhua Highway Improvement Project in Taiwan." *International Journal of Civil Engineering*, vol. 17, no. 10, pp. 1631-1641, 2019.
86. O. O. Ugwu and T. C. Haupt. "Key performance indicators and assessment methods for infrastructure sustainability—a South African construction industry perspective." *Building and Environment*, vol. 42, no. 2, pp. 665-680, 2007.
87. C.Y. Tsai and A.S. Chang. “Framework for developing construction sustainability items: the example of highway design.” *J Clean Prod*, vol 20, pp. 127–136, 2012.
88. World Bank. *World development rep. 1994: infrastructure for development.* Oxford University Press, Oxford: pp 1–12, 1994.
89. L. Shen, M. Asce, Y. Wu, X. Zhang. “Key assessment indicators for the sustainability of infrastructure projects.” *J Constr Eng Manage ASCE*, vol. 137, no. 6, pp. 441–451, 2011.
90. D.M. Buede and D.T. Maxwell. “Rank disagreement: a comparison of multi-criteria methodologies.” *J Multi Criteria Decis Anal*, vol. 4, no. 1, pp. 1–21, 1995.
91. Y. Zhong, F.Y.Y. Ling and P. Wu. “Using multiple attribute value technique for the selection of structural frame material to achieve sustainability and constructability.” *J Constr Eng Manage ASCE*, vol. 143, no. 2, pp. 320-345, 2016.
92. F.S Mendler and W. Odell. “The HOK guidebook to sustainable design.” *Wiley, New York*, 2000.
93. J. Lee, T.B. Edil, Benson Dist MASCE, Tinjum CH, FASCE JM, M. ASCE. “Building environmentally and economically sustainable transportation infrastructure: green highway rating system.” *J Multi Criteria Decis Anal*, vol. 139, no. 12, pp. 45-52, 2013.
94. L. Shen, Y. Wu, and X. Zhang. "Erratum: Key assessment indicators for the sustainability of infrastructure projects by Liyin Shen, Yuzhe Wu, and Xiaoling Zhang." *Journal of Construction Engineering and Management*, vol. 139, no. 5, pp.56-68, 2013.
95. R.E. Steur, Y. Qi, M. Hirschberger. “Portfolio Selection in the Presence of Multiple Criteria.” *Handbook of Financial Engineering*; Springer: New York, NY, USA, pp. 3–24, 2008.

96. B.T. Peylo and S. Schaltegger. “An equation with many variables: Unhiding the relationship between sustainability and investment performance.” *J. Sustain. Financ. Investig.*, vol. 4, pp. 110-126, 2014.
97. B.T. Peylo. “A Synthesis of Modern Portfolio Theory and Sustainable Investment.” *J. Investig.*, vol. 21, pp. 33-46, 2012.
98. C. L. Choguill. "Developing sustainable neighbourhoods." *Habitat International*, vol. 32, no. 1, pp. 41-48, 2008.
99. R. Rackwitz, A. Lentz, and M. Faber, "Socio-economically sustainable civil engineering infrastructures by optimization," *Structural Safety*, vol. 27, no. 3, pp. 187-229, 2005.
100. A. Colorni, E. Laniado, and S. Muratori. "Decision support systems for environmental impact assessment of transport infrastructures 1 This work is partially supported by PFT2-CNR the Special Project on Transportation, founded by National Research Council. 1." *Transportation Research Part D*, vol. 4, no. 1, pp. 1-11, 1999.
101. A. Azapagic. "Developing a framework for sustainable development indicators for the mining and minerals industry." *Journal of Cleaner Production*, vol. 12, no. 6, pp. 639-662, 2004.
102. W. Rickels, J. Dovern, J. Hoffmann, M. F. Quaas, J. r. O. Schmidt, and M. Visbeck. "Indicators for monitoring sustainable development goals: An application to oceanic development in the European Union." *Earth's Future*, vol. 4, no. 5, pp. 252-267, 2016.
103. W.D. Yu, S.T. Cheng, W.C. Ho, and Y.H. Chang. "Measuring the Sustainability of Construction Projects throughout Their Lifecycle: A Taiwan Lesson." *Sustainability*, vol. 10, no. 5, pp. 1523, 2018.
104. GRI. *Sustainability reporting guidelines on economic, environmental, and social performance*. Global reporting initiative, June 2000. www.globalreporting.org (30 Oct 2002).
105. GRI. *Companies using GRI reporting guidelines. Global reporting initiative*. http://www.globalreporting.org (30 Oct 2002).

106. ILO 87. *Freedom of association and protection of the right to organize. International Labour Organization.* Geneva, August 1948. http://www.unhchr.ch/html/ menu3/b/j—ilo87.htm (7 Nov 2002).
107. WCED. *Our common future. The report of the World Commission on Environment and Development*. Oxford: Oxford University Press, 1987.
108. Vaughan. *The greening of financial markets*. Geneva: UNEP, 1995.
109. W.T. Hsu. *Establishment of National Level Sustainability Indicator System for Construction Industry.* Ph.D. Thesis, Department of Civil Engineering, National Central University, Taiwan, 2011.
110. L. Huang, J. Wu, and L. Yan. "Defining and measuring urban sustainability: a review of indicators." *Landscape Ecology,* vol. 30, no. 7, pp. 1175-1193, 2015.
111. K.F.Huang, R. Dyerson, L.Y. Wu, G. Harindranath. "From temporary competitive advantage to sustainable competitive advantage." *Br J Manag*., vol. 26, no. 4, pp. 617–636, 2015.
112. S.A. Zahra, H.J. Sapienza and P. Davidsson. "Entrepreneurship and dynamic capabilities: a review, model and research agenda." *J Manag Stud*, vol. 43, no. 4, pp. 917–955, 2006.
113. C.J. Katsanis CJ. "System dynamics modeling for a decision support system for assessing construction productivity." *In: 5th construction specialty conference of the Canadian Society for Civil Engineering*, Moncton, Nouveau-Brunswick, Canada, 2003.
114. W. Jeronimo Silvestre, P. Antunes and W. Leal Filho. "The corporate sustainability typology: analyzing sustainability drivers and fostering sustainability at enterprises." *Tech Econ Develop Econ,* vol. 24, no. 2, pp. 1–21, 2016.
115. N. Ross, Bowen Paul Anthony, and D. Lincoln. "Sustainable housing for low-income communities: lessons for South Africa in local and other developing world cases." *Constr Manag Econ,* vol. 28, no. 5, pp. 433–449, 2010.
116. I. Montiel and J. Delgado-Ceballos (2014). "Defining and measuring corporate sustainability: are we there yet?" *Org Envi*, vol. 27, no. 2, pp. 113–139, 2014.

117. L. Bourdeau. “Sustainable development and the future of construction: a comparison of visions from various countries.” *Build Res Inf,* vol. 27, no. 6, pp. 354–366, 1999.
118. N.J. and T. Knudsen. “The resource-based tangle: towards a sustainable explanation of competitive advantage.” *Manag Decis Econ,* vol. 24, no. 4, pp. 291–307, 2003.
119. Y. Tan, L. Shen and Y. Hong. “Sustainable construction practice and contractors.’ competitiveness: a preliminary study.” *Habitat Int,* vol 35, pp. 225–230, 2011.
120. R.Y. Huang and W.T. Hsu. “Framework development for state level appraisal indicators of sustainable construction.” *Civil Eng Environ Syst, vol.* 28, no. 2, pp. 143–164, 2011.
121. X. Gan et al. "When to use what: Methods for weighting and aggregating sustainability indicators." *Ecological Indicators*, vol. 81, pp. 491-502, 2017.
122. M. Nardo, M. Saisana, A. Saltelli, S. Tarantola, A. Hoffman, and E. Giovannini. “Handbook on Constructing Composite Indicators: Methodology and User Guide.” Organization for Economic Co-operation and Development (OECD) Publishing: Paris, France, 2008.
123. H. Al-Kilidar, S. Davis, C. Kutay and C. Killen. “Towards Project Portfolio Management for Sustainable Outcomes in the Construction Industry.” *In Proceedings of the 8th Project Management Australia Conference*, Sydney, Australia, 2–5 August 2011.
124. M. Braulio-Gonzalo, M. D. Bovea, and M. J. Rua. "Sustainability on the urban scale: Proposal of a structure of indicators for the Spanish context." *Environmental Impact Assessment Review,* vol. 53, pp. 16-30, 2015.
125. Ha¨kkinen T. “Assessment of indicators for sustainable urban construction.” *Civil Eng Environ Syst*, vol. 24, no. 4, pp. 247–259, 2007.
126. O.S. Moses and O.C. Ekwutosi OC. “Implication of strategic fit and sustainability on organizational effectiveness.” The international academic research conference in Vienna, pp. 194–213, 2018.
127. M. Linnenluecke and A. Griffiths. “Corporate sustainability and organizational culture.” *J of World Busi*, vol. 45, pp. 357–366, 2010.

