

**ANKARA YILDIRIM BEYAZIT UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED
SCIENCES**



**ESTABLISHING A MULTI-CRITERIA DECISION-MAKING
SUPPORTING TOOL FOR RECONSTRUCTION PROJECTS
OF PUBLIC BUILDINGS IN IRAQ**

**M.Sc. Thesis by
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ANKARA

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OF PUBLIC BUILDINGS IN IRAQ**

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**by
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M.Sc. THESIS EXAMINATION RESULT FORM

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Last but not least, I extend my appreciation to all the resources, institutions, and individuals who contributed to the successful completion of this research. Their collective efforts have shaped this thesis into a comprehensive and insightful contribution to the field of civil engineering.

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ESTABLISHING A MULTI-CRITERIA DECISION-MAKING SUPPORTING TOOL FOR RECONSTRUCTION PROJECTS OF PUBLIC BUILDINGS IN IRAQ

ABSTRACT

Multi-criteria decision-making (MCDM) is a decision-making approach specifically designed to handle situations where multiple objectives need to be considered. These objectives may support to each other or also create conflicts. This thesis presents a comprehensive investigation into the domain of post-Crisis reconstruction decision-making, focusing on the application of MCDM techniques to enhance the efficacy of choosing intervention strategies for damaged public buildings. Focusing on Iraq's unique circumstances, this study contributes to comprehension of how MCDM methods can be incorporated into reconstruction initiatives. It accomplishes this by designing an MCDM support tool, tailored to the Iraqi context, which aids in making informed decisions that consider a wide array of criteria. The study commences with an exploration of existing literature, identifying gaps and areas where MCDM provide innovative solutions to the challenges faced in post-conflict environments. A case study of a damaged hospital in Iraq serves as the backdrop for testing the tool's effectiveness. As the outcomes of the case study, expert insights underscore the transformative impact of the MCDM Support tool compared to traditional methods. The chosen intervention aligns with project goals and receives support from technical reports and expert expectations, emphasizing the tool's role in fostering clear objectives for efficient decision-making in reconstruction projects. At the end of the study, recommendations for further enhancement of the tool's accuracy, scalability, and stakeholder involvement are also discussed.

Keywords: MCDM, decision-support, post-war, post-conflict, reconstruction management

IRAK'TAKİ KAMU BİNALARININ YENİDEN İNŞA PROJELERİ İÇİN ÇOK KRİTERLİ KARAR VERME DESTEK ARACININ OLUŞTURULMASI

ÖZ

Çok kriterli karar verme (ÇKKV), özellikle birden fazla hedefin değerlendirilmesi gerektiği durumların ele alınması için tasarlanmış bir yaklaşımdır. Bu hedefler birbirlerini destekleyebilir veya çatışma yaratabilir. Bu tez, özellikle hasar görmüş kamu binalarına müdahale stratejilerinin seçimi konusunda verimliliğini artırmak için ÇKKV tekniklerinin uygulanmasına odaklanarak, kriz sonrası yeniden yapılandırma karar verme alanına geniş kapsamlı bir inceleme sunmaktadır. Bu çalışma, Irak'ın özel durumuna odaklanarak, ÇKKV yöntemlerinin yeniden yapılandırma projelerine nasıl dahil edilebileceğinin anlaşılmasına katkı sunmaktadır. Bunu Irak bağlamına göre kurulan ve geniş bir kriter yelpazesini değerlendirerek karar verme sürecine yardım eden ÇKKV destek aracı ile sağlamaktadır. Çalışma, ÇKKV'nin savaş sonrası ortamlardaki zorluklara yenilikçi çözümler sunabileceği boşlukları ve alanları tanımlayan literatür araştırması sunmaktadır. Sonrasında, tasarlanan aracın etkinliğini test etmek için Irak'taki hasar görmüş bir hastane örneği dayanak olarak kullanılmıştır. Örnek vaka çalışması bulgularına göre, uzmanlar ÇKKV destek aracının geleneksel yöntemlere kıyasla dönüştürücü etkisini vurgulamıştır. Bu metot ile yapılan müdahale teknik raporlardan ve uzman beklentilerinden elde edilen proje amaçları ve sonuçları ile paralel gözükmektedir. Bu da aracın yeniden yapılandırma projelerinde karar verme verimliliğindeki rolünü desteklemektedir. Çalışma sonunda, aracın doğruluğunu ve ölçeklendirilebilmesini artırmak için, ve proje paydaşlarının katılımı konusunda öneriler de tartışılmıştır.

Anahtar Kelimeler: ÇKKV, karar destek, savaş sonrası, çatışma sonrası, yeniden yapılanma yönetimi

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NOMENCLATURE

Roman Letter Symbols

Si+	Positive ideal solution
Si-	Negative ideal solution
Ai	I-th alternative
A+	Positive ideal solution
A-	Negative ideal solution

Acronyms

MCDM	Multi-criteria decision-making
MCDMS	Multi -criteria decision-making support
TOPSIS	Order preference by similarity to ideal solution
MCDSS	Multi -criteria decision-supporting systems
MCDA	Multi -criteria decision analysis
MODM	Multi -objective decision making
MADM	Multi -attribute decision making
DSS	Decision support systems
AHP	Analytical hierarchy process
VIKOR	Vlsekriterijumska optimizacija i kompromisno resenje
IPD	Integrated project delivery
MHESP	Material handling equipment selection problem
ANP	Analytic network process
PROMETHEE	Preference ranking organization method for enrichment evaluations
F-ANP	Fuzzy analytic network process
KDSMS	Knowledge-based decision support system
DEMATEL	Decision-making trial and evaluation laboratory
MIVES	Integrated value model for sustainable assessment
ZOGP	Zero-one goal programming
MAUT	Multi attribute utility theory
DEA	Data envelopment analysis
PP	Public procurement
PGA	Peak ground acceleration

COPRAS	Complex proportional assessment
COPRAS-G	Complex proportional assessment - grey
ELECTREIII	Élimination et choix traduisant la réalité
NGT	Nominal group technique
EDAS+	Distance from average solution
ESEES	Evaluation and selection of engineering equipment suppliers
ROC	Order centroid method
FAHP	Fuzzy analytical hierarchy process
CPCT	Concurrency-partitioning and crashing techniques
FDSS	Fuzzy decision support system
SSM	Soft systems methodologies
VFT	Value focused thinking
RC	Reinforced concrete
TFN	Triangular fuzzy numbers
SLaMA	Simple lateral mechanism analysis
R&M	Repair and maintenance
CB	Commercial building
AEC/FM	Architecture, engineering, construction, and facility management
GAIA	Global automated information access
MATLAB	Matrix laboratory
SPSS	Statistical package for social sciences
NDT	Non-destructive testing
CFRP	Carbon fiber reinforced polymer
GIS	Geographic information systems
SMART	Simple multi-attribute rating technique
SECA	Simultaneous evaluation of criteria and alternatives
UI	User interface
RPI-MCDM	Reconstruction project in Iraq: multi criteria decision supporting tool
GUI	Graphical user interface
NumPy	Numerical python
UN	United nations

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CHAPTER 1

INTRODUCTION

Multi-criteria decision-making support (MCDMS) refers to a process of evaluating and selecting options based on multiple, often conflicting, criteria. In Iraq, the implementation of MCDMS is particularly relevant due to the complex political, economic, and social challenges that the country faces [1]. MCDM can be applied in various fields such as investment decisions, public policy, and resource allocation to name few [2]. The goal of MCDMS is to find a solution that balances conflicting criteria and supports decision-making in an objective and transparent manner. With its ability to deal with uncertainty and multiple objectives, MCDMS is a useful tool for decision-makers in Iraq to address the challenges and make informed decisions that consider multiple perspectives [1]. The reconstruction of Iraq after years of conflict and instability has presented numerous challenges for decision-makers.

The reconstruction of public buildings in Iraq is a critical and complex challenge, involving multiple criteria and stakeholders. The process of intervention in public building reconstruction projects is often specified, based on subjective judgment, and lacks transparency and accountability [3]. As a result, reconstruction efforts may not align with community needs and priorities, may result in suboptimal outcomes, and may fail to maximize the limited resources and capacities available [4].

The goal of this study is to develop and validate a Multi-Criteria Decision-Making Support (MCDMS) tool that can aid the decision-making process in public building reconstruction in Iraq, by providing a transparent, systematic, and evidence-based method for prioritizing projects. The tool should take into consideration the specific context and challenges of public building reconstruction in Iraq, and should be based on robust data and information, and stakeholder engagement and participation. The study will also provide insights into the challenges and opportunities of implementing MCDM tools in the context of post-disaster recovery and reconstruction, which can inform future research and practice in this field.

1.1 Problem Definition

In the context of post-crisis recovery in Iraq, the absence of a comprehensive Multi-Criteria Decision-Making (MCDM) support tool for guiding interventions in damaged public buildings has led to significant challenges. Traditional decision-making approaches have often fallen short in considering the diverse criteria involved, resulting in suboptimal choices and inefficient resource allocation.

The lack of a comprehensive and systematic MCDM support tool for deciding the way of intervention in damaged public buildings in Iraq presents a significant gap in the management of post-disaster recovery efforts.

1.2 Research Question

How can a Multi-Criteria Decision-Making Support (MCDMS) tool be developed and implemented to support the selection and prioritization interventions of public building reconstruction projects in Iraq, considering factors such as cost, feasibility, community needs, and environmental impact?

To tackle this, we'll explore questions about what the tool should consider, how it can adapt to changing situations, where we get the necessary information, how easy it is to use, how different people can agree on decisions, and how well it works in practice. In this section, we dive into these questions to find better ways of making decisions about rebuilding in post-conflict Iraq.

1.3 Scope and Objectives of The Study

The scope of the study is to review and analyse existing MCDMS methodologies and tools, identify and gather relevant criteria and data sources for particularly public building reconstruction projects in Iraq and develop a comprehensive MCDMS tool to prioritize and select best intervention procedures for public building reconstruction projects.

The Objectives of this study can be listed as follow:

- To develop a comprehensive set of criteria for prioritizing public building reconstruction projects in Iraq, based on a review of the relevant literature, and stakeholder engagement and participation.
- To establish a MCDMS tool and validate it by applying it on a case study.
- To demonstrate the potential benefits of using the MCDMS tool in improving the alignment, coordination, and cost-effectiveness of public building reconstruction efforts in Iraq.

1.4 Research Methodology

The study employs this research methodology for its strong alignment with the specific research problem at hand. The methodology incorporates mechanisms for assessing the tool's real-world impact, underscoring the commitment to measuring its effectiveness in improving decision-making and project outcomes. The study methodology is illustrated by the following:

- A review of the existing literature on MCDM and its application in Iraq and in construction and reconstruction projects in general to provide a comprehensive understanding of the concepts, theories, and previous studies related to the topic.
- Collect data on the criteria and alternatives under consideration. This involve conducting interviews and observations to gather information from relevant stakeholders as primary data resources.
- Identify and select the criteria that are relevant to the decision-making process in reconstruction projects in Iraq based on experts' opinion and previous studies then suggest alternatives to be analysed based on the collected data.
- Create the tool with the application of Order Preference by Similarity to Ideal Solution (TOPSIS) Method to analyse the collected data [5].
- Select a case study for a damaged public building in Iraq and implement the tool as a supporting tool.

- Based on the results of the data analysis, a ranking of alternatives and selecting a solution that align with the criteria decided earlier.
- Evaluate and validate the results of the MCDMS analysis by comparing the results with actual outcomes and the technical reports.
- Dictating the recommendations and the main obstacles and opportunities for implementing the MCDMS in reconstruction projects in Iraq.

Figure 1.1 illustrates the Research methodology design as process of collecting data, creating the tool and evaluate the tool performance.

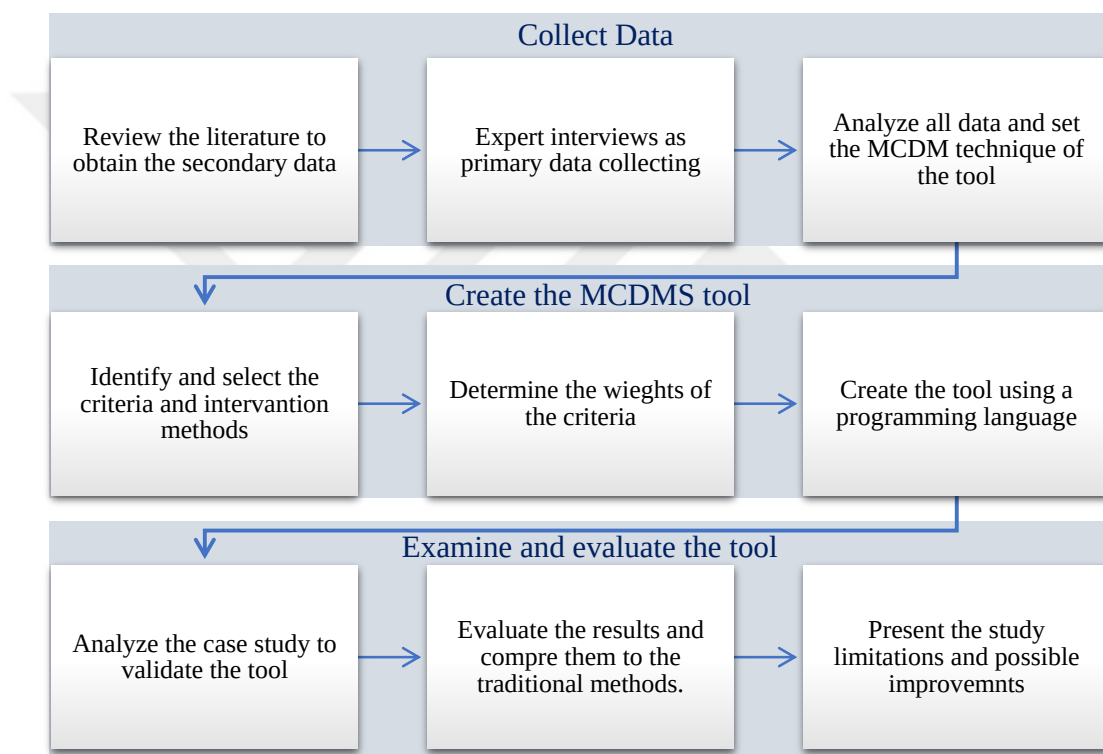


Figure 1.1 Research methodology design

1.5 Study Limitations

This research focuses on the process of selecting the best course of action when it comes to repairing damage specifically in public buildings, with a particular emphasis on Iraq. The reason for focusing on Iraq is that since there is currently a lack of a clear

and established methodology for making decisions in this regard, especially in the wake of recent conflicts in the country.

The study will examine the decision-making process from a management perspective, considering the technical information provided by a team of experts. However, it will not delve into the technical aspects of evaluating damaged buildings or the assessments used. Conducting this research presented challenges in terms of data collection, given the lack of previous studies to draw upon, as well as the difficulty in accessing information from multiple stakeholders involved in such projects. Also, The research faced limitations in terms of time.

Developing the MCDM tool itself presented a substantial challenge. The tool needed to be user-friendly, yet comprehensive, considering a wide range of criteria and alternatives. Striking a balance between complexity and usability was a significant concern. Moreover, like any research involving prediction and decision-making, dealing with assumptions and uncertainties was inevitable. Clarifying these assumptions and addressing uncertainties added complexity to the decision-making process.

1.6 Scientific Contribution

The study will contribute to the literature on post-disaster recovery and reconstruction, by developing and testing a novel and context-specific approach to prioritizing public building reconstruction projects. The suggested tool will enable decision-makers to make evidence-based and informed decisions, and promote transparency and accountability in the reconstruction process, which will ensure that community needs and priorities are considered and addressed in the reconstruction efforts.

1.7 Organization of the Thesis

This study is composites of 5 chapters as follow: chapter 1 is an introduction part to the study illustrate the background of the study, scope and limitations, and methodology as well as defining problem statement. Chapter 2 covers the previous studies in the research area and give the literature review in aspects like; applications of MCDM in reconstruction projects, previous studies on MCDM in Iraq, gaps in the

existing literature. Chapter 3 presents data collection and analysis to create the MCDM tool. After that, Chapter 4 validates the tool by implementing it as MCDM supporting tool in a selected case study. Chapter 5 gives the conclusion of what was observed in the research and the implementation. Also, dictating the recommendation for future work, while Bibliography shows the references used in this study.



CHAPTER 2

LITERATURE REVIEW

The reconstruction of public buildings in Iraq is a pressing issue due to the damage caused by war, natural disasters, and neglect. Inadequate facilities pose a significant threat to the country's social and economic development, making decision-making in the reconstruction of public buildings a complex problem that requires a multidimensional perspective.

Although MCDM techniques and decision-support tools have their advantages, they may face limitations in their applicability to reconstruction projects in Iraq. A lack of reliable data, expertise, and financial resources could hinder the implementation of MCDM-based decision-making processes. Moreover, cultural and political factors may also play a role in the decision-making process, making it challenging to achieve consensus among stakeholders. This literature review aims to explore the current state-of-the-art in the field of multi-criteria decision-supporting systems (MCDSS) tools and their applicability to the reconstruction of public buildings in Iraq.

2.1 Key terms of Multi-Criteria Decision Making (MCDM)

In the fields of management and engineering, decision-making can be a persistent challenge due to the complexity of projects and the need for robust decisions at various stages of project development. For instance, decisions made during the feasibility study stage can determine the viability of a project for investors, and proper decisions by architects and engineers can reduce risks associated with industrial accidents, structural failures, extreme natural phenomena, and dangerous human activities. To facilitate decision-making in this field, formal methods such as multicriteria decision-making (MCDM) and optimization methods can be applied. However, decision-making in this field is typically conducted under uncertainty, and uncertainty and sensitivity analysis methods can be used to identify factors that affect decision-making [6].

As the complexity and scale of decision-making situations increase, along with the cost of making incorrect decisions, there is a growing need for mathematical methods and software to support decision-makers in generating and comparing alternatives, evaluating their consequences, and selecting the best options while excluding unacceptable ones [7]. In the context of decision-making, MCDM can help improve the quality, efficiency, rationality, and explicitness of decisions by breaking down complex problems into smaller, more manageable pieces [8].

2.1.1 Multi-Criteria Decision Analysis (MCDA)

MCDA offers systematic evaluation methodologies for considering all options based on various criteria and can aid in ranking and selecting the preferred options (See Figure 2.1). It is commonly understood that finding the optimal solution to a multi-objective problem may not be straightforward or even possible. In such cases, MCDA techniques can be helpful by addressing uncertainties and accommodating multiple perspectives and interests [9]. The application of MCDA can pose difficulties when uncertainties are significant. Uncertainties are prevalent in most strategic decision-making scenarios, where information may be imprecise, uncertain or lacking. Such uncertainties can create challenges in decision-making, particularly when the probability of significant events cannot be accurately assessed [10].



Figure 2.1 MCDA problem solving flowchart.

In the field of decision-making processes, there are various categories of Multi-Criteria Decision Making (MCDM) including Multi-Objective Decision Making (MODM) and Multi-Attribute Decision Making (MADM). Each category comprises several methods such as priority-based, outranking, distance-based, and mixed methods. These

methods have unique characteristics and can be classified as deterministic, stochastic, and fuzzy methods [11].

2.1.2 Decision Support Systems (DSS)

A decision support system (DSS) is characterized as a software tool that comprises of a database, algorithm, and user interface. These components work together within a computer or operating system to assist in the decision-making process in a visualized format. By utilizing a DSS, the quality and reliability of the decision-making system can be improved [12]. In order to enable informed decision making, decision support systems (DSS) are often used to bring together the appropriate information and models. This allows decision makers to access relevant data across the organization, making it easier to choose among alternatives. DSS can support decision making interactively and in a way that is tailored to the specific decision at hand [13].

Various decision support systems (DSSs) use different approaches for assisting decision-makers. A common classification method involves categorizing DSSs as communication-driven, data-driven, document-driven, knowledge-driven, and model-driven. Model-driven DSSs employ mathematical or statistical models to analyse and select between different alternatives. However, traditional model driven DSSs usually use the same type of models to address a particular set of decision-making problems. Combining multiple types of models in DSSs could improve their effectiveness and broaden their range of applications [7].

2.1.3 Multi-Criteria Decision Support Systems (MCDSS)

A new research area has emerged, combining Multi-Criteria Decision Making (MCDM) and Decision Support Systems (DSS). The development of MCDSS requires careful consideration of both philosophy and methodology. The first MCDSS was developed in the 1970s, with a focus on studying multi-objective mathematical programming problems. These early systems were mostly developed for academic purposes, but MCDSSs have since become widely used as supportive tools in the decision-making process [14].

The integration of MCDA tools into a DSS model base has empowered decision makers with advanced capabilities to analyse, explore and compare alternatives. A significant number of MCDSSs have been developed to tackle a range of MCDA problems such as strategic planning, selection, group decision making, and negotiation, according to Eom and Min's (1999) findings [15]. MCDSSs allow for explicit integration of decision makers' structural preferences and capture the cognitive dimension of the decision-making process [15]. Incorporating Multi-Criteria Decision Analysis Support Systems (MCDSSs) into decision-making processes provides a more transparent framework.

2.2 Existing Literature on the application of MCDM

This section presents a review of selected studies that focus on the application of Multi-Criteria Decision-Making (MCDM) techniques in construction and reconstruction projects, encompassing both national (Iraq) and global contexts. Emphasizing the comprehensiveness of the selected studies, the review specifically focuses on research that addresses the diverse aspects associated with construction and reconstruction projects, including technical, environmental, social, and economic considerations.

By examining studies that encompass these multiple dimensions, a more holistic understanding of the application of MCDM techniques in the field can be attained. Within this review, particular attention is given to the MCDM methods employed by the researchers, as they form the basis for decision-making processes. The criteria utilized in the studies are also explored, providing insights into the key factors that inform the decision-making process in construction and reconstruction projects.

2.2.1 Multi-Criteria Decision Support Systems in The Construction Projects

In contemporary construction practices, the integration of stability is regarded as a crucial aspect in various project-related activities such as planning, management, evaluation, and decision-making. This integration is aimed at enhancing the overall quality and value of the project. The effectiveness of project planning and its successful execution have a direct impact on achieving the desired objectives throughout the construction process [16]. Consequently, an ongoing emphasis is

placed on employing project planning methods that encompass economic, social, and environmental sustainability aspects, ensuring the long-term viability and enduring success of construction projects [17]. Throughout the various stages of a construction project, decision-makers encounter numerous dilemmas. These challenges can arise during site selection, the planning and design phase, technology and material selection, project management, ensuring quality, and addressing risk-related concerns. Each decision made contributes to the overall success and durability of the constructed edifice or structure [18].

In the following section, we provide a concise overview of noteworthy studies, highlighting their contributions in terms of the MCDM the methods of analysis employed, the criteria considered, and the specific decision support tools utilized in MCDM applications within the construction industry.

2.2.1.1 Applications in Construction Materials

For selecting suitable construction materials, [19] developed a decision support system (DSS) that utilizes multiple criteria decision-making (MCDM) techniques to assist in the selection of the most sustainable structural material within the integrated project delivery (IPD) framework. The study focused on the four pillars of sustainability: technical, economic, social, and environmental. A hybrid MCDM approach, combining the Analytical Hierarchy Process (AHP), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), and (VIKOR) in a fuzzy environment, was employed to construct the DSS. To validate the system, a hypothetical eight-story building was used as a case study. The research objective was to develop a decision support system that could integrate the preferences of all stakeholders into the IPD framework, enabling the selection of the most sustainable structural material. The evaluation criteria included technical factors such as durability, constructability, and maintainability; economic factors such as material cost, construction cost, maintenance cost, and end-of-life cost; social factors such as compatibility with local heritage, skilled labour availability, fire resistance and safety, and job opportunity creation; and environmental factors such as greenhouse gas emissions, impact during manufacturing/construction, and recycle and reuse potential. By considering these

criteria, the research aimed to create a comprehensive decision-making tool that supports the selection of sustainable structural materials in construction projects while accommodating the preferences of various stakeholders.

For Material Handling Equipment Selection Problem (MHESP), [20] presents an integrated fuzzy multi-criteria decision-making methodology. The proposed approach combines fuzzy sets, Analytic Network Process (ANP), and Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE) to effectively evaluate and select alternative material handling equipment. The evaluation criteria for MHESP are weighted using the fuzzy-ANP (F-ANP) approach, while the fuzzy-PROMETHEE (F-PROMETHEE) approach is employed to assess the alternative equipment. The methodology is applied to a manufacturing company to demonstrate its effectiveness. The criteria considered in this study encompass operational considerations (Reliability, Maintainability, Adaptability, and Operational flexibility), strategical considerations (Productivity, Quality, and Safety), environmental considerations (Reusability as raw-material, Re-manufacturability, and Power usage), and economical considerations (Purchasing cost, Establishment cost, Operating cost, and End-of-use value).

While [21] introduces the development of a knowledge-based decision support system called the Knowledge-based Decision Support system for roofing Material Selection and cost estimating (KDSMS). The system aims to assist in the selection of optimal materials for different roof sub-elements in the roofing industry. It consists of a database and knowledge base equipped with an inference engine. The database stores various roofing materials along with their attribute values, while the knowledge base contains qualitative and quantitative knowledge gathered from domain experts and technical literature. The proposed system utilizes the TOPSIS (Technique of ranking Preferences by Similarity to the Ideal Solution) multiple criteria decision-making method to address the materials selection and optimization problem. The selected criteria include life span, initial cost, sustainability, ease of installation, freedom from maintenance, maintenance cost, life cycle cost, thermal performance, weight, and thickness. By employing this system, decision-makers can make informed choices regarding roofing material selection and achieve optimal outcomes.

By computing the proposed strategy, [22] presents a model for selecting sustainable materials in building construction. The model employs life cycle assessment to evaluate the comprehensive environmental impacts of materials throughout their entire life cycle. To ensure a sustainable approach, the selection criteria are categorized into four groups: economic, technical, socio-cultural, and environmental factors. The criteria encompass various aspects such as weight, chemical resistance, water resistance, fire resistance, strength, life expectancy, material and construction costs, transportation costs, service and maintenance costs, overhead costs, energy costs during operation, market value, energy and resource consumption, human comfort and health, environmental impacts, aesthetics, and social, religious, and cultural identity. Analytic Network Process is utilized as a multi-criteria decision-making method, considering the relationships among the criteria and sub-criteria. The priorities of the criteria are determined through expert consensus using pairwise comparison questionnaires conducted with the aid of "Super Decisions" software.

[23] proposes a hybrid multi-criteria decision-making (MCDM) methodology to evaluate the best sustainable construction material based on sustainable indicators. The study collects indicators from existing literature and incorporates the input of construction sector professionals to assess sustainable construction materials. The main criteria include initial cost, maintenance cost, disposal cost, productivity, revenue, meeting user needs, energy saving, potential for recycling and reuse, production and transportation, resistance to decay, fire resistance, ease of reconstruction, operational life, aesthetics, use of local materials, health and safety, and labour availability. The proposed framework is validated through a case study and compared to existing literature and feedback from respondents. The hybrid MCDM approach combines the Decision-Making Trial and Evaluation Laboratory (DEMATEL) to analyse the interrelationship and influence of sustainable indicators, the Analytic Network Process (ANP) to analyse the interdependence in feedback among indicators, and the Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) to evaluate the weight of sustainable materials and identify the best sustainable material among the alternatives.

2.2.1.2 Applications in Construction Technology, Quality and Management

[24] presented a comprehensive algorithm aimed at evaluating the potential deployment and distribution of a new technology or product within the construction sector. To facilitate this assessment, a multi-stage model incorporating various alternatives and criteria is proposed, and an analytical multi-stage evaluation model is developed. A practical example is provided to demonstrate the evaluation of the microenvironment using a combination of the Analytic Hierarchy Process (AHP) and Permutation methods. The selection of criteria is based on four principles: Comprehensiveness, Applicability, Transparency, and Practicability. Accordingly, 12 criteria are identified, including Novelty of the product, Environmental impact, Recycling, Service life, quality of use, Production differentiation, Period of Warranty, Labor costs, Direct costs, Indirect costs, Expected profit, and Technology effectiveness. Notably, the expertise of stakeholders or the company's capabilities is recommended for determining the significance of assessment criteria at the micro level, as these criteria often rely on subjective judgments.

Meanwhile, [25] identified the most sustainable technology for constructing schools in an area with a significant shortage of such buildings. The research utilizes the Integrated Value Model for Sustainable Assessment (MIVES), which is a dynamic assessment tool specifically optimized for this case study. The study focuses on the most significant and differentiating indicators, including timeframes, initial and maintenance costs, waste generation, emissions, energy consumption during different life cycle phases, safety considerations, building expansions, and functional changes. MIVES is a Multi-Criteria Decision Making (MCDM) approach that incorporates the concept of value functions and relies on expert workshops to assign weights and develop value functions, thereby ensuring rigor and objectivity in the assessment process.

In [26] the authors aimed to address the issue of environmental pollution in construction, this research proposes a Multiple Criteria Decision Making (MCDM) approach. The study presents a structured and systematic framework that utilizes quantitative assessments to prioritize construction methods for green building projects. This framework also assists construction companies in the practical implementation of

these methods. The criteria considered include reducing construction costs, minimizing environmental damage costs, implementing resource recycling and reuse, utilizing low-energy resources, achieving zero energy waste, reducing carbon dioxide emissions, enhancing worker health and safety, and mitigating the impact of pollution on the local ecology. This study aims to develop an evaluation model for construction methods that promotes optimal environmental sustainability in green building projects. To achieve this goal, an integrated model is proposed, which combines three decision-making techniques: the Decision-Making Trial and Evaluation Laboratory (DEMATEL) method, the Analytic Network Process (ANP) method, and the Zero-One Goal Programming (ZOGP) formulation. By employing the MCDM approach, this investigation provides a valuable tool for construction industry practitioners to select construction methods that are environmentally friendly and promote sustainable practices.

From managerial point of view, [27] presented a comparative analysis of well-known multicriteria decision-making (MCDM) techniques to assess their suitability in supporting the decision-making process for Public Procurement (PP) tenders. PP tenders are a specific type of supplier selection process that is characterized by stringent rules and requires a tailored assessment approach. The focus of the analysis is on the most used methods in supplier selection: Analytic Hierarchy Process (AHP), Preference Ranking Organization Method for Enrichment of Evaluations (PROMETHEE), Multi Attribute Utility Theory (MAUT), and Data Envelopment Analysis (DEA). The study evaluates these methods based on a set of predetermined criteria, including Ergonomics, Functionality, Aesthetics, Assortment, Safety, Product quality, Production quality, Distribution quality, Products environmental, Production environmental, Warranty, Distribution environmental, Post-sales, Delivery, Transport & Assembly, and Packaging. The findings provide insights into the applicability and effectiveness of these MCDM techniques in the context of PP tenders.

2.2.1.3 Applications in Structural Systems and Elements

In the structural analysis field, [28] focuses on the application of the TOPSIS method to assess the structural behaviour of masonry buildings in South Italy when subjected

to vertical addition using traditional and innovative technologies. The main objective of the study is to determine the effectiveness of each technology through an extensive campaign of numerical analyses. Furthermore, a cost-benefit approach is adopted to identify the most suitable vertical addition solution. The obtained numerical results are further validated using a novel multicriteria decision-making (MCDM) method. This MCDM approach enables a comprehensive comparison of the different techniques or alternatives based on specific performance criteria, including structural parameters (such as maximum PGA at the Life Safety Limit State and maximum vertical load at the Ultimate Limit State), environmental factors (such as Life Cycle Assessments related to materials production and Energy Performance Index for building winter heating), and economic considerations (such as super-structure cost).

More comprehensive study was conducted by [29] who explores the impact of existing sustainability requirements on the selection of structural systems and materials for high-rise buildings. The decision-making process involves evaluating various alternatives based on qualitative and quantitative criteria. The COPRAS (Complex Proportional Assessment) method is employed, which considers the accuracy of performance measures by establishing a direct and proportional relationship between the significance and utility of the alternatives and the criteria values and weights. The COPRAS-G method, utilizing interval values, is employed to assess the selection of an efficient structural system. To prioritize the criteria, a survey was conducted among experts, resulting in the identification of 11 criteria, including effective height, column spacing, slab span, design and construction costs, performance timeline, and sustainability indicators such as embodied energy and carbon. Through this approach, the study aims to support decision-makers in selecting the most suitable structural system while considering sustainability requirements and the specific criteria deemed important by experts in the field.

By focusing more on the technical aspect, [30] utilizes the PROMETHEE multicriteria decision-making technique to evaluate and select the most suitable structural system for multi-housing projects. The research involves gathering engineering judgments and expert opinions through a designed questionnaire, which focuses on PROMETHEE parameters including criteria weights. The team of experts consists of engineers and managers from consulting firms and general contractors who have

extensive experience in similar projects. The study assesses different systems based on criteria such as Cost, Ease of Construction, Energy Saving, Dead load, Number of Stories, and Age and durability. By employing PROMETHEE, the research provides a systematic approach to effectively evaluate and choose the optimal structural system for multi-housing projects.

Once again, [31] propose a novel algorithm that integrates two well-known multicriteria decision-making (MCDM) techniques, ELECTRE III and PROMETHEE II, to rank structural systems. This hybrid decision-making method is specifically developed for the selection of appropriate structural systems. The study identifies 16 criteria for the selection process, including cost, dead load, life and durability, fire resistance, span, floor thickness, construction speed, ease of construction, energy saving, environmental considerations, weather compatibility, architecture compatibility, industrialization, safety, adaptability to future changes, and equipment dependency. By combining the ELECTRE III and PROMETHEE II methods, the authors aim to enhance the accuracy and effectiveness of the decision-making process for ranking structural systems based on these criteria.

Moving to selecting a suitable structural element, [32], the decision-making process involved not only the Employer but also technical individuals. To ensure a harmonization of opinions, the NGT technique and Delphi-based method were employed, considering that different criteria could represent the interests of individual participants. The study leveraged the MCDM method EDAS+ to rank exterior wall systems in the architectural and construction industry. By using this method, the ranking was unbiased by experience or marketing influence. The selected criteria for evaluation included Weight, Construction cost, Reduction in costs of exploitation, Ease of processing, Local availability of materials, Thermal conductivity coefficient, Labour force availability, Construction speed, and Regulations. This research demonstrates the application of MCDM techniques as a powerful tool to assist decision-makers in the architectural and construction industry, enabling them to make informed choices and address specific challenges.

Criteria categorization is a widely used technique, but its classification can be unclear. When creating a final set of criteria, it is important that they are complete, operational,

non-redundant, and minimal. However, meeting all these criteria at the same time can be a difficult task.

The previous survey showed different economic and technical criteria representing the availability of experienced technicians and engineers and necessary machinery and construction materials. Economic life cycle, environmental protection related issues, safety of the project site, and vulnerability are also issues related to the country and location in which the project will be constructed, and they should also be addressed in the decision-making process. Table 2.1 summarizes all mentioned MCDM criteria used globally in the construction sector.

Table 2.1 Main MCDM criteria used globally in the construction sector.

<i>Source</i>	<i>Technical</i>	<i>Environmental / Social</i>	<i>Economic</i>
[24]	Novelty of the product, Recycling, Service life, quality of use, Technology effectiveness, Production differentiation.	Environmental impact	Period of Warranty, Labor costs, Direct costs, Indirect costs, Expected profit.
[28]	Maximum PGA at the Life Safety Limit State and maximum vertical load at the Ultimate Limit State	Life Cycle Assessments, Energy Performance Index	Super-structure cost
[30]	Ease of Construction, Dead load, Number of Stories and Age and durability	Energy Saving	Cost
[25]	Safety considerations, building expansions, and functional changes, timeframes	Waste generation, emissions, energy consumption	Initial and maintenance costs,
[22]	Weight, life expectancy, chemical and water resistance, fire resistance, strength.	Energy and resource consumption, human comfort and health, environmental impacts, aesthetics, and social, religious, and cultural identity	Material and construction costs, transportation costs, service and maintenance costs, overhead costs, energy costs during operation, market value

Table 2.1 Main MCDM criteria used globally in the construction sector (Continued)

<i>Source</i>	<i>Technical</i>	<i>Environmental / Social</i>	<i>Economic</i>
[19]	Durability, constructability and maintainability.	Compatibility with local heritage, skilled labour availability, fire resistance and safety, and job opportunity creation, greenhouse gas emissions, impact during manufacturing/construction, and recycle and reuse potential.	Material cost, construction cost, maintenance cost, and end-of-life cost.
[31]	Dead load, life and durability, span, floor thickness, construction speed, ease of construction, architecture compatibility, industrialization, safety, adaptability to future changes, and equipment dependency.	Fire resistance, energy saving, environmental considerations, weather compatibility.	Cost.
[32]	Weight, Ease of processing, local availability of materials, Labor force availability, Construction speed, and Regulations.	Thermal conductivity coefficient	Construction cost, Reduction in costs of exploitation,
[26]	Implementing resource recycling and reuse, enhancing worker health and safety	Utilizing low-energy resources, achieving zero energy waste, reducing carbon dioxide emissions, mitigating the impact of pollution	Reducing construction costs, minimizing environmental damage costs,

Table 2.1 Main MCDM criteria used globally in the construction sector (Continued)

<i>Source</i>	<i>Technical</i>	<i>Environmental / Social</i>	<i>Economic</i>
[27]	Production/product quality, Functionality, Safety, Warranty, Distribution quality, Delivery, Transport & Assembly, and Packaging.	Ergonomics, Aesthetics, Production/product environmental and Distribution environmental.	Post-sales
[23]	Production and transportation, resistance to decay, fire resistance, ease of reconstruction, operational life	Energy saving, potential for recycling and reuse, aesthetics, use of local materials, health and safety, and labour availability, meeting user needs	Initial cost, maintenance cost, disposal cost, revenue
[21]	Life span, ease of installation, freedom from maintenance, weight, and thickness	Thermal performance, sustainability	Initial cost, maintenance cost, life cycle cost
[20]	Reliability, Maintainability, Adaptability, Operational flexibility, Productivity, Quality, and Safety	Reusability as raw-material, Re-manufacturability, and Power usage	Purchasing cost, Establishment cost, Operating cost, and End-of-use value
[29]	Effective height, column spacing, slab span, performance timeline, and sustainability indicators.	Embodied energy and carbon.	Design and construction costs.

2.2.2 Multi-Criteria Decision Support Systems in The Construction Projects in Iraq

Today's competitive environment makes it difficult to resolve real-world decision problems by considering a single criterion or attribute. To address this challenge, Multi-Criteria Decision-Making (MCDM) has emerged as a new branch for decision-making processes [11].