128. Y. Miyatake. “Technology development and sustainable construction.” *J Manag Eng*, vol. 12, no. 4, pp. 23–27, 1996.
129. J.B. Barney . “Firm resources and sustained competitive advantage.” *J Manag,* vol. 17, pp. 99–120, 1991.
130. R. Yunus, J. Yang , E. Too. “Sustainability factors in industrialized building system.” In: World sustainable building conference (SB11), Helsinki, Finland, 2011.
131. G. Egilmez and O. Tatari. “A dynamic modeling approach to highway sustainability: strategies to reduce overall impact.” *Transp Res Part A*, vol. 46, pp. 1086–1096, 2012.
132. Public Construction Council, Ecological Construction Project Cases. “Sustainable Public Construction Portal.” Available online: http://eem.pcc.gov.tw/node (accessed on 15 January 2016).
133. R. Baumgartner. “Managing corporate sustainability and CSR: a conceptual framework combining values, strategies and instruments contributing to sustainable development.” *Corp Soci Resp and Envir Mang*, vol. 21, pp. 258–271, 2014.
134. Y. Ho and S. Wang. “System dynamics model for the sustainable development of science city.” In: The 23rd international conference on the system dynamics society, Boston, USA, System Dynamics Society, Albany, New York, United States of America, 2005.
135. B. Farbey, F. Land, and D. Targett. “How to Evaluate Your IT Investment: A Study of Methods and Practice.” Butterworth-Heinemann, Oxford, UK, 1993.
136. G. Bradley. “Benefit Realization Management: A Practical Guide for Achieving Benefits Through Change.” Gower, Aldershot, UK, 2010.
137. C. Ashurst, N. Doherty, and J. Peppard. “Improving the impact of IT development projects: the benefits realization capability model.” *Eur. J. Inf. Syst.* Vol.17, pp. 352–370, 2008.
138. M. Hasnain, M. J. Thaheem, and F. Ullah. "Best Value Contractor Selection in Road Construction Projects: ANP-Based Decision Support System." *International Journal of Civil Engineering*, vol. 16, no. 6, pp. 695-714, 2018.

139. Y.-Y. Chih and O. Zwikael. "Project benefit management: A conceptual framework of target benefit formulation." *International Journal of Project Management*, vol. 33, no. 2, pp. 352-359, 2015.
140. O. Zwikael, Y.-Y. Chih, and J. R. Meredith. "Project benefit management: Setting effective target benefits." *International Journal of Project Management*, vol. 36, no. 4, pp. 650-658, 2018.
141. 340. G. Fernandez-Sanchez and F. Rodriguez-Lopez. “A methodology to identify sustainability indicators in construction project management—Application to infrastructure projects in Spain.” Ecol. Indic, vol. 10, pp. 1193-1201, 2010.
142. R.C. Marques, N. Ferreira da Cruz, P. Simões, S.F. Ferreira, M.C. Pereira, and S. De Jaeger. “Economic viability of packaging waste recycling systems: A comparison between Belgium and Portugal, Resources, Conservation and Recycling.” *Resour. Conserv. Recycl.*, vol. 85, pp. 22-33, 2014.
143. A. Anonymous. "Benefits Realization Management: A Practice Guide." PM Network, vol. 33, no. 3, pp. 71-76, 2019.
144. M. Carcary, E. Doherty, G. Conway, and S. McLaughlin. "Cloud Computing Adoption Readiness and Benefit Realization in Irish SMEs-An Exploratory Study." Information Systems Management, vol. 31, no. 4, pp. 313-327, 2014.
145. D. H. h. Dupont and P. Eskerod. "Enhancing project benefit realization through integration of line managers as project benefit managers." *International Journal of Project Management*, vol. 34, no. 4, pp. 779-785, 2016.
146. C. T. T. Edwards and E. v. E. Plaganyi. "Protecting old fish through spatial management: is there a benefit for sustainable exploitation?" *Journal of Applied Ecology*, vol. 48, no. 4, pp. 853-863, 2011.
147. P. E. D. Love, J. Matthews, I. Simpson, A. Hill, and O. A. Olatunji. "A benefits realization management building information modeling framework for asset owners." *Automation in Construction*, vol. 37, pp. 1-10, 2014.
148. C. Marian, D. Eileen, C. Gerard, and M. Stephen. "Cloud Computing Adoption Readiness and Benefit Realization in Irish SME, An Exploratory Study." *Information Systems Management*, vol. 31, no. 4, pp. 313-327, 2014.

149. M. Lange, J. Mendling and J. Recker, "A Comprehensive EA Benefit Realization Model-An Exploratory Study," 2012 45th Hawaii International Conference on System Sciences, Maui, HI, USA, 2012, pp. 4230-4239.

150. J. Thorp. “The Information Paradox — Realizing the Business Benefits of Information Technology.” McGraw-Hill, Toronto, Canada, 1998.

151. D. Remenyi, M. Sherwood-Smith. “Business benefits from information systems through an active realization programme.” *Int. J. Proj. Manag.*, vol. 16, pp. 81–98, 1998.

152. J. McKay, P. Marshall. “The IT evaluation and benefits management cycle, in: W.V. Grembergen (Ed.), Information Technology Evaluation Methods and Management.” Idea Group Publishing, London, UK, 2001.

153. C. Ashurst and N.F. Doherty. “Towards the formulation of a ‘best practice’ framework for benefits realization in IT projects.” *Electron. J. Inf. Sys. Eval.*, vol. 6, pp. 1–10, 2003.

154. G. Reiss, M. Anthony, J. Chapman, G. Leigh, A. Pyne, P. Rayner. *Gower Handbook of Programme Management*. Gower Publishing, UK, 2006.

155. C. Lin and G. Pervan. “the practice of IS/IT benefits management in large Australian organizations.” *Inf. Manag.*, vol. 41, pp. 13–24, 2003.

156. D. Remenyi, A. Money, Sherwood-Smith, and Z. Irani. “The effective measurement and management of IT costs and benefits, Computer Weekly Professional Series.” Butterworth-Heinemann, Oxford, UK, 2000.

157. J. Peppard, J. Ward and E. Daniel. “Managing the realization of business benefits from IT investments.” *MIS Q. Exec.*, vol. 6, no. 1, pp. 1–11, 2007.

158. B. Wernerfelt. “A resource-based view of the firm.” *Strateg. Manag*. 5, pp. 171–180, 1984.

159. R. Amit and P.J.H. Shoemaker. “Strategic assets and organizational rent.” *Strateg. Manag.*, vol. 14, pp. 33–46, 1993.

160. J.F. Barney. “Firm resources and sustained competitive advantage.” *J. Manag.*, vol. 1, pp. 99–120, 1991.

161. C. Bowman and V. Ambrosini. “Value creation versus value capture: towards a coheren definition of value in strategy.” *Br. J. Manag.*, vol. 11, pp. 1–15, 2000.

162. J.Ward, J. Peppard. Strategic Planning for Information Systems. John Wiley and Sons Chichester, UK, 2002.
163. C.E. Helfat and M.A. Peteraf. “The dynamic resource-based view: capability lifecycles.” *Strateg. Manag.*, vol. 24, no. 10, pp. 997–1010, 2003.
164. W. Wenger, R. McDermott, and W.M. Synder. “Cultivating Communities of Practice.” Harvard Business School Press, Boston, 2002.
165. S. Newell, C. Tansley, and J. Huang. “Social capital and knowledge integration in an ERP project team: the importance of bridging and bonding.” *Br. J. Manag.*, vol. 15, no. S1, pp. 43–57, 2004.
166. F. Booty. *Facilities Management Handbook*. 4th ed. Elsevier/Butterworth-Heinemann, Oxford, 2009.
167. C. Lin and G. Pervan. “The practice of IS/IT benefits management in large Australian organizations.” *Inf. Manag.*, vol. 41, pp. 13–24, 2003.
168. A. D. Azar, C. Militaru, and C. P. Mattar. "Time, Cost and Quality Management Trilogy and its Impact on Lebanese Construction Projects Success." *Applied Mechanics and Materials*, vol. 834, pp. 217-222, 2016.
169. C. Black, A. Akintoye, and E. Fitzgerald. "An analysis of success factors and benefits of partnering in construction." *International Journal of Project Management*, vol. 18, no. 6, pp. 423-434, 2000.
170. D. W. M. Chan, A. P. C. Chan, P. T. I. Lam, and J. M. W. Wong. "An empirical survey of the motives and benefits of adopting guaranteed maximum price and target cost contracts in construction." *International Journal of Project Management*, vol. 29, no. 5, pp. 577-587, 2011.
171. T. Ganbat, H.-Y. Chong, P.-C. Liao, and C.-Y. Lee. "A Cross-Systematic Review of Addressing Risks in Building Information Modelling-Enabled International Construction Projects." *Archives of Computational Methods in Engineering: State of the Art Reviews*, vol. 26, no. 4, pp. 899-931, 2019.
172. R. Holt. "Creating whole life value proxemics in construction projects." *Business Strategy and the Environment*, vol. 10, no. 3, pp. 148-154, 2001.
173. E. S. Keen. "Future Directions in the Engineering and Construction Industry." *Cost Engineering*, vol. 33, no. 5, pp. 17-25, 1991.