The current global crisis has resulted in the need for modern firms to respond proactively to disruptive changes in market dynamics, emerging technologies, and new competition architecture. However, in the real world, particularly in Iraq, it is challenging to adapt and innovate within a centralized management system. Consequently, a new paradigm of intelligent decision-making that is more general, flexible, and adaptable to change is necessary.

Several studies have focused on the prioritization and assessment of reconstruction projects, but there remains a gap in the application of Multiple Criteria Decision Making (MCDM) in identifying the necessary interventions. To address this gap, this section presents a summary of relevant studies conducted in the field of MCDM in the construction industry in Iraq.

These studies have made significant contributions by employing various analysis methods, considering diverse criteria, and utilizing specific decision support tools for MCDM applications. The purpose of this overview is to provide a comprehensive understanding of the advancements in decision-making processes within the Iraqi construction industry using MCDM techniques. By leveraging the insights and lessons learned from these studies, it is possible to achieve an efficient application of MCDM in reconstruction projects, enhancing decision-making processes in this context.

2.2.2.1 Applications in Construction Management and Materials

For more effective supplier selecting, [1] conducted a survey consisting of three stages, involving both public and private companies in the Iraqi construction sector, to identify the main criteria and sub-criteria for supplier selection, along with their priorities. The main criteria identified through the survey were the quality of the product, commercial aspects (Competitive price, Life cycle cost), delivery (Delivery schedule and duration), reputation and position (Satisfactory past performance, Amount of relevant works Cooperation), and system quality (Safety, Quality assurance and environmental Quality). To determine the importance weights of these criteria, the analytical hierarchy process (AHP), an effective technique in multiple criteria decision making (MCDM), was employed based on expert judgments. Subsequently, a management software system called the Evaluation and Selection of Engineering Equipment

Suppliers (ESEES) was developed using the results obtained from AHP. The developed model was validated through a case study conducted at the municipality of Baghdad, which involved the selection of pump suppliers for infrastructure projects. The main criteria considered in this study were the quality of the product, commercial aspects, delivery and implementation, reputation and position, and system quality. The ESEES model proved to be a valuable tool for supplier evaluation and selection, providing a structured approach to enhance decision-making processes in the selection of engineering equipment suppliers.

To identify the factors influencing the selection of building materials based on sustainability principles, [33] proposed two-stage approach. The first stage involved a comprehensive theoretical study that focused on understanding the characteristics of sustainable building materials. In the second stage, a practical study was conducted to determine the relative importance of the factors influencing material selection. The research employed multi-criteria decision-making methods, specifically the goal achievement matrix and analytical hierarchy process (AHP), to facilitate the selection process. The criteria considered in the decision-making process included environmental, technical, social, and economic aspects. By considering these criteria, the research provides valuable insights into the selection of building materials that align with sustainability principles. The findings contribute to the advancement of sustainable construction practices and aid decision-makers in making informed choices regarding material selection.

2.2.2.2 Applications in Project Design and Management

To assess and evaluate the performance of contractors in construction projects. [34] focuses on identifying the criteria used to select the best-performing contractor and determining an optimal contractor from a list of potential candidates. To achieve this objective, data was collected from relevant literature on factors influencing contractor performance and the application of the multiple criteria complex proportional assessment (COPRAS) method. Additionally, personal interviews were conducted with qualified engineers, contractors, and project owners. The collected data was analysed and ranked using the Order Centroid method (ROC). The criteria considered

in the evaluation include resource availability, communication issues, human-related factors, tender problems, external factors, work-related stress, budget management, quality of work, technical knowledge, timeliness of performance, and project management. Through the application of the COPRAS method and analysis of the identified criteria, this research provides insights into evaluating contractor performance in construction projects. The findings contribute to improving the decision-making process and selecting the most suitable contractor based on performance-related factors.

[35] focuses on the application of the Fuzzy TOPSIS technique to aid in decision-making for selecting an optimized master plan for cities. The objective is to evaluate alternative master plans and identify the most suitable one. To achieve this, data from literature reviews on urban planning and the Fuzzy TOPSIS technique, along with personal interviews with specialists, were collected. The study employs Fuzzy AHP and Fuzzy TOPSIS techniques to evaluate and select the optimized master plan, aiming to reduce time and cost associated with decision-making among alternatives. The criteria for evaluation, derived from the Fuzzy Analytic Hierarchy Process (FAHP) technique, include economic, environmental, social, land use, and technical aspects. By utilizing these techniques and criteria, the research aims to provide a robust decision-making framework for selecting an optimized master plan for cities.

[36] defined the criteria used to determine the optimal project in terms of construction performance. The study aims to emphasize the significance of construction performance and how the COPRAS-G (COMplex PROportional ASsessment - Grey) approach can be utilized to evaluate the construction performance of projects in Diyala governorate. The study focuses on defining the criteria used to determine the optimal project in terms of construction performance and provides a list of the main projects in the governorate to facilitate the selection of the most suitable one.

To achieve the research objectives, data was collected from relevant literature on evaluating complex alternatives, multi-criteria decision making, grey relations, and structural performance. Additionally, personal interviews were conducted with specialists involved in the design and implementation of these projects. The analysis of the collected data revealed that cost, time, and quality are the most significant criteria for comparing projects. Specifically, the cost criterion holds greater importance

compared to other criteria. The identified criteria for the analysis include cost, time, quality, productivity, owner satisfaction, systems, societal and individual satisfaction, safety and security, innovation, and the environment.

Investigating the challenges of managing multi-objective projects, [37] utilized a combination of techniques that align with the project's nature. The focus is on improving decision-making accuracy in project planning and control by selecting the most suitable technique from a group of options, such as Gantt chart and crashing technique. These techniques serve various objectives. To overcome potential conflicts among these objectives, a novel approach called Concurrency-Partitioning and Crashing Techniques (CPCT) is proposed.

Additionally, a Fuzzy Decision Support System (FDSS) based on fuzzy Multi-Criteria Decision-Making method (fuzzy MCDM) is employed. The study considers several criteria in the decision-making process, including the number of activities, activity and project duration, material cost, indirect cost per day, direct cost per day, daily working hours per shift, total project time, total project cost, and total number of laborers. By integrating the CPCT approach and fuzzy MCDM, this research offers a comprehensive solution for effectively managing multi-objective projects, enhancing decision-making accuracy, and addressing conflicts that may arise during the project planning and control phase.

2.2.2.3 Applications in Structural Systems

Aiming to establish a comprehensive framework for decision-making in construction projects, [38] explores the potential of utilizing value engineering as a Multi-Criteria Decision Making (MCDM) tool in construction management within the context of Iraq. Through an analysis of an actual case study conducted at the Islamic Sciences College of the University of Fallujah, the research demonstrates the applicability of value engineering in Iraq, displaying its effectiveness in providing clear, concise, and rapid results. The case study revealed a viable alternative that enhances durability while reducing time and cost. To facilitate the decision-making process, a tool was developed using Microsoft Excel.

The criteria considered in the evaluation include enhancing rigidity, environmental compatibility, ease of repair, modification ability, thermal and sound isolation, code compatibility, and fast construction. Overall, the research emphasizes the potential benefits of integrating value engineering as an MCDM tool in construction management in Iraq. The findings underscore the effectiveness of value engineering in optimizing project outcomes by considering multiple criteria and providing practical solutions.

In Iraq, the conventional approach to decision-making in construction projects has been primarily focused on single-criteria analysis, with a primary emphasis on cost reduction to maximize profits. In recent years, there has been an increasing recognition of the need to adopt a comprehensive approach that goes beyond purely technical considerations when making decisions regarding construction projects in Iraq.

This recognition stems from an understanding that reconstruction efforts not only involve technical aspects, but also have broader implications for the environment, society, and the economy. However, this approach has led to a lack of comprehensive criteria in decision analysis.

Previous studies have also tended to focus on specific aspects of the project, further limiting the range of criteria considered. Table 2.2 provides an overview of the main criteria utilized in each of these studies, highlighting the need for a more comprehensive and multi-criteria decision-making approach in the construction industry in Iraq.

Table 2.2 Main MCDM criteria used in the construction projects in Iraq.

<i>Source</i>	<i>Technical</i>	<i>Environmental / Social</i>	<i>Economic</i>
[1]	Quality of the product, delivery (Delivery schedule and duration), reputation and position (Satisfactory past performance, Amount of relevant works Cooperation)	System quality (Safety, Quality assurance and environmental Quality)	commercial aspects (Competitive price, Life cycle cost)
[36]	Quality, Productivity, Owner and system satisfaction, Innovation.	societal and individual satisfaction, time, safety, environment, and security	Cost
[38]	enhancing rigidity, ease of repair, modification ability, code compatibility, and fast construction.	thermal and sound isolation, environmental compatibility	Life Cycle Cost
[34]	Resource availability, human-related factors, tender problems, quality of work, technical knowledge, timeliness of performance, and project management.	External factors.	Budget management,
[37]	The number of activities, activity and project duration, total project time, and total number of laborers.	–	total project cost, indirect and direct cost per day, material cost
[33]	Technical aspect	Environmental aspect, social aspect	Economic aspect
[35]	Technical aspect, land use	Environmental aspect, social aspect	Economic aspect

2.2.3 Multi-Criteria Decision Support Systems in The Reconstruction Projects

In the aftermath of a disaster, a significant budget is usually allocated to support reconstruction projects. However, the limited funds mean that decision-makers must prioritize which projects to allocate funding to [4]. Building renovation projects involve a series of decisions spanning various phases, including building selection, renovation design, alternative selection, construction, operation, usage, and eventual demolition or reuse.

Multi-criteria decision-making (MCDM) is a decision-making approach specifically designed to handle situations where multiple objectives need to be considered, even when these objectives may conflict with one another. By employing MCDM techniques, decision-makers can navigate the complexities of decision-making in building renovation, effectively balancing and prioritizing different objectives to achieve desired outcomes [39].

This section presents a literature review focused on the application of Multi-Criteria Decision-Making (MCDM) methods in the context of reconstruction projects. Specifically, the review emphasizes the importance of considering all relevant dimensions, including technical, environmental-social, and economic aspects, in order to comprehensively address the complexities associated with such projects.

2.2.3.1 Applications in Renovation Practices

[40] develops a specialized multi-criteria decision support method tailored for housing renovation. The method considers a range of factors beyond the traditional environmental and economic variables, incorporating technical and social parameters that influence the selection of renovation strategies. By comprehensively evaluating and quantifying the multidisciplinary performance of various renovation options, this method assists in decision-making regarding the extent and design of the renovation work. The identified factors include duration, scale, technical complexity, relocation, social concerns, noise and nuisance, waste production, energy reduction, standard improvements, and visual change. By considering these factors, stakeholders can make informed choices that address not only environmental and economic aspects but also

technical and social considerations, contributing to more effective and well-rounded housing renovation projects.

To address sustainability in building renovation, [41] adopts a comprehensive approach. The study involves a literature review, exploration of existing assessment methods, individual and focus group interviews, and the application of Soft Systems Methodologies (SSM) with Value Focused Thinking (VFT). Through these methods, data related to sustainability objectives were collected, structured, and verified using a Delphi study. The paper presents the research outcomes, which include the development of a framework incorporating new categories, criteria, and indicators for assessing the sustainability of renovation projects. This framework can be applied throughout different project stages and serves as a decision-making tool and a means of communication with stakeholders. The study follows a consensus-based process, laying the groundwork for the future development of a Decision Support System (DSS) and assessment tool specifically tailored for building renovation contexts. The criteria considered in the framework encompass functionality (indoor comfort, energy efficiency, material and waste, water efficiency, pollution, quality of services), accountability (aesthetic, integrity, identity, security, sociality, spatial), and feasibility (investment cost, operation and maintenance cost, financial structures, flexibility and management, innovation, stakeholders' engagement, and education).

2.2.3.2 Applications in Retrofit Practices

To better selection of seismic retrofit of an under designed reinforced concrete (RC) structure, [42] demonstrates the application of a methodological framework. Various traditional and innovative strategies for retrofitting are available, each with different merits in terms of criteria such as installation and maintenance costs, application time, performance, durability, and invasiveness. Selecting the most suitable solution for a specific case is often challenging due to the non-commensurable and conflicting nature of these criteria, necessitating the use of multi-criteria decision-making (MCDM) techniques. The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method is commonly employed in such cases, while the eigenvalue approach is utilized to determine the relative importance (weights) of the criteria. The

considered factors encompass both social/economical aspects (installation cost, maintenance cost, duration of works/disruption of use, functional compatibility) and technical considerations (skilled labour requirement/technology level, size of foundation intervention, risk of significant and limited damage). By employing this methodological framework and considering the relevant factors, decision-makers can make informed choices when retrofitting RC structures, leading to more effective and satisfactory outcomes.

In the same context, [43] presents a process for developing a decision support tool that automates the generation and ranking of building retrofit alternatives. The tool incorporates energy performance analysis, user requirements, relevant benchmarks, and regulations. The process involves several steps, starting with the creation of a Building Information Model representing the current state of the building. Different retrofit scenarios are then generated and refined. The multi-criteria approach based on TOPSIS is adopted to rank the alternatives, considering criteria such as energy performance, physical properties, economics/cost, comfort and wellbeing, renewable energy systems usage, project management and operations, qualitative aesthetic and appearance, and artistic or professional excellence. The developed decision support tool aims to assist in making informed retrofit decisions by evaluating various criteria and identifying the most favourable alternatives.

This time by using The Analytic Hierarchy Process (AHP), [44] proposes an effective decision-making method for selecting the best retrofit alternative for low-rise buildings. The study categorizes the effective criteria into structural, operational, economic, and functional categories. Sixteen sub-criteria are identified as a comprehensive pattern that considers the perspectives of various stakeholders involved in low-rise building retrofitting, including structural and architectural engineers, contractors, clients, and authorities. The sub-criteria include factors such as drift, ductility, irregularity, compatibility, foundation changes, lateral strength, availability, rate of demolition, quality assurance, downtime, vulnerability, cost of materials, cost of operation, cost of maintenance, disruption, and aesthetic. A pair-wise comparison matrix is utilized to determine the weight of each criterion and to score the alternatives based on each criterion. A Fuzzy Importance scale with Triangular Fuzzy Numbers (TFN) is employed to compare the criteria. The proposed method is applied to a case

study, demonstrating its usefulness in assisting designers in selecting the most appropriate retrofit alternative.

Meanwhile, [45] focuses on identifying the optimal retrofitting alternative for a school campus consisting of buildings constructed in the 1980s, following the seismic code of that time. The authors conducted an extensive experimental campaign involving in situ and laboratory testing to gain knowledge about the key structural elements. Various retrofitting options were considered, and two Multi-Criteria Decision Making (MCDM) methods, VIKOR and TOPSIS, were applied and compared to determine the best solution. Given the current use of the buildings, minimizing disruption to occupancy was a critical consideration. Safety conditions and operational phases during the construction site were also given significant attention. The criteria employed in the decision-making process included installation cost, maintenance cost, functional and architectural compatibility, disruption of use, technology level and feasibility, damage risk limitation, possible upgrade working processes, and safety.

By combining technical analysis and MCDM processes, [46] provides insights into the selection of optimal retrofit solutions for seismically deficient Reinforced Concrete (RC) buildings. Furthermore, the study argues for the explicit consideration of seismic economic losses as a crucial decision criterion. To derive fragility/vulnerability curves, three progressively refined structural analysis methods are employed: Simple Lateral Mechanism Analysis (SLaMA), numerical pushover analysis, and non-linear time-history analysis. A seismically deficient RC school index building, representative of typical construction found in developing countries, serves as the case study. The building is retrofitted using concrete jacketing, addition of concrete walls, and addition of steel braces, all designed through Direct Displacement-Based Design. The MCDM analysis is conducted by incorporating various criteria, including intensity-based losses derived from the three considered structural analysis methods. The criteria considered in the analysis encompass total retrofit cost, maintenance cost, retrofit duration, functional compatibility, need for specialized labour, intervention on foundations, and loss.

In more comprehensive way, [47] explores the application of three Multi-Criteria Decision-Making (MCDM) methods to determine optimal solutions for seismic upgrading of existing reinforced concrete frames and vertical addition of existing

masonry buildings. The MCDM methods employed are ELECTRE, TOPSIS, and VIKOR. The study considers seven performance criteria, categorized as quantitative criteria that can be numerically assessed and qualitative criteria that require verbal assessments converted into numerical values for inclusion in the decision matrix. The criteria include the cost of intervention, reduction of vulnerability, feasibility of the intervention, disturbance to the occupiers, functional and aesthetic compatibility, reversibility, and protection from damage. The utilization of these MCDM methods and criteria aids in decision-making processes for selecting the most suitable strategies for seismic upgrading and vertical addition projects.

While [48] focuses on the development of an Analytic Hierarchy Process (AHP) model to facilitate decision-making in the seismic retrofitting of industrial buildings. The model goes beyond considering solely the outcomes of seismic analysis and engineering evaluations; it also incorporates socio-economic factors such as production downtime, which are appropriately weighted. To validate the effectiveness of the model, a case study is conducted, involving the analysis of three alternative retrofitting solutions for a one-story building. The building in the case study has a simple and geometrically regular structural design, constructed using reinforced concrete precast elements. The criteria utilized in the model encompass vulnerability, compatibility, reversibility, tangible costs, and intangible costs.

2.2.3.3 Applications In Repair and Maintenance Practices

For better repair and maintenance (R&M) practices, [49] determines and prioritizes the key criteria for selecting appropriate (R&M) methods for Commercial Buildings (CBs), a significant challenge in the Architecture, Engineering, Construction, and Facility Management (AEC/FM) industry. To achieve this, a Delphi survey was conducted with 20 senior experts from the AEC/FM industry and CBs in Iran. The survey aimed to gather their perceptions and opinions regarding the selection criteria. A total of 16 individual criteria were identified and categorized into five groups: human resources, flexibility and technical capability, risks, cost of maintenance, and facilities and technology. To prioritize these criteria, the Fuzzy Analytic Hierarchy Process (FAHP) technique was employed. The identified criteria include aspects such

as satisfaction and organizational culture (human resources), ease of implementation and structural condition (flexibility and technical capability), identification of malicious factors and environmentally friendliness (risks), energy-saving and legal issues (cost of maintenance), and management/integration and presence of necessary equipment (facilities and technology). By applying the FAHP technique, decision-makers can effectively prioritize these criteria and make informed decisions when selecting R&M methods for CBs, thereby improving the overall maintenance process. [50] presents a review of bridge management decision-making processes for maintenance and rehabilitation activities, highlighting the multiple criteria nature of such problems. It emphasizes the importance of incorporating multiple and conflicting criteria into the decision-making process. The Analytic Hierarchy Process (AHP) is analysed, and a modified version of AHP is proposed to address uncertainty associated with relative importance values and to ensure consistent evaluations. The modified AHP method is applied to evaluate and rank alternative bridge rehabilitation strategies, using a real case study from the industry to demonstrate its practicality and validity. The results of the case study indicate that the developed decision support method effectively evaluates and selects appropriate alternatives for bridge deck improvement projects. The criteria considered in the evaluation include agency cost, user cost, safety, useful life, and environmental impact.