174. R. Kuenzel, J. Teizer, M. Mueller, and A. Blickle. "SmartSite: Intelligent and autonomous environments, machinery, and processes to realize smart road construction projects." *Automation in Construction*, vol. 71, pp. 21-33, 2016.
175. K. N. Ninan and S. Lakshmikanthamma. "Social Cost-benefit Analysis of a Watershed Development Project in Karnataka, India." *AMBIO: A Journal of the Human Environment*, vol. 30, no. 3, pp. 157-161, 2001.
176. T. O. Olawumi and D. W. M. Chan. "Identifying and prioritizing the benefits of integrating BIM and sustainability practices in construction projects: A Delphi survey of international experts." *Sustainable Cities and Society*, vol. 40, pp. 16-27, 2018.
177. D. Rinard. "Greening construction: Making strides in industrial architecture and process." *Pollution Engineering*, vol. 35, no. 10, pp. 20-26, 2003.
178. N. Zhang, X. Deng, X. Zhao, and T. Chang. "Exploring the Sources of Contractors' Competitive Advantage on International HSR Construction Projects." *International Journal of Civil Engineering*, vol. 17, no. 7, pp. 1115-1129, 2019.
179. C. L. Pasquire. "Revolutionize value management: A mode towards sustainability." *International Journal of Project Management*, vol. 25, no. 3, pp. 275-279, 2007.
180. Hayles C. "The role of value management in the construction of sustainable communities." The Value Manager, vol. 10, no. 1, pp.78-86, 2004.
181. J. Batselier and M. Vanhoucke. "Improving project forecast accuracy by integrating earned value management with exponential smoothing and reference class forecasting." *International Journal of Project Management*, vol. 35, no. 1, pp. 28-43, 2017.
182. J. Colin and M. Vanhoucke. "A comparison of the performance of various project control methods using earned value management systems." *Expert Systems With Applications*, vol. 42, no. 6, pp. 3159-3175, 2015.
183. S. Fan and Q. Shen. "The effect of using group decision support systems in value management studies: An experimental study in Hong Kong." *International Journal of Project Management*, vol. 29, no. 1, pp. 13-18, 2011.

184. A. D. Farashah, J. Thomas, and T. Blomquist. "Exploring the value of project management certification in selection and recruiting." *International Journal of Project Management*, vol. 37, no. 1, pp. 14-26, 2019.

185. X. Luo, G. Q. Shen, S. Fan, and X. Xue. "A group decision support system for implementing value management methodology in construction briefing." *International Journal of Project Management*, vol. 29, no. 8, pp. 1003-1010, 2011.

186. M.-Y. Leung and A. M. M. Liu. "Analysis of value and project goal specificity in value management." *Construction Management & Economics*, vol. 21, no. 1, pp. 11-19, 2003.

187. T. Gillier, S. Hooge, and G. r. Piat. "Framing value management for creative projects: An expansive perspective." *International Journal of Project Management*, vol. 33, no. 4, pp. 947-955, 2015.

188. L. G. l. Jimenez and L. B. Pascual. "Multicriteria cash-flow modeling and project value-multiples for two-stage project valuation." *International Journal of Project Management*, vol. 26, no. 2, pp. 185-192, 2008.

189. D. H. Dupont and P. Eskerod. "Enhancing project benefit realization through integration of line managers as project benefit managers." *International Journal of Project Management*, vol. 34, no. 4, pp.103-112, 2016.

190. S. Male, J. Kelly, S. Fernie, M. Gronquist, G. Bowles. "The value management benchmark: a good practice framework for clients and practitioners." London: Thomas Telford, 1998.

191. S. Darshana, R. Michael, and G. Guy. "Using performance measurement models for benefit realization with enterprise systems - the Queensland government approach (Case Study)." *In Proceedings of the 9th European Conference on Information Systems (ECIS'2001)*. University of Maribar, Kranj, Slovenia, 2001, pp. 837-847.

192. D. Danesh, M. Ryan, and A. Abbasi. "Multi-criteria Decision-making Methods for Project Portfolio Management: A Literature Review." *International Journal of Management and Decision Making*. vol. 16, no. 1, pp. 34-45, 2017.

193. N. Zainul Abidin and CL. Pasquire. “Delivering sustainability through value management: the concept and performance overview.” *Eng Constr Archit Manage*, vol. 12, no. 2, pp. 168–80, 2005.
194. B. Addis, R. Talbot. “Sustainable construction procurement: a guide to delivering environmentally responsible projects.” Construction Industry Research and Information Association (CIRIA) C571, London: CIRIA, 2001.
195. N. Zainul Abidin and CL. Pasquire. “Moving towards sustainability through value management.” *In: Proceedings of the joint international symposium of CIB working commissions W55, W65 and W107*, Singapore, vol. 2, October 2003. pp. 258–68.
196. J. Batselier and M. Vanhouck. “Practical Application and Empirical Evaluation of Reference Class Forecasting for Project Management.” *Project Management Journal*, vol. 47, no., pp. 36–51, 2016.
197. M. Thiry. “Strategic value management.” PMI Global Congress, EMEA, Dubai, United Arab Emirates. Newtown Square, PA: Project Management Institute, 2014.
198. O. Oluwabukunm, A. Clinton, and T. Wellington. “Application of Value Management Methodologies to Project Selection in Nigerian Construction Industry.” *Conference On Infrastructure Development and Investment Strategies*, Africa, Zambia, 2015.
199. M. Schneider. “Value management and sustainability: an opportunity to revolutionize the construction industry.” *Managing Sustainable Values. In: Proceedings of the international conference of the Institute of Value Management*, 6–7 May, Hong Kong, 1999.
200. “The added value of the project selection process.” The Free Library,. Retrieved Apr 10 2021, from: https://www.thefreelibrary.com/The+added+value+of+the+project+selection+process.-a0466290296
201. J. Kelly, K. Hunter, S. Male. “The client’s value system explored: case studies from the UK public sector.” *In: Proceedings of the joint international symposium of CIB working commissions W55, W65 and W107*, Singapore, vol. 1, 2003. pp. 423–433.

202. T. Gillier, S. Hooge, and G. r. Piat. "Framing value management for creative projects: An expansive perspective." *International Journal of Project Management*, vol. 33, no. 4, pp. 947-952, 2015.

203. L. G. l. Jimenez and L. B. Pascual. "Multicriteria cash-flow modeling and project value-multiples for two-stage project valuation." *International Journal of Project Management*, vol. 26, no. 2, pp. 185-194, 2008.

204. MY Leung, AMM Liu. "Developing a value management model – by value-goal system approach." *In: Proceeding of the 14th annual conference of the association of researchers in construction management (ARCOM), Reading*, 1998. pp. 496–505.

205. M. Dallas. "Revolutionizing the way, we build, Managing sustainable values." *In: Proceedings of the international conference of the Institute of Value Management*, 6–7 May, Hong Kong, 1999.

206. SW Fong. "Value management – going all out for knowledge creation." *The Value Manager* 2003. http://www.hkivm.com.hk/publications/ 03/TVM2003-1.pdf.

207. N. Zainul Abidin. "Using value management to improve the consideration of sustainability within construction." *PhD thesis*, United Kingdom: Loughborough University, 2005.

208. H. R. Abbasianjahromi and H. Rajaie. "Application of fuzzy CBR and MODM approaches in the project portfolio selection in construction companies." *Iranian Journal of Science and Technology, Transactions of Civil Engineering*, vol. 37, no. C1, pp. 143-155, 2013.

209. N. Prascevic and Z. Prascevic. "Application of fuzzy AHP for ranking and selection of alternatives in construction project management." *Journal of Civil Engineering and Management*, vol. 23, no. 8, pp. 1123-1135, 2017.

210. P.X.W. Zou, G. Zhang, and J. Wang. "Understanding the key risks in construction projects in China." *Int. J. Proj. Manage.*, vol. 25, pp. 601–614, 2007.

211. B. Vahdani, S. M. Mousavi, H. Hashemi, M. Mousakhani, and S. Ebrahimnejad. "A New Hybrid Model Based on Least Squares Support Vector Machine for Project Selection Problem in Construction Industry." *Arabian Journal for Science and Engineering*, vol. 39, no. 5, pp. 4301-4314, 2014.