2.2.3.4 Applications In Risk Mitigation and Procurement Methods

Aiming to prioritize seismic risk mitigation, [51] presents the utilization of Multi-Criteria Decision Analysis (MCDA) methods applied in Wellington, the earthquake-prone capital city of New Zealand. Seismic risk mitigation, involving retrofitting or demolitions, is a critical requirement in numerous cities located along the Pacific Rim and other high seismic hazard areas. The proposed prioritization strategy, based on MCDA methods (TOPSIS, and VIKOR), offers a rapid and dependable decision support tool for policymakers, enabling them to determine the optimal sequence for their retrofitting programs. The study illustrates how various measures, grouped under four overarching criteria - life safety, geospatial role, economic role, and socio-cultural role - can be effectively incorporated into a practical framework for establishing

intervention policy priorities. Key criteria considered include the building's location, flooring systems, age/type, height, community significance, improvement value, and function.

Moreover, [52] identifies nineteen procurement selection criteria and highlights four prominent procurement methods used by public universities: outsourcing by specialist term contract, outsourcing by tendered schedule term contract, outsourcing by repair and maintenance contract, and outsourcing by measured term contract. The decision-making framework is developed using the Analytic Hierarchy Process (AHP) technique and Expert Choice Software to integrate the criteria and alternatives. The framework is then validated through structured interviews conducted with selected public universities. The validation process ensures that the developed framework is effective and applicable in real-world scenarios. The identified criteria encompass various aspects such as contractor availability, quality level, financial capability, time certainty, public accountability, scope clarity, and government policies.

The significance of decision-makers prioritizing technical and energy efficiency aspects in reconstruction projects has been observed. These considerations demonstrate a commitment to ensuring the improved performance and sustainability of the reconstructed structures. However, it is important to recognize that the level of stakeholder participation varies greatly among different reconstruction projects, indicating the uniqueness of each case.

The insights and methodologies presented in the reviewed studies provide valuable guidance for practitioners and decision-makers in navigating the complexities of reconstruction projects. In the reviewed literature, several key criteria have been identified and employed to assess and guide reconstruction projects. These criteria encompass a wide range of factors that influence the decision-making process. Table 2.3 provides a comprehensive summary of these criteria, offering valuable insights into their significance and relevance.

Table 2.3 Main MCDM criteria used in the reconstruction projects.

<i>Source</i>	<i>Technical</i>	<i>Environmental / Social</i>	<i>Economic</i>
[40]	Duration, scale, technical complexity, relocation, standard improvements, and visual change	social concerns, noise and nuisance, waste production, energy reduction	
[42]	Application time, Performance, Durability		Installation and maintenance costs
[49]	ease of implementation and structural condition identification of malicious factors and presence of necessary equipment	Satisfaction, organizational culture, environmentally friendliness, energy-saving and legal issues	cost of maintenance
[52]	Contractor availability, quality level, time certainty and scope clarity	Public accountability and government policies	Financial capability
[50]	Safety and useful life	environmental impact	agency cost and user cost
[41]	Flexibility, management, innovation, and stakeholders' engagement.	indoor comfort, energy efficiency, material and waste, water efficiency, pollution, quality of services, aesthetic, integrity, identity, security, sociality.	investment cost, operation and maintenance cost, financial structures.
[47]	Reduction of vulnerability, feasibility of the intervention, reversibility, and protection from damage	Disturbance to the occupiers, functional and aesthetic compatibility	Cost of intervention
[43]	Physical properties, project management and operations.	energy performance, comfort and wellbeing, renewable energy systems usage, qualitative aesthetic and appearance, and Neighbourhood.	Economics/cost

Table 2.3 Main MCDM criteria used in the reconstruction projects (Continued)

<i>Source</i>	<i>Technical</i>	<i>Environmental / Social</i>	<i>Economic</i>
[44]	Drift, ductility, irregularity, compatibility, foundation changes, lateral strength, availability, rate of demolition, quality assurance, downtime, vulnerability.	Disruption, and aesthetic	Cost of materials, cost of operation, cost of maintenance.
[45]	Technology level and feasibility, damage risk limitation, possible upgrade working processes.	Safety, functional and architectural compatibility, disruption of use.	Installation cost, maintenance cost.
[46]	Retrofit duration, need for specialized labor, intervention on foundations	Functional compatibility	Total retrofit cost, maintenance cost and loss.
[51]	Flooring systems, Lateral systems	Building's location age/type, height, and community significance	Improvement value, and function
[48]	vulnerability, reversibility compatibility (Structural)	Compatibility (functional, architectural)	Tangible costs, and intangible costs

2.2.4 Multi-Criteria Decision Support Systems in The Reconstruction Projects in Iraq

The decision-making process in these projects often relies on knowledge-based or single criteria decision-making techniques, with a predominant focus on the technical aspect, particularly through structural assessments. In some cases, initial cost assessments are also employed as part of the decision-making process [53]. However, it is important to note that this approach, which predominantly emphasizes the technical dimension and initial cost considerations, presents limitations in fully addressing the complexities and multidimensional nature of reconstruction projects. By solely focusing on structural assessments and initial cost estimates, other crucial aspects such as environmental, social, and long-term economic factors may be

overlooked. In the context of reconstruction projects in Iraq, the managerial aspect continues to encounter significant obstacles that hinder its overall performance.

Post-conflict reconstruction in Iraq presents several challenges that need to be addressed to ensure effective and efficient rebuilding of public buildings. One of the key challenges is the coordination between various competent authorities involved in the reconstruction process. Limited financial support is another significant constraint, often leading to rationing of resources and necessitating minimal intervention [54]. The prevailing difficult security conditions further impede the movement of personnel and transportation of essential materials, hampering the reconstruction efforts. Additionally, there is a shortage of experienced staff, which can hinder the successful implementation of reconstruction projects. The limited period for reconstruction does not allow for a comprehensive review and audit of the original building design. Moreover, accessing technical documents related to the building's construction and maintenance history can be problematic, hindering the decision-making process during reconstruction [55].

According to [56], contractor-related problems were the top-ranking issues. The following sub-issues were identified as the dominant ones within this broad category: 1) lack of leadership capabilities and skills, 2) lack of standards for human resources management, 3) lack of education in what drives performance, 4) lack of skills in dealing with time limitations, 5) lack of building of harmonic work teams, 6) lack of vision of how to deal with the owner, external parties, and the work teams, and 7) lack of strategic planning of the work performed by subcontracting companies.

Nevertheless, several studies have been conducted to address the prioritization of reconstruction projects and assess the effectiveness of the proposed plans. These studies aim to provide valuable insights and guidance for decision-makers involved in the reconstruction process. This evaluation process assists decision-makers in identifying potential shortcomings or areas of improvement in the proposed plans, ensuring that they meet the desired objectives and align with the broader goals of reconstruction.

[3] identified suitable planning policies for the reconstruction and rehabilitation of the city of Ramadi. Three development policies were proposed: modernization policy, urban renewal policy, and the policy of renewing residential neighborhoods, along

with a policy of pairing between old and new planning. The study utilized the Analytical Hierarchy Process (AHP), a quantitative analysis method, to evaluate the proposed policies. A direct questionnaire was administered to experts and planning specialists to gather their opinions. The criteria used for evaluation included sustainability planning, restoration of technical and infrastructure services, addressing structural imbalances, and flexibility with the general reconstruction plan. The findings revealed that the policy of combining old and new planning, while considering urbanization, emerged as the most favourable option among the proposed policies. This policy was deemed the best in terms of meeting the criteria and was supported by the credibility and reliability of the results obtained through the AHP analysis.

2.2.5 Insights on the Use of Multi-Criteria Decision Support Systems

In the international construction field, various decision-making techniques have been widely adopted to support informed choices. Among the commonly utilized methods are Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), Analytic Hierarchy Process (AHP), and Analytic Network Process (ANP). These techniques have found application in addressing complex decision problems and evaluating alternatives in construction projects.

TOPSIS has emerged as the most frequently employed method, owing to its ability to determine the best alternative by measuring the distances between each alternative and the ideal solution.

Conversely, in Iraq, the preference for decision-making methods in the construction field aligns with the Analytic Hierarchy Process (AHP) and COmplex PROportional ASsessment of alternatives (COPRAS). These methods are favoured for their suitability in addressing the specific decision requirements and challenges faced in the Iraqi construction context. AHP provides a structured approach to handle complex decision hierarchies and supports the integration of multiple criteria, allowing decision-makers to prioritize alternatives effectively. COPRAS, on the other hand, offers a robust approach for assessing complex decision problems with imprecise and uncertain information, making it well-suited for the Iraqi construction context.

In the field of reconstruction, where the focus is on rebuilding and revitalizing areas affected by disasters or conflicts, several decision-making methods are prevalent. Among the most employed techniques are TOPSIS, AHP, and VlseKriterijumska Optimizacija I Kompromisno Resenje – VIKOR (that means: Multicriteria Optimization and Compromise Solution).

These methods provide valuable support in assessing reconstruction alternatives and prioritizing interventions based on multiple criteria. TOPSIS, similar to its application in the broader construction field, aids in determining the optimal alternative by measuring the proximity to the ideal solution. AHP, with its ability to handle complex decision hierarchies, enables decision-makers to systematically evaluate and compare reconstruction options. VIKOR, known for its capability to handle conflicting objectives, proves beneficial in situations where trade-offs need to be made among different criteria to achieve a satisfactory solution.

Table 2.4 provides a comprehensive overview of the Multi-Criteria Decision-Making (MCDM) techniques and tools utilized in the research field. It highlights the various methods and tools employed to facilitate decision-making processes and evaluate alternatives based on multiple criteria. The table serves as a valuable reference point, highlighting the range of MCDM approaches employed in the reviewed studies, thereby contributing to the understanding of their application in the context of the research topic.

Table 2.4 MCDM Techniques and tools used in the reviewed studies.

	<i>MCDM Method / Tool</i>	<i>Research Field</i>	<i>Source</i>
MCDM in construction projects (Globally)	TOPSIS	Structural Systems	[28]
	PROMETHEE using GAIA analytical tool		[30]
	Combining ELECTRE III and PROMETHEE II		[31]
	COPRAS		[29]
	EDAS+ by combining NGT technique and Delphi-based method	Structural Elements	[32]

Table 2.4 MCDM Techniques and tools used in the reviewed studies (Continued)

	<i>MCDM Method / Tool</i>	<i>Research Field</i>	<i>Source</i>
MCDM in construction projects (Globally)	Creating KDSMS system based on TOPSIS		[21]
	Combining AHP, TOPSIS, and VIKOR in a fuzzy environment creating a DSS software.	Construction	[19]
	ANP, PROMETHEE	Materials	[20]
	DEMATEL, ANP and TOPSIS		[23]
	Super Decisions software based on ANP		[22]
	Combining AHP and Permutation methods	Construction	[24]
	the Integrated Value Model for Sustainable Assessment MIVES	Technology	[25]
	AHP, PROMETHEE, MAUT, and DEA	Construction Management	[27]
	DEMATEL, ANP and ZOGP	Construction Quality	[26]
	COPRAS-G		[36]
MCDM in construction projects (Iraq)	COPRAS, and ROC	Project	[34]
	Concurrency-Partitioning and Crashing Techniques CPCT using MATLAB software	Management	[37]
	Fuzzy AHP and Fuzzy TOPSIS	Project Design	[35]
	AHP using Evaluation and Selection of Engineering Equipment Suppliers ESEES	Construction Management	[1]
	AHP	Construction Materials	[33]
	Value Engineering using Excel Software	Structural Systems	[38]

Table 2.4 MCDM Techniques and tools used in the reviewed studies (Continued)

	<i>MCDM Method / Tool</i>	<i>Research Field</i>	<i>Source</i>
MCDM in reconstruction projects (Globally)	Soft Systems Methodologies SSM, Value Focused Thinking VFT and Delphi.	Renovation	[41]
	Multi-criteria assessment and feasibility analysis.		[40]
	TOPSIS		[42]
	ELECTRE, TOPSIS, and VIKOR		[47]
	TOPSIS creating VB.NET Software		[43]
	AHP and TFN	Retrofit	[44]
	TOPSIS and VIKOR		[45]
	Simple Lateral Mechanism Analysis SLaMA		[46]
	AHP		[48]
	TOPSIS and VIKOR	Risk Mitigation	[51]
	AHP		[50]
	FAHP and Delphi using SPSS and Excel software	Repair and maintenance	[49]
	AHP creating Expert Choice Software	Procurement methods	[52]

2.3 Public Buildings Reconstruction in Iraq

Public buildings encompass a wide range of structures and facilities that serve the collective needs of a community or society. These include but are not limited to government offices, hospitals, schools, and cultural centres. In the context of post-conflict reconstruction, public buildings take on added significance due to their critical role in re-establishing essential services and fostering social cohesion.

Public buildings hold extra importance in the reconstruction efforts in Iraq for several reasons. Firstly, they are the physical embodiments of essential public services. Government offices are the administrative hubs for governance and the provision of public services. Hospitals and clinics offer vital healthcare services, particularly crucial in post-conflict settings with increased health needs. Schools and educational

institutions pave the way for a brighter future by providing children with access to education, ensuring continuity and stability.

In Iraq, the impact of public buildings on the overall reconstruction process is profound. They are not merely physical structures but symbols of resilience, representing the re-establishment of normalcy after conflict. Their rehabilitation and reconstruction signify progress and stability. Additionally, public buildings play a pivotal role in fostering social cohesion and community resilience. They are spaces where people gather, interact, and access essential services, thereby contributing to the overall well-being and sense of security among citizens [3].

These structures serve as vital components of a functioning society, addressing essential needs such as healthcare, education, governance, and cultural heritage preservation. Their restoration not only signifies the physical rebuilding of infrastructure but also represents the revival of essential public services and the restoration of a sense of normalcy in war-torn regions. The focus on public buildings in this study is rooted in their centrality to the post-conflict reconstruction process [57]. Furthermore, the study acknowledges that effective decision-making in this specific domain can have far-reaching effects, positively influencing the recovery and development of war-torn regions like Iraq.

2.4 Damage Assessment in Reconstruction Projects in Iraq

The damage assessment process typically involves a multidisciplinary approach, combining expertise from structural engineers, architects, and relevant stakeholders. According to [53] the damage assessment begins with a visual inspection of the building's exterior and interior, examining the structural elements, walls, roofs, floors, foundations, and non-structural components as the initial inspection helps identify visible signs of damage, such as cracks, deformations, displacement, or water intrusion.

If a damage was noticed in the structural elements a non-destructive testing method were implemented such as ultrasonic testing to assess hidden damage or structural integrity. The post-damage assessment of structural elements, particularly through non-destructive testing (NDT), is essential for evaluating their ability to fulfil their

intended function over time. It focuses on the residual condition of structures following damage, with a specific emphasis on their long-term strength and serviceability performance [55]. Accurately assessing the loss of strength in structural elements after a damage event is crucial for effective rehabilitation and maintenance processes. This assessment provides valuable insights into the structural health of the building and informs decisions regarding repair, ensuring the structure's continued functionality and safety. The assessment process of a building involves evaluating its functionality and compliance with safety standards and regulations [58].

After completing the assessment, a comprehensive report is generated, documenting the findings with supporting evidence such as photographs and measurements. The outcomes of the reports are the percentage and descriptive evaluation of the damage in the building including all structural and non-structural elements. The report tries to evaluate the amount of financial and functional losses in the building. The report also includes recommended actions for addressing any identified issues or deficiencies [53].

2.5 Intervention Methods and Criteria Used

Various intervention methods have been employed to repair, strengthen, and restore these damaged structures. The selection of intervention methods depends on several factors, including the extent of damage, structural conditions, available resources, and the specific requirements of each building [53].

Commonly, repair methods involve repairing damaged components of the building, to restore their functionality and structural integrity. Strengthening techniques are applied when the structural stability of the building has been compromised. These methods aim to enhance the building's resistance to future damage by adding additional supports or reinforcing existing elements. In severe cases where the damage is extensive or poses significant safety risks, reconstruction may be necessary. This involves demolishing the damaged structure and rebuilding it using new materials and construction techniques, ensuring compliance with safety standards and regulations [59].

The most common intervention methods for damaged public buildings are full or partial demolition and reconstruction, and repair. The choice between these methods is often influenced by the availability of financial resources. If sufficient resources are available, reconstruction is typically chosen as the preferred option. On the other hand, if financial resources are limited, the repair option is usually pursued. Repair involves selectively addressing the specific areas or components of the building that have been damaged, without undertaking a complete reconstruction [53].

During interventions for damaged public buildings, it is important to consider not only the functional aspects but also the symbolic, social, and environmental significance of the building. However, it has been observed that in many cases, the demolition option is often preferred without giving sufficient attention to these aspects. The symbolic value of a building holds cultural, historical, and architectural importance that contributes to the identity and heritage of a community.

Preservation and restoration of these symbolic structures can foster a sense of pride, continuity, and cultural identity among the people [54]. Public buildings often serve as gathering spaces and community hubs, playing a vital role in the social fabric of a neighbourhood or city. The loss of such buildings can disrupt social connections and community cohesion. Demolition and reconstruction can have significant environmental implications, including the generation of construction waste, increased energy consumption, and the loss of embodied energy in the existing structure. Adopting sustainable practices such as adaptive reuse, retrofitting, or incorporating environmentally friendly materials can minimize the environmental footprint and promote sustainable development [60].

[55] outlines several practices commonly used in Iraq for building intervention. These include strengthening and repair techniques like jacketing, applying Carbon Fiber Reinforced Polymer (CFRP), or incorporating steel supporting elements. Reconstruction practices involve partial or full demolition and rebuilding of the structure. Additionally, there are practices that involve modifying the building's design during the reconstruction or repair process. These interventions aim to enhance the structural integrity and address damage to ensure the safety and functionality of the building.

[53] highlight six key factors: building condition, funding availability, time needed, meeting the intended function, resource availability, and total cost. Assessing the building's structural integrity and safety, along with available financial resources, influences the chosen approach—whether reconstruction or repair. Minimizing downtime and efficiently serving the building's intended purpose are vital considerations. Evaluating the availability of skilled labour, materials, and technology enables effective planning. Additionally, managing costs and adhering to budget constraints is crucial for a sustainable reconstruction process. Overall, a thorough evaluation of these criteria empowers decision-makers to make informed choices that lead to successful reconstruction projects, benefitting communities in Iraq.

2.6 Gaps in the Existing Literature

The critical review highlights unresolved challenges and research gaps in the area of post-disaster reconstruction, particularly regarding project selection. Despite existing studies being a first step towards understanding post-disaster reconstruction planning, more attention needs to be given to phase selection in situations where constraints prevent all project phases from beginning concurrently. There are also gaps in the use of methodologies and techniques for way of intervention selection, as existing studies have mainly relied on one technique.

Therefore, more integrated techniques for challenging way of intervention selection, particularly in post-disaster reconstruction projects, are needed to achieve specific goals. The insufficient focus on the Iraqi context in the existing literature is particularly problematic. Iraq's history of conflict, diverse sociocultural landscape, and unique challenges in governance and security require research that acknowledges these specificities. A one-size-fits-all approach does not apply in post-conflict settings, and understanding the nuances of Iraq's reconstruction environment is crucial for developing effective strategies.

Furthermore, the importance of stakeholder engagement and participation in decision-making cannot be overstated. In post-conflict settings, trust-building, inclusivity, and local ownership are paramount for sustainable reconstruction. Yet, many studies in the

literature do not adequately explore these dimensions, potentially neglecting the voices and needs of affected communities.