212. S. Ebrahimnejad, S. M. Mousavi, R. Tavakkoli-Moghaddam, H. Hashemi, and B. Vahdani. "A novel two-phase group decision making approach for construction project selection in a fuzzy environment." *Applied Mathematical Modelling*, vol. 36, no. 9, pp. 4197-4217, 2012.

213. R. P. Mohanty. "Project selection by a multiple-criteria decision-making method: An example from a developing country." *International Journal of Project Management*, vol. 10, no. 1, pp. 31-45, 1992.

214. E.W.L. Cheng and H. Li. "Analytic network process applied to project selection." *J. Constr. Eng. Manage*., vol. 131, pp. 459–466, 2005.

215. N.J. Smith. "Managing Risk in Construction Projects." Blackwell, Oxford, 1999.

216. M. Ravanshadnia, H. Rajaie, and H. R. Abbasian. "Hybrid fuzzy MADM project-selection model for diversified construction companies." *Canadian Journal of Civil Engineering*, vol. 37, no. 8, pp. 1082-1090, 2010.

217. Y.T. Tan, L.Y. Shen, C. Langston, and Y. Liu. "Construction project selection using fuzzy TOPSIS approach." *J. Model. Manage*. vol. 5, no. 3, pp. 302–315, 2010.

218. M. Shokri-Ghasabeh, N. Chileshe, and G. Zillante, "From construction project success to integrated construction project selection." *in: Construction Research*

219. J. Wang, Y. Xu, and Z. Li. "Research on project selection system of pre-evaluation of engineering design project bidding." *International Journal of Project Management*, vol. 27, no. 6, pp. 584-594, 2009.

220. MA Badri and D. Davis. "A comprehensive 0‑1 goal programming model for project selection." *Int J Project Manage*, vol. 19, pp. 243‑52, 2001.

221. DC. Okpala. "Evaluation and selection of construction projects in Nigeria." *Constr Manage Econ*, vol. 9, pp.51‑61, 1991.

222. O. Moselhi O and B. Deb. "Project selection considering risk." *Constr. Manage. Econ*, vol. 11, pp. 45‑52, 1993.

223. D. Chua and D. Li. "Key factors in bid reasoning model." *J Constr Eng Manage*, vol. 126, no. 5, pp. 349‑57, 2000.

224. D. Chua, D. Li, and W. Chan. "Case-based reasoning approach in bid decision making." *J Constr Eng Manage*, vol. 127, no.1, pp. 35‑45, 2000.

225. E. Wong, G. Norman, and R. Flanagan. “A fuzzy stochastic technique for project selection.” *Constr Manage Econ*, vol. 18, pp. 407‑14, 2000.

226. A. Fayek. “Competitive bidding strategy model and software system for bid preparation.” *J Constr Eng Manage*, vol. 124, no. l, pp. 148‑52, 1998.

227. J. Moon and C. Kang. “Use of fuzzy set theory in the aggregation of expert judgments.” *Ann Nucl Energy*, vol. 26, no. 6, pp. 461‑9, 1999.

228. L. Machacha and P. Bhattacharya. “A fuzzy-logic-based approach to project selection.” *IEEE Trans Eng Manage*, vol. 47, no.1, pp. 65‑73, 2000.

229. WF Cascio. “Managing human resource.” New York: McGraw-Hill; 1995.

230. K. Molenaar and A. Songer. “Model for public sector design-build project selection.” *J Constr Eng Manage*, vol. 124, no. 6, pp. 467‑79, 1998.

231. L. Meade and A. Presley. “R&D project selection using the analytic network process.” *IEEE Trans Eng Manage*, vol. 49, no.1, pp. 59‑66, 2002.

232. Y. Chen, G. E. Okudan, and D. R. Riley. "Sustainable performance criteria for construction method selection in concrete buildings." *Automation in Construction*, vol. 19, no. 2, pp. 235-244, 2010.

233. H. Wei, C. Niu, B. Xia, Y. Dou, and X. Hu. "A refined selection method for project portfolio optimization considering project interactions." *Expert Systems with Applications*, vol. 142, pp. 84-93, 2020.

234. U. D. Kumar, H. Saranga, J. E. Ramirez-Marquez, and D. Nowicki. "Six sigma project selection using data envelopment analysis." *The TQM Magazine*, vol. 19, no. 5, pp. 419-441, 2007.

235. T. Yong-tao, S. Li-yin, C. Langston, and Y. Liu. "Construction project selection using fuzzy TOPSIS approach." *Journal of Modelling in Management*, vol. 5, no. 3, pp. 302-315, 2010.

236. G. Fernandez-Sanchez and F. Rodriguez-Lopez. "A methodology to identify sustainability indicators in construction project management—Application to infrastructure projects in Spain." *Ecological Indicators*, vol. 10, no. 6, pp. 1193-1201, 2010.

237. S. Yin, B. Li, H. Dong, and Z. Xing. "A New Dynamic Multicriteria Decision-Making Approach for Green Supplier Selection in Construction Projects under

Time Sequence." *Mathematical Problems in Engineering*, vol. 2017, pp. 110-117, 2017.

238. Z. Hu, C. Rao, Y. Zheng, and D. Huang,. “Optimization decision of supplier selection in green procurement under the mode of low carbon economy.” *International Journal of Computational Intelligence Systems,* vol. 8, no. 3, pp. 407–421, 2015.
239. M. Tavana, A. Fallahpour, D.DiCaprio, and F. J. Santos-Arteaga. “A hybrid intelligent fuzzy predictive model with simulation for supplier evaluation and selection.” *Expert Systems with Applications*, vol. 61, no. 11, pp. 129–144, 2016.
240. C.-W. Tsui and U.-P. Wen, “A hybrid multiple criteria group decision-making approach for green supplier selection in the TFT-LCD industry,” *Mathematical Problems in Engineering*, vol. 2014, Article ID709872, 13 pages, 2014.
241. J. Qin, X. Liu, and W. Pedrycz. “An extended TODIM multicriteria group decisionmakingmethod for green supplier selection in interval type-2 fuzzy environment.” *European Journal of Operational Research*, vol. 258, no. 4, pp. 626–638, 2017.
242. P. Ghadimi, A. Dargi, and C. Heavey. “Sustainable supplier performance scoring using audition check-list based fuzzy inference system: a case application in automotive spare part industry.” *Computers and Industrial Engineering*, vol. 105, pp. 12–27, 2017.
243. S. Wang and Q. H. Ma. "A New Strategic Partner Selection Method Base on Factor Analysis in the Construction Industry." *Applied Mechanics and Materials*, vol. 209-211, pp. 1370-1376, 2012.
244. O. Moselhi and B. Deb. "Project selection considering risk." *Construction Management and Economics,* vol. 11, no. 1, p. 45, 1993.
245. S. G. Naoum and C. Egbu. "Modern selection criteria for procurement methods in construction." *International Journal of Managing Projects in Business*, vol. 9, no. 2, pp. 309-336, 2016.
246. A. Shafahi and A. Haghani. "Project selection and scheduling for phase-able projects with interdependencies among phases." *Automation in Construction*, vol. 93, pp. 47-62, 2018.

247. A. P. C. Chan, E. H. K. Yung, P. T. I. Lam, C. M. Tam, and S. O. Cheung. "Application of Delphi method in selection of procurement systems for construction projects." *Construction Management and Economics*, vol. 19, no. 7, pp. 699-718, 2001.
248. F. Parvaneh and S. El-Sayegh. "Project selection using the combined approach of AHP and LP." *Journal of Financial Management of Property and Construction*, vol. 21, no. 1, pp. 39-53, 2016.
249. P. Rezakhani. "Fuzzy multi criteria decision making model for risk factor selection in construction projects." *Bulletin Institute Polyethnic din lasi. Sectia Construction, Architecture*, vol. 58, no. 3, pp. 127-142, 2012.
250. P. Z. Razi, N. I. Ramli, M. I. Ali, and P. J. Ramadhansyah, "Selection of Method in Construction Industry by using Analytical Hierarchy Process (AHP)." vol. 712, no. 1, pp. 45-54, 2020.
251. Y. Wang, S. R. Wu, and Z. H. Wang. "Study of the Comparison and Selection Method of the Mining Project Investment Based on Entropy-Weight Method." *Applied Mechanics and Materials*, vol. 94-96, pp. 1752-1758, 2011.
252. Y.-w. Wang and L.-z. Feng. "A new feature selection method for handling redundant information in text classification." *Frontiers of Information Technology & Electronic Engineering*, vol. 19, no. 2, pp. 221-234, 2018.
253. L. Wang, C. Guo, Y. Li, B. Du, and S. Guo. "An outsourcing service selection method using ANN and SFLA algorithms for cement equipment manufacturing enterprises in cloud manufacturing." *Journal of Ambient Intelligence and Humanized Computing*, vol. 10, no. 3, pp. 1065-1079, 2019.
254. E. T. T. Wong, G. Norman, and R. Flanagan. "A fuzzy stochastic technique for project selection." *Construction Management and Economics*, vol. 18, no. 4, pp. 407-414, 2000.
255. B. Luzon, S. El-Sayegh. “Evaluating supplier selection criteria for oil and gas projects in the UAE using AHP and Delphi.” *International Journal of Construction Management*, vol.3, pp. 45-53, 2016.
256. A. El-Sayegh. “Multi-criteria decision support model for selecting the appropriate construction management at risk firm.” *Construction Management and Economics*, vol. 27:4, pp. 385-398, 2009.

257. S. El-Sayegh, T. Abdraboh, D. Elian, N. Eljarad, and Y. Ahmad. “Developing a bi-parameter biddiing model integrating price and sustainable construction practices.” *International Journal of Construction Management*, vol. 6, pp. 45-65, 2020.
258. S. El-Sayegh, M. Basamji, A. H. Ahmad, and N. Zarif. “Key contractor selection criteria for green construction projects in the UAE.” *International Journal of Construction Management*, vol.4, pp. 34-45, 2019.
259. S. El-Sayegh, S. Manjikian, A. Ibrahim, A. Abouelyousr, and R. Jabbour. “Risk identification and assessment in sustainable construction projects in UAE.” *International Journal of Construction Management*, vol. 10, pp. 23-35, 2018.
260. A. Qazi, A. Shamayleh, S. El-Sayegh, and S. Formaneck. “Prioritizing risks in sustainable construction projects using a risk matrix-based Monte Carlo Simulation approach.” *Elsevier*, vol.6, pp.110-123, 2020.
261. P. Aragones-Beltran, F. Chaparro-Gonzalez, J. P. Pastor-Ferrando, and A. Pla-Rubio. “An AHP (Analytic Hierarchy Process)/ANP (Analytic Network Process)-based multi-criteria decision approach for the selection of solar-thermal power plant investment projects.” *Applied Energy*, vol. 66, pp. 222–238, 2014.
262. S. Ahriz, A. El Yamami, K. Mansouri, and M. Qbadou. “Cobit 5-based approach for its project portfolio management: Application to a Moroccan university.” *International Journal of Advanced Computer Science and Applications*, vol.9, no. 4, pp. 88–95, 2018.
263. A. Hashemizadeh and Y. Ju. “Project portfolio selection for construction contractors by MCDM–GIS approach.” *International Journal of Environmental Science and Technology*, vol. 5, pp. 1–14, 2019.
264. I. Szilagyi, Z. Sebestyen, and T. Toth. “Project ranking in petroleum exploration.” *The Engineering Economist*, vol. 65, no. 1, pp. 66–87, 2020.
265. Y. Wu, C. Xu, Y. Ke, K. Chen, and X. Sun. “An intuitionistic fuzzy multi-criteria framework for large-scale rooftop pv project portfolio selection: Case study in zhejiang, china.” *Applied Energy*, vol. 143, pp. 295–309, 2018.
266. Y. Wu, C. Xu, Y. Ke, X. Li, and L. Li. “Portfolio selection of distributed energy generation projects considering uncertainty and project interaction under different enterprise strategic scenarios.” *Applied Energy*, vol. 236, pp. 444–464, 2019a.

267. Y. Wu, C. Xu, Y. Ke, Y. Tao, and X. Li. "Portfolio optimization of renewable energy projects under type-2 fuzzy environment with sustainability perspective." *Computers & Industrial Engineering*, vol. 133, pp. 69–82, 2019b.
268. M. Tavana, G. Khosrojerdi, H. Mina, and A. Rahman. "A hybrid mathematical programming model for optimal project portfolio selection using fuzzy inference system and analytic hierarchy process." *Evaluation and Program Planning*, vol. 77, pp. 101-703, 2019.
269. F. Demircan Keskin. "A two-stage fuzzy approach for industry 4.0 project portfolio selection within criteria and project interdependencies context." *Journal of Multi-Criteria Decision Analysis*, vol. 27, no. 2, pp. 65–83, 2020.
270. S. Hashemi, S. Kiani, N. Noroozi, and M. Moghaddam. "An image contrast enhancement method based on genetic algorithm." *Pattern Recog Lett* vol. 31, no. 13, pp. 1816–1824, 2010.
271. S. Luke and L.Spector. "Evolving graphs and networks with edge encoding. Preliminary report." In: Late breaking papers at the genetic programming 1996 conference. Stanford University Stanford, CA, vol. 23, pp. 117–124, 1996.
272. C. Zhang C, X. Wang, and C. Duanmu. "Adaptive typhoon cloud image enhancement using genetic algorithm and non-linear gain operation in undecimated wavelet domain." *Eng Appl Artif Intell*, vol. 23, no. 1, pp. 61–73, 2010.
273. M. Shyu and J. Leou. "A genetic algorithm approach to color image enhancement." *Pattern Recog*, vol. 31, no. 7, pp. 871–880, 1998.
274. H. Katagiri, K. Hirasama, J. Hu. "Genetic network programming-application to intelligent agents." In: IEEE international conference on systems, man, and cybernetics, vol. 5, pp. 3829–3834, 2000.
275. M. Emmerich, M. Grotzner, and M. Schutz. "Design of graph based evolutionary algorithms: A case study for chemical process networks." Evol Comput, vol. 9, no. 3, pp. 329–354, 2001.
276. S. Ivekovic, E. Trucco, and Y. Petillot. "Human body pose estimation with particle swarm optimisation." *Evol Comput*, vol. 16, no. 4, pp. 509–528, 2008.

277. L.Y Shen, V.W.Y Tam, L. Tam, and Y.B. Ji. "Project feasibility study: The key to successful implementation of sustainable and socially responsible construction management practice." J. Clean. Prod., vol. 18, pp. 254–259, 2010.
278. CEEQUAL, version 6, https://www.ceequal.com/version-6, 2019.
279. Green Globes Building Certification, Green Globes, https://thegbi.org/green-globes-certification, 2020.
280. Non-Domestic Buildings, BREEAM, version. 3.0, https://www.breeam.com/NC2018/content/02_scope_newcon/scope.htm, 2018.
281. Revised GRI 303: Water and Effluents 2018 and GRI 403: Occupational Health and Safety Standards, Global Reporting Initiative (GRI), 2018.
282. Edge Building Certification, EDGE, https://edgebuildings.com, 2020.
283. LEED for Building Design and Construction, LEED V4, https://www.usgbc.org/resources/leed-v4-building-design-and-construction-current-version, 2019.
284. Elevating Buildings and Best Practices, BOMA 360 2.0, https://www.boma.org/BOMA/Recognition-Awards/BOMA_360_Performance.aspx, 2020.
285. The Standard for Urban and Community Development, Ecodistricts version 1.3, 2018.
286. The Greenroads Rating System, Green Roads, https://www.greenroads.org/publications, 2020.
287. Sustainability in building construction, Sustainability indicators, Part 1: Framework for the development of indicators and a core set of indicators for buildings, ISO 21929-1, 2011.
288. E. Wright, J. Souder. "Use of Sustainability Tools for Assessing and Rating Communities (STAR) Communities Report for the Coos Bay Area." Communities, lands and waterways Data Source report, 2019
289. WELL Building Standard version 2, WELL v2, https://v2.wellcertified.com/v/en/overview, 2018.
290. IUCN Green List Standard Version 1.1, IUCN Green Standard Version 1.1, 2017
291. Buildings and constructed assets, Service life planning, Part 5: Life-cycle costing, ISO 15686-5, 2017.

292. T. Saaty. “Decision Making for Leaders: The Analytic Hierarchy Process for Decisions in a Complex World.” RWS Publications, Pittsburgh, 1999.
293. V. Ahmed, A. Opoku, and Z. Aziz, “Research methodology in the built environment: a selection of case studies,” Abingdon, Oxon: Routledge (in English), vol. 8, pp. 66-87, 2016.
294. C. R. D. Kothari, “Research methodology: methods & techniques,” New Delhi: New Age International (P) Ltd. (in English), 2004.
295. R. Kumar, “Research methodology: a step-by-step guide for beginners,” Los Angeles: Sage (in English), 2014.

Appendix I - Portfolio Value Optimization Selection Criteria Survey

This survey aims to measure the importance of different criteria for selecting projects in the construction industry. The selection criteria are divided into two main groups:” Sustainability”, and “Organization Benefit Realization and Project Success”. The sustainability group consists of the three pillars: Environmental, Social and Economic. The second group consist of project success criteria and organization benefits realization criteria. Each category consists of 5 criteria each. The environmental category includes 6 criteria. The outcome of this survey will be used to develop a model to maximize the client’s portfolio value.