The limited exploration of intervention methods is another significant gap. Different projects may require tailored approaches, and understanding the strengths and weaknesses of various methods is vital for informed choices. Additionally, the sparse attention to decision flexibility underscores the need for adaptable tools that can accommodate changing circumstances, which are prevalent in post-conflict scenarios. the literature often lacks detailed case studies that evaluate the effectiveness of different intervention methods in real-world Iraqi reconstruction contexts. This gap hinders the identification of best practices and lessons learned, which are crucial for informing future decision-making processes.

The literature often lacks detailed case studies that evaluate the effectiveness of different intervention methods in real-world Iraqi reconstruction contexts. This gap hinders the identification of best practices and lessons learned, which are crucial for informing future decision-making processes.

As was illustrated in the previous analysis, The application of MCDM techniques in the reconstruction projects offers several significant benefits, contributing to more effective and sustainable decision-making processes. Through a systematic and transparent framework, MCDM enables decision-makers to consider multiple criteria simultaneously, including economic feasibility, social impact, environmental sustainability, cultural relevance, and technical feasibility.

While considerable research exists on the application of Multi-Criteria Decision-Making (MCDM) in the construction industry, it is notable that a limited number of studies emphasize multiple aspects of the decision-making process. Most of the research tends to focus on specific criteria or individual factors, overlooking the comprehensive nature of decision-making in construction projects. Consequently, there is a need for further exploration and investigation into the integration of various aspects within the MCDM framework to enhance decision-making effectiveness in the construction industry.

The application of Multi-Criteria Decision-Making (MCDM) in reconstruction projects, has been significantly overlooked in Iraq, as evidenced by the scarcity of previous studies. The limited focus on environmental and social aspects, coupled with

an exclusive emphasis on initial costs within the economic aspect, has led to erroneous decision-making practices. Furthermore, the pervasive issues of corruption and inadequate technological resources have further complicated matters, increasing the likelihood of resource wastage.

There are notable gaps in the existing literature concerning damage assessment. Firstly, limited attention has been paid to the development and application of comprehensive methodologies specifically tailored to the Iraqi context. Existing studies often draw from generic approaches, failing to consider the unique challenges posed by Iraq's complex history of conflict and diverse sociocultural landscape. Secondly, there is a dearth of research on the integration of emerging technologies, such as remote sensing and geographic information systems (GIS), into damage assessment processes.

CHAPTER 3

THE DECISION SUPPORT TOOL

This chapter provides a detailed account of the criteria suggested for the development of the proposed decision-making tool, which has been carefully informed by insights from experts' opinions and a comprehensive literature review. Furthermore, the chapter delves into the significance of assigning appropriate weights to the identified criteria. The weighting process plays a crucial role in reflecting the diverse priorities and objectives of reconstruction projects, enabling stakeholders to tailor their interventions in line with the unique context of each endeavour. Moreover, the chapter expounds upon the meticulous design and structure of the decision-making tool. Incorporating user-friendly interfaces, data visualization features, and user-customizable options, the tool aims to provide a seamless and efficient platform for decision-makers.

In this chapter, we present the criteria proposed and their respective weighting, which are derived from insights gathered through expert interviews. The interview questionnaires encompassed four key sections: MCDM in Reconstruction Projects, MCDM Tools, Criteria, and Intervention Methods. Comprehensive lists of the questions posed, and the corresponding answers provided by the experts can be found in the appendices. These interviews constitute a fundamental component of our research, offering valuable perspectives and expertise to inform the development of a robust Multi-Criteria Decision-Making (MCDM) tool for use in public building reconstruction projects in our context.

3.1 Criteria Suggested

The suggested criteria for the tool include three main categories: Criteria used in the field of reconstruction projects in Iraq, Criteria used in previous MCDM applications in construction projects in Iraq, and Criteria used in previous MCDM applications globally in reconstruction projects.

These diverse sets of criteria aim to provide a comprehensive and context-sensitive framework for evaluating reconstruction projects in Iraq, considering technical, social, economic, and environmental aspects to foster resilient and sustainable outcomes.

3.1.1 Criteria used in the field of reconstruction projects in Iraq

The insights derived from interviews with experts in the field of reconstruction in Iraq shed light on the fundamental criteria that serve as the cornerstones of decision-making processes. Each criterion plays a critical and interconnected role in shaping the trajectory of reconstruction initiatives. Follows are the significance of each criterion and their collective impact on the decision-making landscape in Iraq.

1. **Building condition:** emerged as a foundational criterion, encompassing the structural integrity and stability of the existing infrastructure. Given the damage caused by conflict, assessing the condition of buildings is paramount in determining the feasibility of reconstruction and the required intervention strategies.
2. **Meeting the funding conditions:** this holds significant importance in a resource-constrained environment. With financial resources often limited in post-conflict regions, adhering to the requirements and conditions set forth by funding authorities becomes essential to secure financial support for reconstruction projects.
3. **Time requirements:** the urgency to restore public buildings to their functional state is evident in post-conflict scenarios. Timely completion of reconstruction projects is essential to restore essential services and instil a sense of normalcy in the lives of affected communities.
4. **Meeting the building required function:** encompasses the careful assessment of the intended purpose and functionality of the structure. Understanding the specific needs and demands of the community ensures that reconstruction efforts align with their aspirations, leading to enhanced usability and long-term benefits.

5. Availability of financial and human resources: assessing the availability of skilled labour, technical expertise, and financial backing is essential to devise realistic and achievable reconstruction plans.
6. Cost: evaluating the total cost of reconstruction, considering all necessary resources and expenditures (including all life cycle costs), is pivotal in establishing project feasibility and ensuring financial sustainability.

3.1.2 Criteria used in previous MCDM Application in construction projects in Iraq

Building upon the preceding application of MCDM in construction projects, the inclusion of additional criteria becomes imperative to comprehensively address the complexities inherent in the post-conflict reconstruction context. In this regard, three key criteria merit special attention:

1. Maintainability: assumes significance as it pertains to the long-term sustainability and durability of reconstructed public buildings. The consideration of maintenance requirements and strategies during the decision-making process minimizes the need for frequent repairs.
2. Maximization of functionality: recognizing the evolving needs of communities and adapting the reconstructed structure to accommodate future requirements. A flexible design that allows for potential expansions or adaptive reuse provides resilience and ensures the building remains relevant and responsive to changing demands.
3. Availability of Knowledge and Technology: the extent to which relevant knowledge, information, and technological resources are accessible and utilized in each decision-making process. This entails having up-to-date data on building materials, construction techniques, structural systems, relevant regulations and required technology.

3.1.3 Criteria used in previous MCDM Application in global reconstruction projects

To make informed decisions, several factors need to be considered. Firstly, the situation related to the consequences of the disaster needs to be assessed, including the state of buildings and accessibility of affected areas. Secondly, the needs of the affected inhabitants must be estimated, considering the targeted future situation and the sectors concerned by reconstruction projects. Lastly, specific details of each reconstruction project, including location, requested funds, and provided services, must be taken into account and weighed against the population's needs [4].

In response to the growing emphasis on social and environmental considerations in reconstruction projects, it becomes imperative to broaden the criteria for decision-making. Building upon the lessons learned from previous applications of MCDM in reconstruction projects worldwide, two significant criteria have been identified: User Satisfaction and Energy Efficiency.

1. **User Satisfaction:** reflecting the degree to which the reconstructed building meets the needs and preferences of its users. Ensuring that the building design accommodates the requirements and aspirations of the community contributes to their well-being and fosters a sense of ownership and pride.
2. **Energy Efficiency:** The integration of energy-efficient technologies and design principles minimizes the building's environmental footprint, reduces energy consumption, and lowers operational costs.
3. **Emissions:** The level of pollutants and harmful emissions released into the environment during the project's implementation and operation. During the decision-making process, stakeholders consider the emissions criterion to ensure that the chosen alternative minimizes its negative environmental impact and adheres to regulatory standards.

Following are Table 3.1 and Table 3.2, illustrating the criteria used in the suggested Multi-Criteria Decision-Making tool for reconstruction projects in Iraq.

Table 3.1 Criteria used in the suggested tool grouped by their sources.

Criteria	Source
Building condition	Current used Criteria (obtained from interview with experts)
Resources availability	
Time needed	
Meeting the required function	
Maintainability	
Total cost	Criteria used in previous MCDM Application in construction projects
Availability of Knowledge and Technology	
Meeting the funding Conditions	
Maximization of functionality	Criteria used in previous MCDM Application in global reconstruction projects
User Satisfaction	
Energy efficiency	
Emissions	

Table 3.2 Criteria Used in the suggested tool grouped by category.

Code	Criteria	Category
C1	Building condition	Technical
C2	Resources availability	
C3	Time needed	
C4	Meeting the required function	
C5	Maintainability	
C6	Availability of Knowledge and Technology	Economic
C7	Total cost	
C8	Meeting the funding Conditions	
C9	Maximization of functionality	Social
C10	User Satisfaction	
C11	Energy efficiency	Environmental
C12	Emissions	

3.2 Weighting the Suggested Criteria

The process of weighting the criteria involves soliciting the opinions and expertise of various stakeholders, including architects, engineers, government officials, and community members. These individuals possess valuable insights into the unique challenges and priorities of the reconstruction project.

In decision-making, objectives are defined as clear and concise statements that represent what is important in a given situation. Criteria, on the other hand, are specific metrics used to measure progress towards achieving the objectives. By clearly identifying objectives and criteria, decision-makers can better evaluate alternatives and make informed choices that align with their goals [9]. In order to prioritize different criteria according to overall objectives, weights are applied. It is recommended that the decision model is chosen before collecting preference weights, as the procedure may vary depending on the MCDA technique [9].

There are three types of weighting methods: equal weights, subjective weighting, and objective weighting. Equal weights are simple to apply and do not require much input yet can produce results nearly as good as optimal weighting methods. Subjective weighting allows decision-makers to assign priorities based on their preferences. Examples of subjective methods include AHP, SMART, and SECA. However, subjective techniques are prone to uncertainty due to differences in interpretations of the problem by different decision makers [12]. On the other hand, objective weighting uses given data, determines weighting factors and mathematical formulas based on the consistency and sensitivity of the data [12].

To determine the criteria weights, a series of structured interviews was conducted to gather the stakeholders' preferences. During these interactions, participants rank the criteria based on their perceived significance in achieving the project's objectives. The collected data are then analysed to calculate the relative weights of each criterion. The weighting process requires careful consideration and should consider not only the technical aspects but also the social, economic, and environmental factors that are relevant to the reconstruction project.

In this study, the weighting technique involved conducting interactions with participants to obtain their subjective rankings of the criteria's significance in

achieving the project's objectives. Through these interactions, each criterion was assigned a weight based on the participants' perceptions. It is essential for all the criteria's weights to sum up to one, as this ensures a consistent and standardized approach in the decision-making process.

The selection of this weighting technique aligns with the TOPSIS method, which was chosen as the decision-making technique for this study. TOPSIS requires the criteria to be weighted to calculate the overall performance score of alternatives accurately. Table 3.3 illustrates the suggested weights assigned to each criterion.

Table 3.3 Suggested Criteria Weights

Code	Criteria	Weight	%
C1	Building condition	15	0.15
C2	Resources availability	10	0.10
C3	Time needed	8	0.08
C4	Meeting the required function	8	0.08
C5	Maintainability	7	0.06
C6	Availability of Knowledge and Technology	10	0.10
C7	Total cost	7	0.08
C8	Meeting the funding Conditions	12	0.12
C9	Maximization of functionality	6	0.06
C10	User Satisfaction	5	0.05
C11	Energy efficiency	5	0.07
C12	Emissions	7	0.05

3.3 Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)

TOPSIS, a multicriteria decision-making method developed by Hwang and Yoon in 1981, aims to find the best alternative based on the closest distance to the ideal solution and furthest from the anti-ideal solution. This approach employs the Euclidean distance to evaluate the relative proximity of an alternative to the optimal solution [61].

The decision to utilize the TOPSIS technique in this case was based on several factors that contribute to its suitability and effectiveness in the context of reconstruction projects in Iraq.

- Firstly, TOPSIS has already gained widespread acceptance and application in the engineering community in the construction projects, making it a familiar and accessible method for decision-makers in the field. This familiarity reduces the need for extensive explanations and enhances the ease of implementation.
- Additionally, previous research by [19] indicated that TOPSIS is the most commonly used technique, reinforcing its relevance and applicability in this specific domain. By leveraging a well-established and frequently employed method, decision-makers can benefit from existing knowledge and experiences, leading to more informed and reliable decision-making.
- Moreover, the distance-based nature of the TOPSIS technique contributes to its efficiency as a decision support tool. By measuring the distances of alternatives from the ideal and negative ideal solutions, TOPSIS allows for a clear differentiation between alternatives, facilitating the identification of the best possible option. This efficiency is particularly valuable in reconstruction projects, where time constraints and resource limitations often demand a streamlined decision-making process.
- Furthermore, the simplicity and ease of implementation of TOPSIS have contributed to its widespread use, and its steps remain the same regardless of the number of attributes. Moreover, the method can be easily programmed and implemented using different software applications such as Microsoft Excel, Decerns MCDA, Scikit-Criteria, R, Online Output, and MATLAB makers [8].

TOPSIS is a multicriteria decision-making method that considers both the distance to the positive ideal solution (S_i^+) and the negative ideal solution (S_i^-) to determine the proximity of each alternative to the ideal solution. Based on this comparison, an alternative priority arrangement (A_i) can be achieved. The positive ideal solution (A^+) is defined as the sum of the best attainable values for each attribute, while the negative ideal solution (A^-) is the sum of the worst values [62]

As presented in Figure 3.1, after constructing the initial decision matrix with alternatives, criteria and their corresponding performance values, the procedure is as follows: [5]:

- Step 1: normalize the decision matrix to ensure all criteria are on a common scale for fair comparison.
- Step 2: the normalized decision matrix is multiplied by the criteria weights to create the weighted normalized decision matrix. This step accounts for the relative importance of each criterion in the decision-making process conducted in the previous section.
- Step 3: the positive and negative ideal solutions are determined. The positive ideal solution represents the best performance for each criterion, while the negative ideal solution represents the worst performance. These ideal solutions serve as benchmarks for evaluating the alternatives.
- Step 4: involves calculating the separation measures for each alternative. This measure quantifies the distance between each alternative and both the positive and negative ideal solutions. The goal is to find alternatives that are close to the positive ideal solution and far from the negative ideal solution, indicating superior performance.
- Step 5: computes the relative closeness coefficient for each alternative. This coefficient is determined by dividing the distance to the negative ideal solution by the sum of distances to both the positive and negative ideal solutions. The relative closeness coefficient represents how well each alternative compares to the ideal solutions, with higher values indicating better performance.

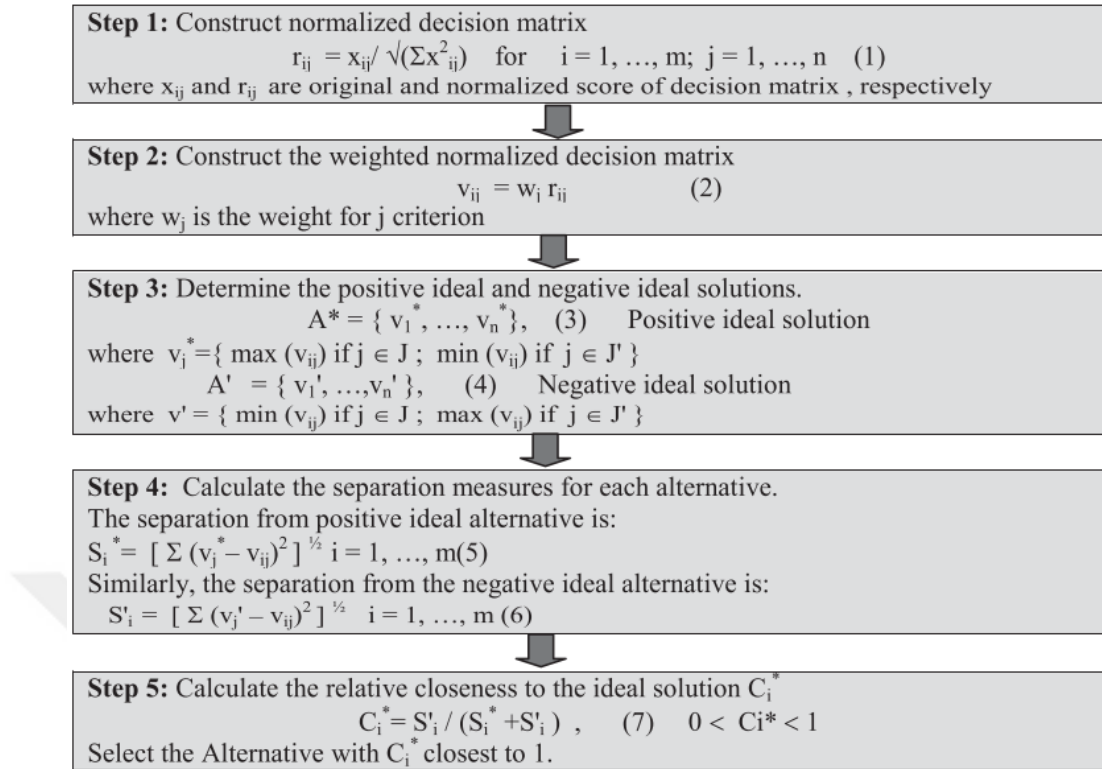


Figure 3.1 Main steps of TOPSIS methodology, Source:[5]

3.4 Design the MCDM supporting tool

Developing a user-friendly MCDM supporting tool can streamline decision-making processes and improve the efficiency of complex evaluations. In this section, we outline the design of an MCDM supporting tool using Python and Tkinter, with a focus on the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) method. It aids in comparing multiple alternatives based on their proximity to the ideal and farthest solution, making it well-suited for handling various decision-making scenarios.

When faced with complex decision-making scenarios, it can be challenging for individuals to effectively evaluate and rank multiple alternatives based on numerous criteria. Traditional manual methods for decision-making may be time-consuming, error-prone, and subject to personal biases. Therefore, there is a need for a user-friendly and efficient tool that applies the TOPSIS methodology to help users objectively assess and compare alternatives to make informed decisions.

The objective of this tool is to provide a user-friendly and interactive application that utilizes the TOPSIS methodology. The tool under the name of Reconstruction Project in Iraq: Multi criteria decision supporting tool, allows users to input data for various alternatives and criteria, assign appropriate weights to criteria, and identify whether each criterion represents a benefit or a cost. The application then calculates the TOPSIS scores for each alternative and presents the results in an easily interpretable format.

3.4.1 User Interface Design

The graphical user interface of the TOPSIS Tool is built using Tkinter. It consists of labels to display the alternatives and criteria names, entry fields for users to input criteria values, and option menus to select benefit or cost for each criterion. Additionally, buttons are provided for various actions, such as calculating TOPSIS scores, adding more alternatives or criteria, clearing the entries, and viewing performance scores.

3.4.1.1 Main Window:

The Main Window of the TOPSIS Tool serves as the primary interface where users can interact with the application and perform their decision-making tasks. It provides an intuitive and user-friendly environment to input data, customize settings, view results, and generate reports using the TOPSIS methodology. Figure 3.2 shows the main window of the program.

I. Alternatives and Criteria Input Section:

- On the left side of the Main Window, users can find a table representing the alternatives and criteria. The rows represent each alternative, while the columns represent each criterion.
- Users can input the performance values of each alternative with respect to each criterion in the provided entry fields. These values reflect how well each alternative performs in meeting the specific criterion.

II. *Criteria Weights and Benefit/Cost Selection*

- Just below the table, users can specify the importance of each criterion by entering their respective weights. These weights indicate the relative significance of each criterion in the decision-making process.
- For each criterion, users can choose whether it represents a benefit or cost using the dropdown menu. Selecting "Benefit" implies that higher values are preferred for the given criterion, while selecting "Cost" implies that lower values are preferred.

III. *Buttons and Actions*

Several buttons are available at the bottom of the Main Window to facilitate various actions:

- **Project Information:** When clicked, the button triggers a pop-up or a separate section within the UI where users can view and edit information such as project name, evaluator name, date, description, and any other pertinent metadata.
- **Calculate:** Clicking this button triggers the TOPSIS calculation, which computes the performance scores for each alternative based on the entered data and settings.
- **Clear:** This button allows users to clear all entered values in the Alternatives and Criteria Input Section, enabling them to start over with fresh data.
- **Manage Alternatives:** Clicking this button opens an external window that allows the user to manage alternatives. Users can add new alternatives, modify existing alternative names, and update their corresponding labels and entries.
- **Manage Criteria:** This button opens an external window where users can manage criteria. They can rename criteria, add new criteria, and modify existing ones.
- **Performance Score:** Clicking this button shows a table with the Euclidean distance from the ideal best, the Euclidean distance from the ideal worst, and the Performance Score for each alternative.

- How to Use: show an external window explains the program to enhance the user experience by providing accessible, user-friendly guidance for both new and returning users.
 - Reset: This button allows users to reset the TOPSIS Tool to its initial state, including the default criteria, weights, and benefit/cost selections.
 - Criteria Used: When clicked, this button displays a table with the criteria used in the TOPSIS calculation, along with their corresponding weights.
 - Generate Report: Clicking this button generates a report that includes project information, criteria used, and a performance score table. This report provides users with a comprehensive overview of the decision-making process and outcomes.
- 

Decision Support Tool

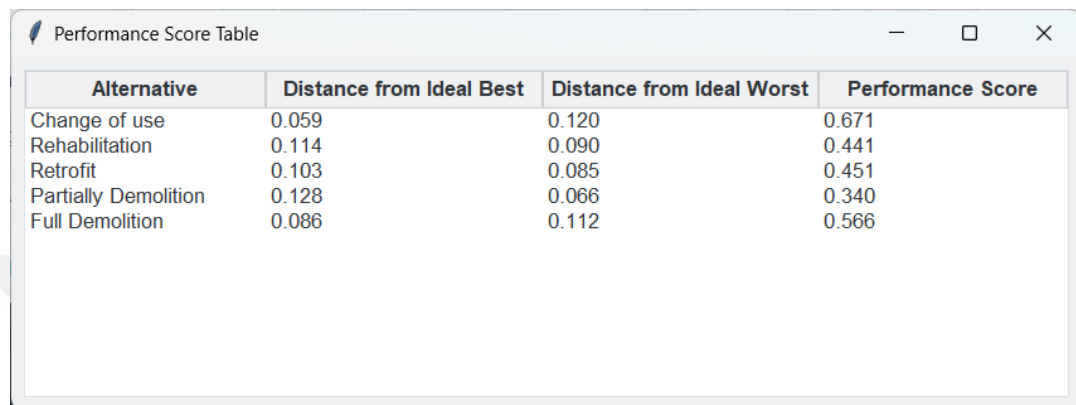
	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	
Change of use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Rehabilitation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Retrofit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Partially Demolition	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Full Demolition	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Weight:	0.15	0.1	0.08	0.08	0.06	0.1	0.08	0.12	0.06	0.05	0.07	0.05	
Benefit/Cost:	Benefit >	Benefit >	Benefit >	Benefit >	Benefit >	Benefit >	Benefit >	Benefit >	Benefit >	Benefit >	Benefit >	Benefit >	

Project Information Manage Alternatives Manage Criteria Criteria Used Calculate Performance Score Generate Report How to use Clear Reset

Figure 3.2 Main window of the program

3.4.1.2 Performance Score Table:

The Performance Score Table is displayed in a pop-up window after clicking the "Performance Score" button. It shows the TOPSIS scores for each alternative along with the Euclidean distance from the ideal best and worst, illustrated in Figure 3.3.



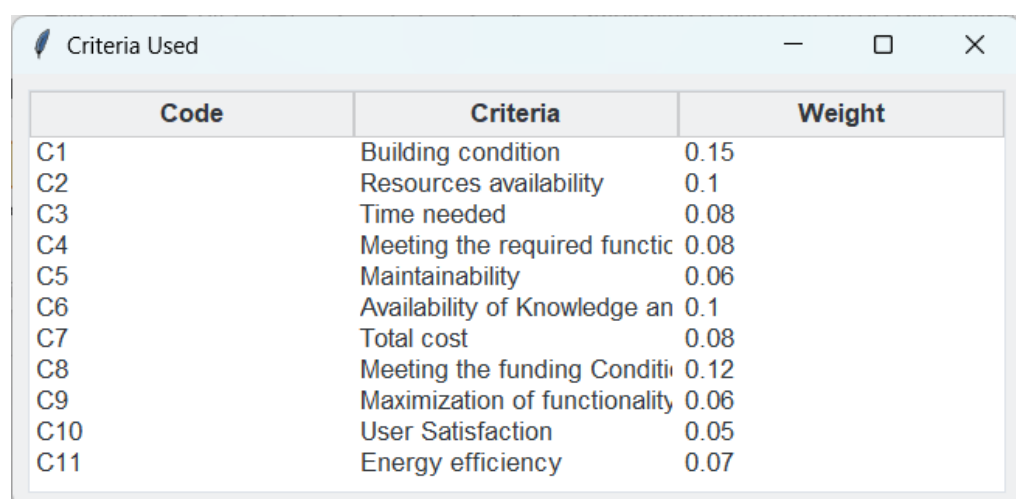
A screenshot of a software window titled "Performance Score Table". It contains a table with four columns: "Alternative", "Distance from Ideal Best", "Distance from Ideal Worst", and "Performance Score". The table lists five alternatives: "Change of use", "Rehabilitation", "Retrofit", "Partially Demolition", and "Full Demolition", each with corresponding numerical values.

Alternative	Distance from Ideal Best	Distance from Ideal Worst	Performance Score
Change of use	0.059	0.120	0.671
Rehabilitation	0.114	0.090	0.441
Retrofit	0.103	0.085	0.451
Partially Demolition	0.128	0.066	0.340
Full Demolition	0.086	0.112	0.566

Figure 3.3 Performance Score Table

3.4.1.3 Criteria Used Table:

The Criteria Used Table is displayed in a pop-up window after clicking the "Criteria Used" button. It shows the criteria used in the TOPSIS calculation along with their corresponding weights as shown in Figure 3.4.



A screenshot of a software window titled "Criteria Used". It contains a table with three columns: "Code", "Criteria", and "Weight". The table lists eleven criteria, each with a code (C1 to C11) and a weight value.

Code	Criteria	Weight
C1	Building condition	0.15
C2	Resources availability	0.1
C3	Time needed	0.08
C4	Meeting the required func	0.08
C5	Maintainability	0.06
C6	Availability of Knowledge an	0.1
C7	Total cost	0.08
C8	Meeting the funding Condi	0.12
C9	Maximization of functionality	0.06
C10	User Satisfaction	0.05
C11	Energy efficiency	0.07

Figure 3.4 Criteria Codes, Names and weights

3.4.1.4 How to Use:

When the user clicks the "How to use" button, a pop-up window appears with detailed user manual explanations on how to effectively use the TOPSIS Methodology Tool as presented in Figure 3.5.

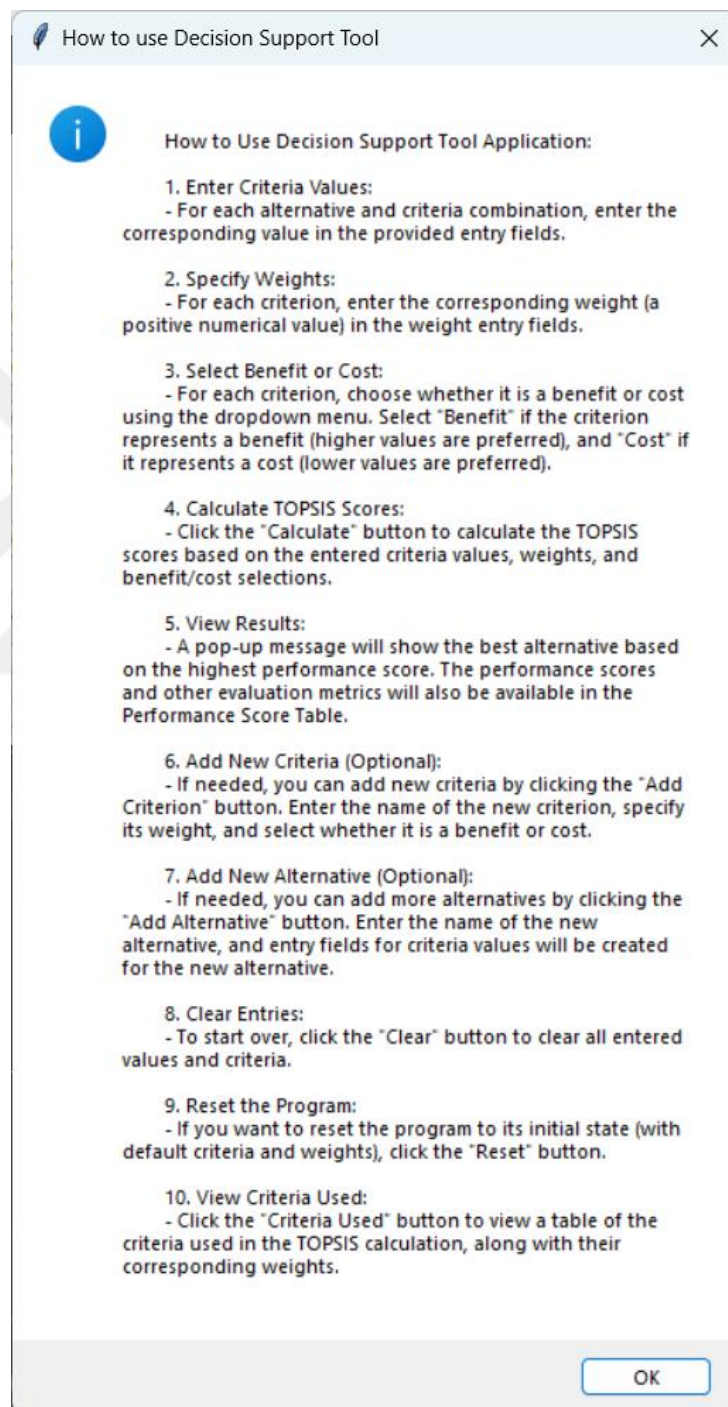


Figure 3.5 "How to use" window in the program

3.4.2 Using the Tool

- **Entering Criteria Values:** For each alternative and criterion combination, enter the corresponding value in the provided entry fields. The values represent the performance of each alternative with respect to each criterion.
- **Specifying Weights:** For each criterion, enter the corresponding weight in the weight entry fields. The weight represents the relative importance of each criterion. The weights should be positive numerical values and sum up to be one. Default values will be assigned by the researcher which can be modified by the user if needed.
- **Selecting Benefit or Cost:** For each criterion, choose whether it is a benefit or cost using the dropdown menu. Select "Benefit" if the criterion represents a benefit (higher values are preferred), and "Cost" if it represents a cost (lower values are preferred).
- **Manage Alternatives (Optional):** If needed, the user can add more alternatives by clicking the "Add Alternative" button or click on "Change name" to rename an alternative. Enter the name of the new alternative, and entry fields for criteria values will be created for the new alternative (See Figure 3.6).

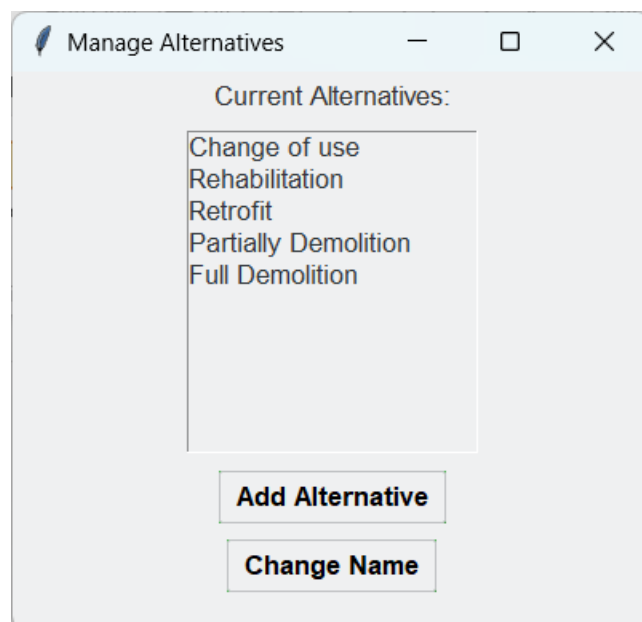


Figure 3.6 Add new alternative window

- **Manage Criteria (Optional):** If needed, the user can add more criteria by clicking the "Add Criterion" button or click on "Change name" to rename a criterion. Enter the name of the new criterion, specify its weight, and select whether it is a benefit or cost (See Figure 3.7).

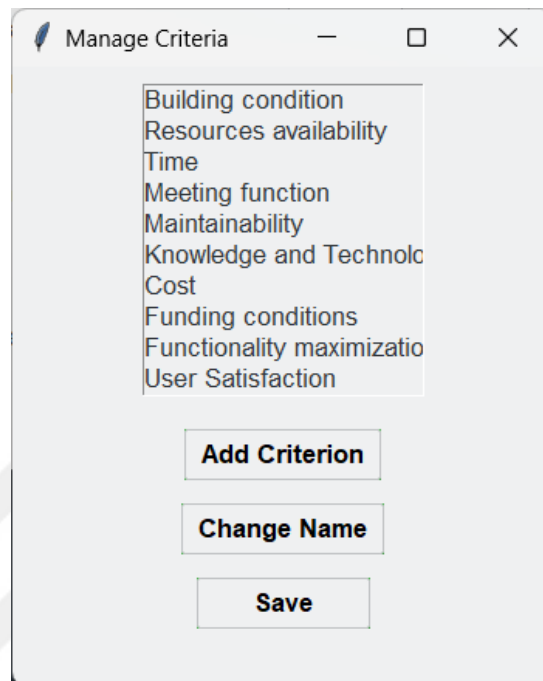


Figure 3.7 Add new criteria window

- **Calculating TOPSIS Scores:** Click the "Calculate" button to calculate the TOPSIS scores based on the entered criteria values, weights, and benefit/cost selections.
- **Viewing Results:** A pop-up message will show the best alternative based on the highest performance score (See Figure 3.8). The performance scores and other evaluation metrics will also be available in the Performance Score Table.

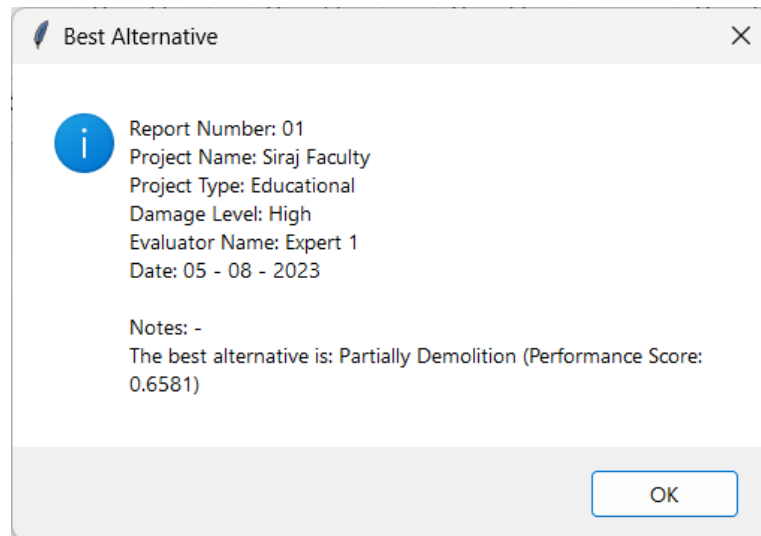


Figure 3.8 Best alternative pop-up window

- Generate a report: Click on “Generate Report” to show the project information, criteria used and preference score table all together to be used as decision making report as illustrated in Figure 3.9.
- Resetting the Tool: To start over, click the "Clear" button to clear all entered values and criteria. If you want to reset the tool to its initial state (with default criteria and weights), click the "Reset" button.

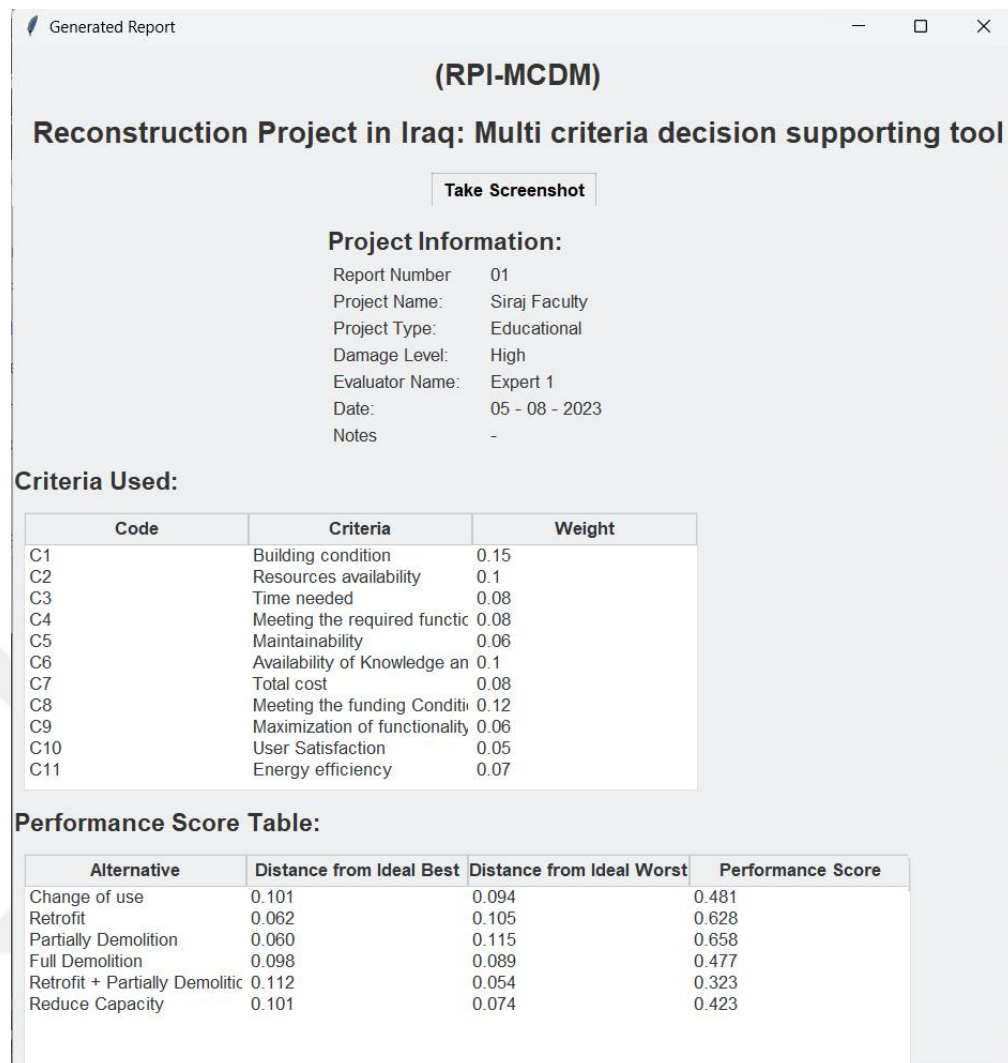


Figure 3.9 Decision Making Report

3.4.3 Implementation Details (Programming and Libraries)

The TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) Tool is implemented using the Python programming language and the Tkinter library for the graphical user interface. The tool follows the TOPSIS methodology to calculate the performance scores for each alternative based on multiple criteria.