I am conducting this research for my PhD’s dissertation (ESM 799) under the supervision of Dr. Sameh El-Sayegh from the Civil Engineering Department at the American University of Sharjah (AUS).

Kindly note the following:

- Your participation in this research project is voluntary
- You may refuse to participate or discontinue your participation at any time during the research
- The results will be reported in aggregate form
- There is no risk associated with your participation in this study.

-There are no direct benefits to you for participating in this study; however, others may benefit in the future from the information that is learned.

Thank you for agreeing to take part in this survey. This survey should take around 10-12 minutes to complete. Be assured that all answers you provide will be kept in the strictest confidentiality. If you have any questions or concerns regarding the research topic, please contact Taha Anjamrooz on b00038789@aus.edu. Thank you!

☐ ***By clicking this, I consent to my participation in the survey.***

This study was reviewed and approved by the University IRB. If you have questions or concerns about this study and would like to consult someone other than the researcher(s), you may contact the University at:

American University of Sharjah
PO Box 26666, Sharjah
United Arab Emirates
Email: IRB@aus.edu

Your Company	☐Local	☐International		
Years of Experience	☐<5	☐5 to 10	☐11 to 20	☐>20
Company Role	☐Client/Employer	☐Eng. Consultant	☐Project Management	☐Others
The Size of your projects (Dhs)	☐<50M	☐50 to 200M	☐201 to 500M	☐>500M

Do you use sustainability as a criterion in selecting projects? ☐Yes ☐No

Do you think incorporating sustainability in the selection decision is important?

☐Strongly Disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly Agree

What criteria do you currently use to select projects?

☐Project Success criteria ☐Organizational Benefits Criteria ☐Sustainability Criteria

☐Organizational Benefits and Sustainability Criteria ☐Project Success Criteria and Organizational Benefits Criteria ☐Project Success Criteria and Sustainability Criteria ☐All Three categories

Survey

If you compare each of the following pairs of criteria, which do you think is more important? Compare each of the following pairs of criteria and mark the number along the segment, the following table explains the scale:

AHP Scale of Importance for Comparison of Pairs	Numeric Rating
Extremely More Important	9
Very Strongly More Important	7
Strongly More Important	5
Moderately More Important	3
Equally Important	1

SECTION 1

This section will be comparison between six different criteria in the Environmental Pillar: Energy Use (Reduction of Energy Use & Use of Renewable Energy), Material Use (Usage of Recycled Material & Use of Green Material), Water Use (Reduction of Water Consumption & Renewable Water Resources), Land Use (Land Use and Rehabilitation Vs. Impact on Biodiversity), Pollution, and Waste Management

	Extremely				Equal Importance				Extremely	
Energy Use	9	7	5	3	1	3	5	7	9	**Material Use**
Energy Use	9	7	5	3	1	3	5	7	9	**Water Use**
Energy Use	9	7	5	3	1	3	5	7	9	**Land Use**
Energy Use	9	7	5	3	1	3	5	7	9	**Pollution**
Energy Use	9	7	5	3	1	3	5	7	9	**Waste Management**
Material Use	9	7	5	3	1	3	5	7	9	**Water Use**
Material Use	9	7	5	3	1	3	5	7	9	**Land Use**
Material Use	9	7	5	3	1	3	5	7	9	**Pollution**
Material Use	9	7	5	3	1	3	5	7	9	**Waste Management**
Water Use	9	7	5	3	1	3	5	7	9	**Land Use**
Water Use	9	7	5	3	1	3	5	7	9	**Pollution**
Water Use	9	7	5	3	1	3	5	7	9	**Waste Management**
Land Use	9	7	5	3	1	3	5	7	9	**Pollution**
Land Use	9	7	5	3	1	3	5	7	9	**Waste Management**
Pollution	9	7	5	3	1	3	5	7	9	**Waste Management**

SECTION 2

This section will be comparison between five different criteria in the Social Pillar: Public health and Safety, Employee training and education, Relation with local community, Improvement of Infrastructure, and Encourage Alternative Modes of Transportation

	Extremely ←				Equal Importance				→ Extremely	
Health & Safety	9	7	5	3	1	3	5	7	9	Employee Training & Education
Health & Safety	9	7	5	3	1	3	5	7	9	Relation with Local Community
Health & Safety	9	7	5	3	1	3	5	7	9	Improvement of Infrastructure
Health & Safety	9	7	5	3	1	3	5	7	9	Alternative Transportation
Employee Training & Education	9	7	5	3	1	3	5	7	9	Relation with Local Community
Employee Training & Education	9	7	5	3	1	3	5	7	9	Improvement of Infrastructure
Employee Training & Education	9	7	5	3	1	3	5	7	9	Alternative Transportation
Relation with Local Community	9	7	5	3	1	3	5	7	9	Improvement of Infrastructure
Relation with Local Community	9	7	5	3	1	3	5	7	9	Alternative Transportation
Improvement of Infrastructure	9	7	5	3	1	3	5	7	9	Alternative Transportation

SECTION 3

This section will be comparison between five different criteria in the Economic Pillar: Life-cycle cost, Contribution to GDP and wealth creation, Employment creation, Innovation and technological advance, and Use of National Supplier

	Extremely ←				Equal Importance				→ Extremely	
Life-cycle Cost	9	7	5	3	1	3	5	7	9	Contribution to GDP
Life-cycle Cost	9	7	5	3	1	3	5	7	9	Employment Creation
Life-cycle Cost	9	7	5	3	1	3	5	7	9	Innovation & Technology
Life-cycle Cost	9	7	5	3	1	3	5	7	9	Use of National Suppliers
Contribution to GDP	9	7	5	3	1	3	5	7	9	Employment Creation
Contribution to GDP	9	7	5	3	1	3	5	7	9	Innovation & Technology
Contribution to GDP	9	7	5	3	1	3	5	7	9	Use of National Suppliers
Employment Creation	9	7	5	3	1	3	5	7	9	Innovation & Technology
Employment Creation	9	7	5	3	1	3	5	7	9	Use of National Suppliers
Innovation & Technology	9	7	5	3	1	3	5	7	9	Use of National Suppliers

SECTION 4

This section will be comparison between three pillars of the sustainability: Environmental, Social and Economic

	Extremely ←				Equal Importance				→ Extremely	
Environmental	9	7	5	3	1	3	5	7	9	Social
Environmental	9	7	5	3	1	3	5	7	9	Economic
Social	9	7	5	3	1	3	5	7	9	Economic

SECTION 5

This section will be comparison between five different criteria in Organization Benefit Realization: Strategic Fit, Profitability, Organizational Quality (Branding and Reputation), Organizational Risk, and Resilience

	Extremely				Equal Importance				Extremely	
Strategic Fit	9	7	5	3	1	3	5	7	9	Profitability
Strategic Fit	9	7	5	3	1	3	5	7	9	Organizational Quality
Strategic Fit	9	7	5	3	1	3	5	7	9	Organizational Risk
Strategic Fit	9	7	5	3	1	3	5	7	9	Resilience
Profitability	9	7	5	3	1	3	5	7	9	Organizational Quality
Profitability	9	7	5	3	1	3	5	7	9	Organizational Risk
Profitability	9	7	5	3	1	3	5	7	9	Resilience
Organizational Quality	9	7	5	3	1	3	5	7	9	Organizational Risk
Organizational Quality	9	7	5	3	1	3	5	7	9	Resilience
Organizational Risk	9	7	5	3	1	3	5	7	9	Resilience

SECTION 6

This section will be comparison between different criteria in Project Success Criteria: Project Time, Project Risk, Project Cost, Project Quality, and Project Resources

	Extremely				Equal Importance				Extremely	
Project Time	9	7	5	3	1	3	5	7	9	Project Risk
Project Time	9	7	5	3	1	3	5	7	9	Project Cost
Project Time	9	7	5	3	1	3	5	7	9	Project Quality
Project Time	9	7	5	3	1	3	5	7	9	Project Resources
Project Risk	9	7	5	3	1	3	5	7	9	Project Cost
Project Risk	9	7	5	3	1	3	5	7	9	Project Quality
Project Risk	9	7	5	3	1	3	5	7	9	Project Resources
Project Cost	9	7	5	3	1	3	5	7	9	Project Quality
Project Cost	9	7	5	3	1	3	5	7	9	Project Resources
Project Quality	9	7	5	3	1	3	5	7	9	Project Resources

SECTION 7

This section will be comparison between Organization Benefit Realization category and Project Success category

	Extremely				Equal Importance				Extremely	
Organization Benefit Realization Criteria	9	7	5	3	1	3	5	7	9	Project Success Criteria

SECTION 8

This section will be comparison between the "Sustainability" group and "Organization Benefit Realization and Project Success" group