3.4.3.1 Libraries and Modules:

- Tkinter: Tkinter is a standard Python library for creating graphical user interfaces (GUI). It provides various widgets, such as labels, buttons, entry fields, and option menus, which are used to build the interactive interface of the TOPSIS Tool.
- ttkthemes: ttkthemes is a third-party Python library that extends the capabilities of Tkinter by providing additional themed styles for the GUI elements. It is used to enhance the appearance of the TOPSIS Tool with modern and visually appealing themes.
- NumPy: NumPy is a fundamental package for scientific computing in Python. It provides support for large, multi-dimensional arrays and matrices, along with a collection of mathematical functions to perform calculations efficiently. The library is utilized in the TOPSIS Tool for matrix operations during the TOPSIS calculation.

3.4.3.2 System Architecture

The MCDM supporting tool is built as a desktop application using Python and Tkinter. The system architecture comprises three main components:

- TOPSISApp Class

The core of the tool is encapsulated in the TOPSISApp class. This class is responsible for creating the graphical user interface, handling user interactions, and performing the TOPSIS calculations. It contains methods to calculate TOPSIS scores, display results, add new criteria, modify weights, modify alternatives, and provide a "How to use" guide.

- Tkinter Widgets

The TOPSISApp class utilizes various Tkinter widgets to construct an intuitive and user-friendly GUI. These widgets include labels for alternatives and criteria, entry

fields for user inputs, weight entry fields, dropdown menus for benefit/cost selections, buttons to trigger actions, and a performance score table.

- TOPSIS Calculation

The `calculate_topsis` method within the `TOPSISApp` class performs the actual TOPSIS calculation based on the user-entered data. This process involves normalizing the criteria values, applying weights, determining ideal best and worst solutions, calculating the distances from these solutions, and finally, calculating the performance scores for each alternative.

3.4.3.3 The TOPSIS calculation is performed based on the following steps:

- Normalize the criteria values: Each criterion value for an alternative is divided by the column-wise L2 norm of the corresponding criterion values across all alternatives.
- Weighted normalized matrix: The normalized matrix is multiplied elementwise with the respective weights for each criterion.
- Ideal best and ideal worst alternatives: The ideal best alternative is obtained by taking the maximum value for each criterion in the weighted normalized matrix, while the ideal worst alternative is obtained by taking the minimum value for each criterion.
- Calculate the Euclidean distance from the ideal best and ideal worst alternatives for each alternative.
- Calculate the performance score: The performance score for each alternative is computed by dividing the Euclidean distance from the ideal worst alternative by the sum of the Euclidean distances from the ideal best and ideal worst alternatives.
- Identify the best alternative: The alternative with the highest performance score is considered the best alternative.

CHAPTER 4

VALIDATION OF THE DESIGNED TOOL THROUGH A CASE STUDY

This chapter presents a detailed analysis of the effectiveness of the Multi-Criteria Decision-Making Support tool, which was specifically developed to aid decision-makers in selecting optimal reconstruction alternatives for public buildings in Iraq. The MCDM tool is designed to integrate technical, environmental, social, and economic criteria, ensuring a holistic evaluation of the available alternatives.

It aims to streamline the decision-making process, considering the diverse objectives and priorities of stakeholders involved in post-conflict reconstruction projects. To demonstrate the practical application of the MCDM tool, a detailed case study of a public building reconstruction project in Iraq will be presented. The case study will highlight the tool's efficacy in addressing real-world challenges, weighing diverse criteria, and guiding stakeholders towards sustainable and socially responsible reconstruction decisions.

4.1 Overview of the Case Study Project

The case study project involves the reconstruction of a hospital situated in the city of Hit within the al-Anbar province of Iraq. The hospital's reconstruction aims to enhance medical services, cater to the community's healthcare needs, and contribute to the overall rehabilitation of the region.

4.1.1 Geographical and socio-economic context of Hit

Hit, located in the al-Anbar province of Iraq, holds a unique geographical and socio-economic context that significantly shapes the considerations and challenges of its reconstruction efforts. Geographically, Hit is situated along the Euphrates River, providing access to water resources that are essential for overall sustenance (see Figure 4.1). The city is positioned within a desert climate characterized by hot summers and mild winters, which necessitates infrastructure design that can withstand extreme

temperature variations. Socio-economically, Hit has a history deeply affected by conflict and instability, resulting in considerable damage to its infrastructure and displacement of its residents. The region's socio-economic context also impacts its resources and capacities. The availability of skilled labour, materials, and financial resources plays a critical role in determining the feasibility and pace of reconstruction activities. Given the post-conflict setting, the availability of these resources might be constrained, requiring strategic planning to optimize their use and ensure sustainable progress. Moreover, the geopolitical dynamics of the region can influence the reconstruction process as they are a bit away from the province centre. Collaborative efforts with local authorities, community leaders, and relevant stakeholders are crucial to overcome the negligence of the city.

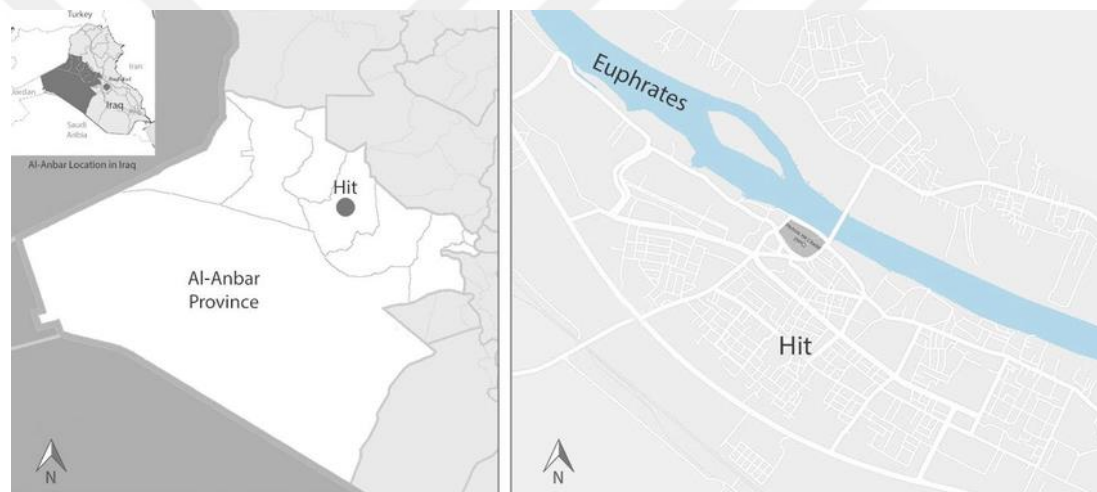


Figure 4.1 Hit City Location on the map, Source: [63]

4.1.2 Context and significance of the project

The aftermath of conflict often leaves essential infrastructure, such as healthcare facilities, severely damaged or non-functional. In this context, the rehabilitation and enhancement of a hospital hold paramount importance in revitalizing medical services, promoting community well-being, and aiding the overall recovery of the affected area. The significance of the project extends beyond mere physical reconstruction. The restoration of its functionality not only addresses the immediate medical needs of the community but also contributes to rebuilding social trust and providing essential

services for residents returning to their homes. Additionally, a functional hospital enhances the region's resilience to future challenges by strengthening the healthcare system's capacity to respond effectively.

4.1.3 Project's scope, scale, and timeline.

The scope of this project is extensive, encompassing both the physical reconstruction of the hospital's infrastructure as well as the broader goal of restoring essential healthcare services to the community. The hospital's layout is structured into eight distinct sections, each designed to cater to specific healthcare needs (See Figure 4.2). The hospital's reconstruction involves addressing various aspects, including architectural, structural, and functional considerations, to ensure that it meets medical standards and effectively serves the needs of the community.

In terms of scale, the hospital reconstruction is a significant endeavour due to its role as a critical healthcare facility for the city and surrounding areas. The timeline for the project is a key aspect that reflects the urgency of reinstating healthcare services to the community. Given the vital role that the hospital plays in addressing medical needs, the reconstruction process is expected to be conducted efficiently and within a defined period. Delays in the reconstruction timeline could have significant consequences for the city's residents, who rely on the hospital for medical care and emergencies.



Figure 4.2 The building top view and plan layout

4.1.4 The project's stakeholders

The project involves a wide range of stakeholders who collectively contribute to the project's success and its alignment with the community's needs. The effective engagement and collaboration of these stakeholders are vital for making informed decisions throughout the reconstruction project. The key stakeholders include:

1. **Government Authorities:** Various government agencies and officials, both at the local and regional levels, are essential stakeholders. They play a role in providing approvals, permits, and necessary support for the project's smooth execution. Like; Hit Municipality Directorate, Anbar Provincial Council, Iraqi ministries linked to the Ministry of Finance, and others.
2. **Healthcare Professionals:** Medical staff, and administrators associated with the hospital are pivotal stakeholders. Their expertise and insights are crucial for designing the hospital's facilities and operations in a way that ensures effective medical services. Like Anbar Health Directorate and Iraqi Ministry of Health .
3. **Engineering Teams:** Architects, engineers, and construction workers engaged in the reconstruction process are vital stakeholders. Their technical expertise and work will shape the physical infrastructure and layout of the hospital. Like the consulting engineering team and the engineering team of the Constructing company.
4. **Local Community:** The residents of Hit and the surrounding areas are among the most significant stakeholders. The hospital serves as a vital healthcare facility for their well-being, making their input crucial to ensure that the reconstructed hospital meets their healthcare requirements, especially with the existence of one hospital that does not meet the city's needs.
5. **Fund Organizations:** Entities providing financial support, resources, and expertise for the hospital's reconstruction are stakeholders with a vested interest in the project's successful outcome and to meet their conditions for the donating. Such as Governmental Support Fund for Affected Areas and UN Support Programs.

6. **Regulatory Bodies:** Regulatory agencies responsible for overseeing healthcare facilities' compliance with medical standards and regulations are essential stakeholders to ensure that the reconstructed hospital meets necessary guidelines. Such as health departments and quality assurance boards.

4.1.5 Current Status of The Building

Work began at the hospital in 2012. Military operations started in the city of Hit in 2015, causing a halt in its operations. Hit Hospital was subjected to bombardment several times during the years 2015 and 2016. The hospital consists of a reinforced concrete structure with the partitions built using concrete blocks. The building is composed of 6 main sections, along with two sections for the doctor's residence and a section for the service building (See Figure 4.3).

According to the structural damage assessment, most of the main sections are structurally sound, but some foundations need replacement or retrofit. Other sections like the doctor's residence and services area have shown more significant damage that might require rebuilding. The specified plan or strategy that was selected for the hospital's reconstruction involves a combination of retrofitting certain sections and completely rebuilding others. Figure 4.4 depicts the current state of Hit Hospital. This visual representation offers insight into the present condition of the hospital.

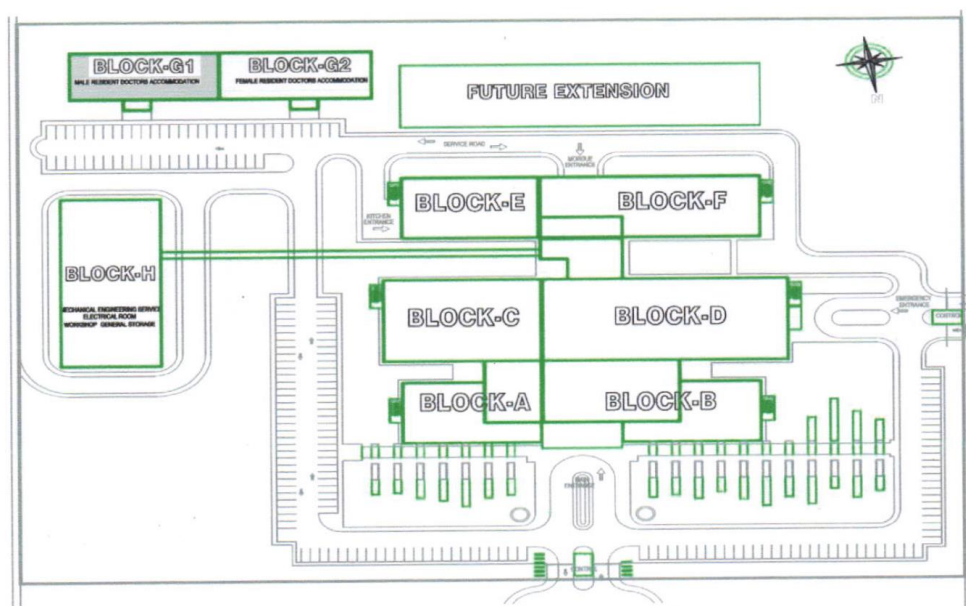


Figure 4.3 Hit Hospital Plan Layout



Figure 4.4 Hit Hospital Current Situation [64]

4.2 Integration of Criteria and Alternatives into the MCDM Tool

In the case of the hospital reconstruction project in Hit, the tool covers a diverse set of criteria representing technical, economic, environmental, and social aspects as explained in the previous chapter. These criteria include but are not limited to structural integrity, construction cost, energy efficiency, environmental impact, community impact, and functionality. Moreover, the MCDM tool incorporates various alternatives for the reconstruction project.

The established criteria for the hospital reconstruction project have been carefully selected and deemed comprehensive as illustrated in the previous chapter, reflecting a range of key considerations crucial for informed decision-making. While the criteria remain unchanged, certain alterations were introduced to the alternatives to refine the evaluation process and account for the unique circumstances of the project. One significant change in the alternatives is the exclusion of the rehabilitation option due to the building's structural condition post-damage, rendering it unsuitable for rehabilitation. Consequently, this alternative was removed from consideration.

In the initial round of evaluations, an additional alternative was introduced to expand the scope of options. This entailed the inclusion of two alternatives: retrofitting and partially demolition. The decision to incorporate these alternatives was based on expert input, ensuring a comprehensive exploration of possible strategies.

Each criterion is assigned a weight that reflects its relative importance in achieving the project's overall objectives. The process of assigning weights involves engaging stakeholders and experts to provide their insights and preferences. The evaluation process encompassed several key criteria like, the time required for implementing each intervention method was gauged in terms of the number of months necessary for completion. Simultaneously, the total cost was expressed in millions of Iraqi dinars for every alternative, providing a clear cost perspective for decision-making.

Additionally, a range from 1 to 10 was employed to assess the remaining criteria. The provided Figure 4.5 and Figure 4.6 illustrates the outcomes of the first and second rounds of expert evaluations for the identified alternatives. In the subsequent round of evaluations, the alternatives were further extended to encompass a new dimension: reducing capacity. This new alternative investigates the implications of lowering the hospital's capacity as a means of addressing certain constraints or budget limitations if needed. This addition allows for a more holistic assessment of trade-offs between different aspects of the project.

Decision Support Tool

	Building condition	Resources availability	Time	Meeting function	Maintainability	Knowledge and Technology	Cost	Funding conditions	Functionality maximization	User Satisfaction	Energy efficiency	Emissions
Change of use	1	8	12	1	4	4	7508	1	3	2	5	8
Retrofit	6	7	18	9	6	7	1500	8	6	9	7	7
Partially Demolition	6	8	20	9	7	8	2500	7	7	7	6	3
Full Demolition	3	7	24	9	9	8	10000	5	8	6	5	1
Retrofit + Partially Demolition	9	7	18	9	7	7	2000	8	7	8	7	6
Weight:	0.15	0.1	0.08	0.08	0.06	0.1	0.08	0.12	0.06	0.05	0.07	0.05
Benefit/Cost:	Benefit >	Benefit >	Cost >	Benefit >	Benefit >	Benefit >	Cost >	Benefit >	Benefit >	Benefit >	Benefit >	Benefit >

Project Information Manage Alternatives Manage Criteria Criteria Used Calculate Performance Score Generate Report How to use Clear Reset

Figure 4.5 1st round decision making process.

Decision Support Tool

	Building condition	Resources availability	Time	Meeting function	Maintainability	Knowledge and Technology	Cost	Funding conditions	Functionality maximization	User Satisfaction	Energy efficiency	Emissions
Change of use	1	8	12	1	4	4	750	1	3	2	5	8
Retrofit	6	7	18	9	6	7	1500	8	6	9	7	7
Partially Demolition	6	8	20	9	7	8	2500	7	7	7	6	3
Full Demolition	3	7	24	9	9	8	10000	5	8	6	5	1
Retrofit + Partially Demolition	9	7	18	9	7	7	2000	8	7	8	7	6
Reduce Capacity	9	8	8	6	2	5	1000	9	3	5	7	7
Weight	0.15	0.1	0.08	0.08	0.06	0.1	0.08	0.12	0.06	0.05	0.07	0.05
Benefit/Cost	Benefit	Benefit	Cost	Benefit	Benefit	Benefit	Cost	Benefit	Benefit	Benefit	Benefit	Benefit

Project Information Manage Alternatives Manage Criteria Criteria Used Calculate Performance Score Generate Report How to use Clear Reset

Figure 4.6 2nd round decision making process.

4.3 Decision Making Process

The involvement of local experts from the city played a pivotal role in shaping informed decisions throughout the decision-making process. These experts brought forth a wealth of engineering expertise and a comprehensive understanding of the community's specific needs and aspirations. Their contributions extended beyond technical insights to encompass a holistic perspective that considered both the practical engineering aspects and the broader social implications of the reconstruction project. In essence, the collaboration with local experts enriched the decision-making process by amalgamating engineering expertise with community insights. Their contributions provided a balanced and comprehensive approach to addressing the hospital's reconstruction needs, underscoring the importance of involving stakeholders with both technical and community-oriented perspectives.

Based on the evaluation carried out by the panel of experts during the initial decision-making round, the intervention method that garnered the highest consensus and effectiveness for the hospital's reconstruction project is the amalgamation of retrofitting and partial demolition. This outcome underscores the meticulous consideration that the experts bestowed upon the various criteria, including cost, functionality enhancement, and implementation period.

The retrofit + partially demolition strategy emerged as the prime choice with a performance score of 0.701 due to its judicious balance between enhancing the hospital's structural integrity, improving its operational functionality, and optimizing the cost-efficiency factor. This approach not only addresses the immediate needs of the hospital but also projects a forward-looking perspective, considering the potential challenges and demands that may arise in the years ahead. Figure 4.7 illustrates the decision-making process of the first round.