	Extremely				Equal Importance				Extremely	
Sustainability Criteria	9	7	5	3	1	3	5	7	9	Organization Benefit Realization and Project Success Criteria

Geometric Mean for the Collected Data from the Survey										
Environmental Criteria										
Q9	9A	7A	5A	3A	1	3B	5B	7B	9B	GEO Mean
	7	10	6	3	7	1	0	0	0	3.95
Q10	9A	7A	5A	3A	1	3B	5B	7B	9B	
	7	9	4	2	8	1	1	1	1	2.77
Q11	9A	7A	5A	3A	1	3B	5B	7B	9B	
	6	9	2	1	7	4	3	2	0	1.90
Q12	9A	7A	5A	3A	1	3B	5B	7B	9B	
	8	5	2	5	5	0	1	3	5	1.68
Q13	9A	7A	5A	3A	1	3B	5B	7B	9B	
	6	8	6	3	3	2	2	3	1	2.30
Q14	9A	7A	5A	3A	1	3B	5B	7B	9B	
	2	8	5	4	7	0	3	2	3	1.65
Q15	9A	7A	5A	3A	1	3B	5B	7B	9B	
	5	7	8	0	4	3	2	5	0	1.87
Q16	9A	7A	5A	3A	1	3B	5B	7B	9B	
	7	5	5	3	5	1	1	2	5	1.74
Q17	9A	7A	5A	3A	1	3B	5B	7B	9B	
	4	4	7	5	8	0	1	3	2	1.88
Q18	9A	7A	5A	3A	1	3B	5B	7B	9B	
	6	7	8	2	6	2	1	1	1	2.71
Q19	9A	7A	5A	3A	1	3B	5B	7B	9B	
	3	8	6	2	5	2	2	3	3	1.61
Q20	9A	7A	5A	3A	1	3B	5B	7B	9B	
	3	5	7	5	6	3	0	4	1	1.79
Q21	9A	7A	5A	3A	1	3B	5B	7B	9B	
	3	9	1	5	7	0	3	1	5	1.49
Q22	9A	7A	5A	3A	1	3B	5B	7B	9B	
	2	6	6	5	9	0	1	3	2	1.77
Q23	9A	7A	5A	3A	1	3B	5B	7B	9B	
	5	3	1	6	15	0	2	0	2	1.67

Geometric Mean for the Collected Data from the Survey										
Social Criteria										
Q24	9A	7A	5A	3A	1	3B	5B	7B	9B	
	4	5	9	3	12	0	0	0	1	2.73
Q25	9A	7A	5A	3A	1	3B	5B	7B	9B	
	4	11	4	3	8	2	2	0	0	2.76
Q26	9A	7A	5A	3A	1	3B	5B	7B	9B	
	7	6	4	4	11	1	0	0	1	2.77
Q27	9A	7A	5A	3A	1	3B	5B	7B	9B	
	9	6	12	4	2	0	0	0	1	4.75
Q28	9A	7A	5A	3A	1	3B	5B	7B	9B	
	5	5	2	8	12	1	0	1	0	2.39
Q29	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	4	4	5	8	5	4	0	3	1.10
Q30	9A	7A	5A	3A	1	3B	5B	7B	9B	
	6	4	5	6	7	4	0	0	2	2.20
Q31	9A	7A	5A	3A	1	3B	5B	7B	9B	
	0	2	2	2	12	7	5	0	4	0.64
Q32	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	5	4	6	10	5	0	1	2	1.47
Q33	9A	7A	5A	3A	1	3B	5B	7B	9B	
	3	7	4	4	13	1	0	0	2	2.12
Economic Criteria										
Q34	9A	7A	5A	3A	1	3B	5B	7B	9B	Ratio
	3	3	12	4	7	3	0	1	1	2.33
Q35	9A	7A	5A	3A	1	3B	5B	7B	9B	
	2	9	5	6	6	2	2	1	1	2.21
Q36	9A	7A	5A	3A	1	3B	5B	7B	9B	
	2	8	7	2	3	6	3	1	2	1.59
Q37	9A	7A	5A	3A	1	3B	5B	7B	9B	
	4	4	6	6	6	2	3	3	0	1.80
Q38	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	5	6	5	7	6	2	2	0	1.48
Q39	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	7	2	5	12	3	1	3	0	1.50
Q40	9A	7A	5A	3A	1	3B	5B	7B	9B	
	4	6	6	4	10	4	0	0	0	2.43
Q41	9A	7A	5A	3A	1	3B	5B	7B	9B	
	2	4	5	5	9	2	3	2	2	1.36
Q42	9A	7A	5A	3A	1	3B	5B	7B	9B	
	3	4	7	4	11	2	1	1	1	1.91
Q43	9A	7A	5A	3A	1	3B	5B	7B	9B	
	3	7	7	2	9	4	0	1	1	2.09

Geometric Mean for the Collected Data from the Survey

Pair-Wise Comparison Between 3 Pillars										
Q44	9A	7A	5A	3A	1	3B	5B	7B	9B	Ratio
	2	6	7	5	11	2	0	0	1	2.31
Q45	9A	7A	5A	3A	1	3B	5B	7B	9B	
	2	8	6	4	8	3	0	2	1	2.06
Q46	9A	7A	5A	3A	1	3B	5B	7B	9B	
	0	4	0	3	13	7	4	1	2	0.76
Organizational Benefit Realization (BRM) Criteria										
Q47	9A	7A	5A	3A	1	3B	5B	7B	9B	Ratio
	0	4	2	1	11	7	6	2	1	0.72
Q48	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	5	9	2	9	5	1	2	0	1.68
Q49	9A	7A	5A	3A	1	3B	5B	7B	9B	
	0	3	8	5	8	4	1	3	2	1.26
Q50	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	5	6	5	10	2	1	3	1	1.57
Q51	9A	7A	5A	3A	1	3B	5B	7B	9B	
	2	4	10	7	7	0	0	3	1	2.27
Q52	9A	7A	5A	3A	1	3B	5B	7B	9B	
	0	1	12	7	6	4	0	3	1	1.63
Q53	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	7	6	7	8	2	1	0	2	2.08
Q54	9A	7A	5A	3A	1	3B	5B	7B	9B	
	0	1	2	4	18	3	2	2	2	0.86
Q55	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	3	6	6	14	2	0	1	1	1.70
Q56	9A	7A	5A	3A	1	3B	5B	7B	9B	
	3	2	5	8	13	2	1	0	0	2.00

Geometric Mean for the Collected Data from the Survey										
Project Success (PR) Criteria										
Q57	9A	7A	5A	3A	1	3B	5B	7B	9B	
	0	2	8	6	9	4	1	1	3	1.30
Q58	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	3	2	4	18	2	0	3	1	1.17
Q59	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	4	6	7	10	3	1	1	1	1.71
Q60	9A	7A	5A	3A	1	3B	5B	7B	9B	
	2	5	6	5	14	1	1	0	0	2.18
Q61	9A	7A	5A	3A	1	3B	5B	7B	9B	
	0	6	5	6	9	4	1	2	1	1.52
Q62	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	3	6	8	10	2	2	1	1	1.64
Q63	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	5	5	11	12	0	0	0	0	2.57
Q64	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	1	7	9	10	3	1	1	1	1.61
Q65	9A	7A	5A	3A	1	3B	5B	7B	9B	
	2	5	8	5	12	2	0	0	0	2.44
Q66	9A	7A	5A	3A	1	3B	5B	7B	9B	
	2	2	7	9	11	2	1	0	0	2.13
Pair-Wise Comparison Between Organizational Benefit Realization Criteria and Project Success Criteria										
Q67	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	5	2	6	15	2	0	3	0	1.50
Pair-Wise Comparison Between Sustainability Group & Benefit Realization and Project Success Criteria										
Q68	9A	7A	5A	3A	1	3B	5B	7B	9B	
	1	4	2	5	13	4	2	2	1	1.16

Analytic Hierarchy Process (AHP) - Pairwise Comparison Matrix						
	Environment					
	Energy Use	Material Use	Water Use	Land Use	Pollution	Waste Management
Energy Use	1.00	3.95	2.77	1.90	1.68	2.30
Material Use	0.25	1.00	1.65	1.87	1.74	1.88
Water Use	0.36	0.60	1.00	2.71	1.61	1.79
Land Use	0.53	0.54	0.37	1.00	1.49	1.77
Pollution	0.60	0.57	0.62	0.67	1.00	1.67
Waste Management	0.44	0.53	0.56	0.57	0.60	1.00

Analytic Hierarchy Process (AHP) - Normalized Matrix								
	Environment							
	Energy Use	Material Use	Water Use	Land Use	Pollution	Waste Management	Corresponding Rating	Consistency Measure
Energy Use	0.3154	0.5488	0.3976	0.2183	0.2068	0.2206	0.318	6.716
Material Use	0.0799	0.1390	0.2370	0.2141	0.2147	0.1808	0.178	6.475
Water Use	0.1137	0.0841	0.1434	0.3109	0.1983	0.1721	0.170	6.371
Land Use	0.1656	0.0744	0.0529	0.1146	0.1831	0.1699	0.127	6.188
Pollution	0.1880	0.0798	0.0891	0.0772	0.1233	0.1604	0.120	6.259
Waste Management	0.1374	0.0739	0.0801	0.0648	0.0739	0.0961	0.088	6.376
							CR	0.071

Analytic Hierarchy Process (AHP) - Pairwise Comparison Matrix					
	Social				
	Health & Safety	Employee Training & Education	Relation with Local Community	Improvement of Infrastructure	Alternative Transportation
Health & Safety	1.00	2.73	2.76	2.77	4.75
Employee Training & Education	0.37	1.00	2.39	1.10	2.20
Relation with Local Community	0.36	0.42	1.00	0.64	1.47
Improvement of Infrastructure	0.36	0.91	1.56	1.00	2.12
Alternative Transportation	0.21	0.45	0.68	0.47	1.00

Analytic Hierarchy Process (AHP) - Normalized Matrix							
	Social						
	Health & Safety	Employee Training & Education	Relation with Local Community	Improvement of Infrastructure	Alternative Transportation	Corresponding Rating	Consistency Measure
Health & Safety	0.4345	0.4954	0.3286	0.4624	0.4114	0.426	5.090
Employee Training & Education	0.1594	0.1817	0.2851	0.1847	0.1907	0.200	5.055
Relation with Local Community	0.1575	0.0759	0.1191	0.1069	0.1275	0.117	5.020
Improvement of Infrastructure	0.1571	0.1645	0.1863	0.1672	0.1837	0.172	5.061
Alternative Transportation	0.0915	0.0826	0.0810	0.0788	0.0867	0.084	5.062
						CR	0.013

Analytic Hierarchy Process (AHP) - Pairwise Comparison Matrix					
	Economic				
	Life-cycle Cost	Contribution to GDP	Employment Creation	Innovation & Technology	Use of National Suppliers
Life-cycle Cost	1.00	2.33	2.21	1.59	1.80
Contribution to GDP	0.43	1.00	1.48	1.50	2.43
Employment Creation	0.45	0.67	1.00	1.36	1.91
Innovation & Technology	0.63	0.67	0.74	1.00	2.09
Use of National Suppliers	0.56	0.41	0.52	0.48	1.00

Analytic Hierarchy Process (AHP) - Normalized Matrix							
	Economic						
	Life-cycle Cost	Contribution to GDP	Employment Creation	Innovation & Technology	Use of National Suppliers	Corresponding Rating	Consistency Measure
Life-cycle Cost	0.3258	0.4579	0.3716	0.2677	0.1948	0.324	5.232
Contribution to GDP	0.1401	0.1969	0.2490	0.2534	0.2627	0.220	5.173
Employment Creation	0.1473	0.1328	0.1680	0.2294	0.2074	0.177	5.147
Innovation & Technology	0.2056	0.1312	0.1237	0.1689	0.2269	0.171	5.129
Use of National Suppliers	0.1812	0.0812	0.0877	0.0806	0.1083	0.108	5.128
						CR	0.036

Analytic Hierarchy Process (AHP) - Pairwise Comparison Matrix			
	Sustainability		
	Environmental	Social	Economic
Environmental	1.00	2.31	2.06
Social	0.43	1.00	0.76
Economic	0.48	1.32	1.00

Analytic Hierarchy Process (AHP) - Normalized Matrix					
	Project BR Criteria (PBC)				
	Environmental	Social	Economic	Corresponding Rating	Consistency Measure
Environmental	0.5214	0.4989	0.5399	0.52	3.00
Social	0.2259	0.2162	0.1985	0.21	3.00
Economic	0.2527	0.2849	0.2616	0.27	3.00
				CR	0.00

Analytic Hierarchy Process (AHP) - Pairwise Comparison Matrix					
	Organizational Benefit Realization				
	Strategic Fit	Profitability	Organizational Quality	Organizational Risk	Resilience
Strategic Fit	1.00	0.72	1.68	1.26	1.57
Profitability	1.40	1.00	2.27	1.63	2.08
Organizational Quality	0.60	0.44	1.00	0.86	1.70
Organizational Risk	0.79	0.62	1.17	1.00	2.00
Resilience	0.64	0.48	0.59	0.50	1.00

Analytic Hierarchy Process (AHP) - Normalized Matrix							
	Organizational Benefit Realization						
	Strategic Fit	Profitability	Organizational Quality	Organizational Risk	Resilience	Corresponding Rating	Consistency Measure
Strategic Fit	0.2262	0.2204	0.2502	0.2409	0.1877	0.225	5.061
Profitability	0.3157	0.3076	0.3389	0.3098	0.2498	0.304	5.059
Organizational Quality	0.1347	0.1353	0.1491	0.1633	0.2032	0.157	5.050
Organizational Risk	0.1789	0.1892	0.1739	0.1906	0.2394	0.194	5.045
Resilience	0.1445	0.1476	0.0879	0.0954	0.1199	0.119	5.030
						CR	0.011

Analytic Hierarchy Process (AHP) - Pairwise Comparison Matrix					
	Project Success Project				
	Project Time	Project Risk	Project Cost	Project Quality	Project Resources
Project Time	1.00	1.30	1.17	1.71	2.18
Project Risk	0.77	1.00	1.52	1.64	2.57
Project Cost	0.85	0.66	1.00	1.61	2.44
Project Quality	0.58	0.61	0.62	1.00	2.13
Project Resources	0.46	0.39	0.41	0.47	1.00

Analytic Hierarchy Process (AHP) - Normalized Matrix							
	Project BR Criteria (PBC)						
	Risk	Geographical location	Project Duration	Profit	Fit with the organization strategies	Corresponding Rating	Consistency Measure
Project Time	0.2728	0.3280	0.2483	0.2658	0.2118	0.265	5.061
Project Risk	0.2105	0.2531	0.3217	0.2554	0.2489	0.258	5.071
Project Cost	0.2326	0.1666	0.2118	0.2504	0.2363	0.220	5.054
Project Quality	0.1593	0.1538	0.1313	0.1553	0.2060	0.161	5.046
Project Resources	0.1249	0.0986	0.0869	0.0731	0.0969	0.096	5.037
						CR	0.012

Analytic Hierarchy Process (AHP) - Pairwise Comparison Matrix		
	BRM & PS	
	BR	PS
BR	1.00	1.50
PS	0.67	1.00

Analytic Hierarchy Process (AHP) - Normalized Matrix				
	BRM & PS			
	BR	PS	Corresponding Rating	Consistency Measure
BR	0.5994	0.5994	0.599	2.000
PS	0.4006	0.4006	0.401	2.000
			CR	0.010

Analytic Hierarchy Process (AHP) - Pairwise Comparison Matrix		
	Overall Benefits	
	Sus	OBRM
Sus	1.00	1.16
OBRM	0.86	1.00

Analytic Hierarchy Process (AHP) - Normalized Matrix				
	Overall Benefits			
	Sus	OBRM	Corresponding Rating	Consistency Measure
Sus	0.5366	0.5366	0.537	2.000
OBRM	0.4634	0.4634	0.463	2.000
			CR	0.030

Appendix III – Results of Linear Programming for the Case Study in Model B

Project	Total Project Benefits	Budget	Energy Use Score	Selection
P1	6	130	6	0
P2	7	260	7	0
P3	6	95	5	1
P4	7	180	8	1
P5	6	350	6	0
P6	8	150	9	1
P7	7	140	6	1

Objective	27.816		
Constraint -1	565	=<	600
Constraint -2	28	=>	23

Vita

Taha Anjamrooz was born in 1986, in Shiraz, Iran. He was educated in a private school, The International School of Towhid and was granted his high school diploma in June 2004. He then joined the Ajman University and from which he graduated with a Bachelor of Science in Electrical Communication Engineering in August 2009.

Upon his graduation, Mr. Taha worked as an Admin and Human Resource department head in a multinational contracting organization; Al Rajhi Construction Company, through which he was responsible of the successful completion of many critical tasks in high profile infrastructure projects undertaken in the UAE. He was holding position of Sr. Commercial Manager at the end of his career with ARC.

In 2010, Mr. Taha began a master program in Engineering Systems Management at the American University of Sharjah, and graduated in May 2012.

In 2015, he joined DX Contracting LLC, another contracting organization in UAE, holding position of CCAO, he is responsible for performance of Corporate and Operation divisions.

In 2018, Mr. Taha began a PhD program in Engineering Systems Management at the American University of Sharjah.