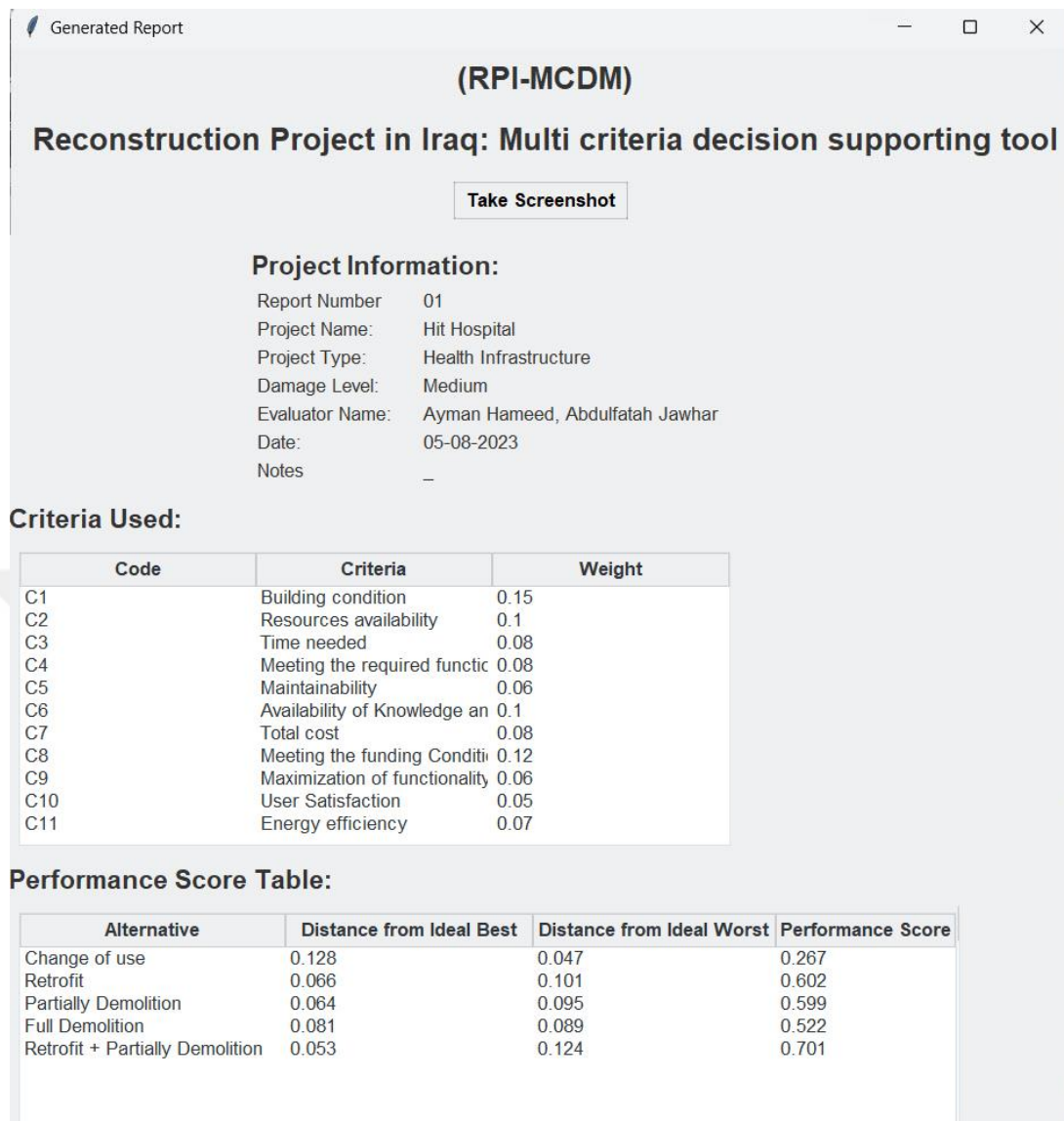


Figure 4.7 First Round Decision-Making Results

Upon further analysis and consideration by the panel of experts, the outcomes of the second round of decision-making have unequivocally pointed towards a prominent intervention approach for the hospital project. This method, cantered on reducing the hospital's capacity, has emerged as the clear frontrunner with a performance score of 0.897. The prospect of reducing the hospital's capacity entails a concurrent retrofit of specific building components, albeit to a lesser extent. This effort is primarily focused on a predetermined number of beds, subject to mutual consensus. Figure 4.8 represents

the evaluations conducted during this round, it becomes evident that this intervention option has garnered substantial support from the experts due to its inherent advantages.

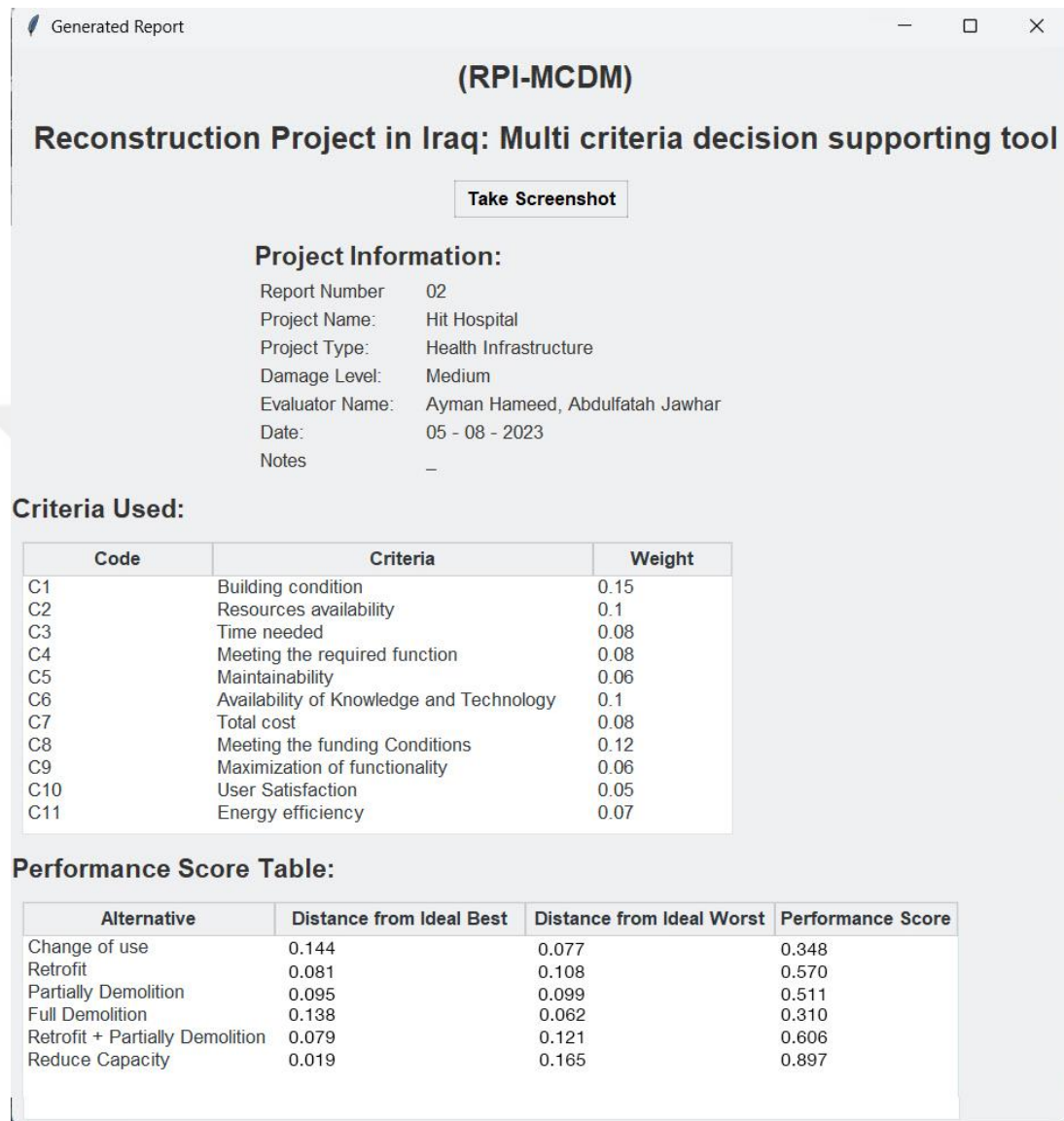


Figure 4.8 Second Round Decision Making Results

4.4 Results and Discussion

This process began with the identification of relevant criteria, encompassing aspects such as cost, functionality, time, and various stakeholder considerations. These criteria are then assigned weights based on expert opinions to reflect their relative importance. Alternatives, representing different reconstruction strategies, are evaluated against the established criteria using MCDM methods such as TOPSIS. The process involves data collection, normalization, and calculations to determine the suitability of each alternative. Experts participate in multiple rounds of evaluation, refining their preferences based on the outcomes of each round.

The final decision emerges from a rigorous analysis of diverse stakeholder experts' inputs and assessment results. It is a product of merging subjective opinions, technical analysis, and quantitative evaluations. The chosen intervention method is the one that emerges as the most promising and aligned with the project's goals, considering factors like cost-effectiveness, functionality enhancement, and implementation feasibility. The most suitable intervention strategy for this case is to prioritize capacity reduction, provided it is a feasible option. In situations where capacity reduction is not feasible, the alternative intervention approach of retrofitting combined with partial demolition emerges as the preferred solution.

The prioritization of capacity reduction reflects a proactive approach to address the hospital's immediate needs while also factoring in potential future demands, optimizing resource allocation, and ensuring a sustainable and resilient healthcare facility. The chosen intervention strategy, whether it is the prioritization of capacity reduction, or the retrofitting combined with partial demolition approach, is fundamentally aligned with the overarching goals and objectives of the reconstruction project. The utilization of the decision support tool, which yielded results consistent with the technical reports and expert expectations, attests to the robustness of the decision-making process.

As pointed by the experts that traditional methods often relied on simplistic and singular criteria, the MCDM tool brings forth a holistic framework encompassing a multitude of multifaceted criteria. The past methods predominantly centred around financial considerations, overlooking intricate factors such as functionality and long-

term sustainability. In stark contrast, that the MCDM tool harmoniously integrates various criteria, ranging from cost-effectiveness to time efficiency, user needs, and environmental impact. Which can be seen in the comprehensive decision in the first round.

Moreover, they discussed that the conventional techniques might have been susceptible to biases and subjective interpretations, leading to suboptimal decisions. Conversely, the MCDM tool orchestrates a more objective and systematic process, involving the input of multiple experts to curtail individual biases and elevate the quality of decision-making. That was noticed in the elimination of the choice of reducing capacity by the construction company, which was the best option in the whole process.

The insights garnered from expert opinions provide valuable perspectives on both the contributions and limitations of the newly devised reconstruction decision-making framework. Experts unanimously acknowledge that the MCDM tool significantly contributes to the field of reconstruction by providing a structured and comprehensive approach that surpasses the conventional methods. This holistic perspective equips decision-makers to navigate the intricate web of reconstruction dynamics and ensures a more sustainable and resilient outcome. Experts appreciate the systematic integration of stakeholder preferences, thereby enhancing the transparency, inclusivity, and consensus-building aspects of the decision-making process.

The selected plan or strategy for the hospital's reconstruction involves a combination of retrofitting certain parts and complete rebuilding of others. The initial step in this process was to implement and utilize the decision-support tool in collaboration with experts. In the first round of using the tool, the results provided support for the already established reconstruction plan, as the outcomes closely aligned with the planned strategy. This affirmed the validity of the chosen approach.

During this second round, the tool facilitated the discovery of a solution that not only met the project's objectives but also achieved cost-effectiveness. This emphasized the critical importance of project objectives in driving decision-making processes. In essence, the tool demonstrated that a well-defined set of objectives can guide decision-makers towards solutions that strike a balance between objectives, cost-efficiency, and overall project success. Therefore, the study underscores the necessity of establishing

and articulating project objectives clearly from the outset, which ultimately leads to more effective and economically viable decision-making in reconstruction projects. However, experts also candidly address certain limitations and challenges encountered during the implementation of the MCDM tool. One common challenge is the tool's complexity might necessitate adequate training and familiarity, which could pose a barrier for less experienced decision-makers. The need for comprehensive expertise across various domains could also present a challenge in situations where interdisciplinary collaboration is required. Moreover, the scalability and adaptability of the MCDM tool to different project sizes and contexts need to be scrutinized.

The experts' opinion highlights a challenge in using the tool: its complexity. To address this concern, a solution could involve simplifying the tool by categorizing criteria onto separate pages. Additionally, experts questioned the scalability and adaptability of the MCDM tool across diverse project sizes and contexts. However, addressing this concern can be achieved through the tool's inherent flexibility—enabling the addition or removal of criteria and alternative solutions, adjusting weights based on available data, and using the tool not just at project initiation but also during project evolution when circumstances change (such as funding shortages or knowledge gaps). This ensures that the tool remains dynamic and applicable throughout various stages of reconstruction projects.

Uncertainties can arise from factors such as changing economic conditions, unforeseen challenges during implementation, and variations in stakeholder preferences. These uncertainties can impact the accuracy of criteria weights and alternative evaluations, potentially leading to different outcomes under altered conditions. Additionally, assumptions made during the decision-making process, like the availability of resources or the long-term effectiveness of chosen interventions, should be carefully examined for potential biases. Despite these challenges, experts concur that the MCDM tool remains a remarkable step forward in advancing the reconstruction decision-making domain.

In our opinion, what is particularly noteworthy is the tool's emphasis on defining project objectives before any planning. This was evident in the second decision-making round, where the tool facilitated the exploration of a new aspect: reducing the

hospital's capacity. This approach not only met the project's objectives but also achieved a potentially better solution with lower costs.

Also, it aligns stakeholders, enhances cost-effectiveness, and ensures that projects are not only technically sound but also in harmony with broader social and environmental goals. It is a testament to the value of integrating advanced decision-support tools into the complex and multifaceted field of reconstruction management.



CHAPTER 5

CONCLUSION

In the context of post-conflict reconstruction and decision-making, this study holds great importance as a source of inspiration for communities recovering from conflict. At the outset, the primary goal of this research was to address the critical gaps in the decision-making process in the aftermath of conflict, where complexities and diverse considerations demand a comprehensive approach. Through an extensive review of existing literature, the study gathered insights into various decision-making methodologies, culminating in the selection of the MCDM approach as an effective solution. This placed the foundation for a tool's development, which emerged as a synthesis of technical precision, stakeholder engagement, and holistic sustainability.

5.1 Study Major Findings

The review reveals that MCDM techniques have been applied to construction projects of public buildings in Iraq, displaying their potential to enhance decision-making processes. The limited focus on environmental and social aspects, coupled with an exclusive emphasis on initial costs within the economic aspect, has led to inaccurate decision-making practices. Furthermore, the extensive issues of corruption and inadequate technological resources have further complicated matters, increasing the likelihood of resource wastage. The current decision making in reconstruction projects has been primarily focused on single-criteria analysis, with a primary emphasis on cost reduction to maximize profits. However, this approach has led to a lack of comprehensive criteria in decision analysis. Which means that no weighting for the criteria is followed leading to less comprehensive and reliable decisions.

The review of the existing literature of application of MCDM in reconstruction projects highlighted a prioritizing for the technical and energy efficiency aspects. These considerations demonstrate a commitment to ensuring the improved performance and sustainability of the reconstructed public structures. Various MCDM methods, such as (AHP), (TOPSIS), and PROMETHEE, have been utilized to address

the complexities in reconstruction efforts. Which can lead to better evaluations and comprehensive insights to the situation of reconstruction projects.

The research significantly contributed to the establishment of a comprehensive set of criteria for prioritizing public building reconstruction projects in Iraq. This accomplishment stemmed from an extensive review of pertinent literature and the active engagement of stakeholders. The criteria were meticulously identified and refined to encapsulate the multidimensional factors crucial for effective reconstruction decision-making. In the most favourable instances, the present process of decision-making considers six main factors or criteria that are utilized for reconstruction projects in Iraq. These factors are building condition, availability of funding, time constraints, congruence with required function, resource accessibility, and overall cost. Additional criteria were proposed following a thorough review of the existing literature, aimed at enhancing the consideration of economic, social, and environmental dimensions. These newly introduced criteria encompass availability of knowledge and technology, meeting the funding conditions, maximization of functionality, user contentment, energy efficiency, and emissions.

The development of the decision support tool using Python and Tkinter library has successfully provided users with a user-friendly and efficient platform for multi-criteria decision-making analysis. The tool's interface has been thoughtfully designed to allow users to input project information, specify alternative and criteria, and assign weights and benefit/cost attributes to each criterion. The integration of the TOPSIS algorithm facilitates the calculation of performance scores for each alternative, aiding users in making informed decisions based on comprehensive evaluation metrics. Additionally, the tool's ability to generate reports and visualize results in tabular format contributes to the clarity and transparency of the decision-making process. The MCDM tool empowers stakeholders to make well-informed choices that not only address immediate reconstruction needs but also align with long-term objectives.

The research successfully developed and introduced a robust MCDMS tool. By combining theoretical foundations and practical insights, the tool serves as an innovative solution for addressing the complex challenges in post-conflict reconstruction decision-making.

The validation process, executed through its application on a real-life case study of a damaged hospital, substantiates the tool's effectiveness and viability. This contribution lies in bridging the gap between theoretical advancements and practical applications, providing decision-makers with a tangible tool for informed choices.

The application of the MCDM tool in the case study of a hospital reconstruction project in Hit, Iraq, facilitated a systematic evaluation of various intervention alternatives. Through the engagement of local experts and stakeholders, the study navigated the complicated situation of decision-making within the context of post-conflict reconstruction. The outcomes highlighted the ability of the tool to effectively meet technical assessments with community insights, adopting decisions that go with the unique socio-economic context of the reconstruction project. The tool's flexible applicability, demonstrated through its alignment with the unique socio-economic context of Hit, underscores its potential to be a transformative force in other post-conflict settings.

As part of the case study analysis, the experts' insights emphasize the transformative nature of the MCDM Support tool in contrast to traditional methods. While the former embraces a comprehensive range of criteria, including financial, functional, and environmental factors, the latter often oversimplified decisions based solely on technical and financial considerations. The MCDM tool's objectivity and systematic process mitigate biases and enhance decision quality, as demonstrated by the rejection of a seemingly favourable option in the reconstruction process. The chosen intervention aligns with project goals and is reinforced by the decision support tool's correspondence with technical reports and expert expectations, confirming the strength of the decision-making process.

The hospital's reconstruction plan involves a mix of retrofitting and rebuilding. The initial tool implementation with experts supported the existing strategy, showing alignment between tool-derived results and the planned approach. Yet, the tool emphasized the crucial role of well-defined project objectives. This became evident in the second round, where the tool guided the discovery of a more cost-effective solution—reducing capacity while achieving project objectives. This underscores the tool's value in reinforcing the importance of clear objectives for optimal and economical decision-making in reconstruction projects.

The research has effectively demonstrated the immense potential of the MCDMS tool in enhancing the alignment, coordination, and cost-effectiveness of public building reconstruction endeavours in Iraq. Through the case study application, the tool displayed its ability to harmonize a multitude of criteria, optimize resource allocation, and promote better decision coordination among stakeholders. To maximize the impact of this research, efforts should be made to publish the findings, methodology, and outcomes of the developed MCDM tool to the wider academic, professional, and policy-making communities. Sharing knowledge and best practices can make positive change in reconstruction decision-making processes.

5.2 Study Limitations and Challenges

Expert opinions underline the MCDM tool's significant contribution to reconstruction decision-making. Despite its benefits, experts acknowledge challenges. The tool's complexity might hinder less experienced decision-makers, necessitating training and familiarity. Interdisciplinary collaboration could be challenging due to the diverse expertise required. Furthermore, the tool's scalability and adaptability across different project sizes and contexts warrant further examination. Although, experts highlight the challenge of the tool's complexity. To address this, one solution is to simplify by categorizing criteria. Concerns exist about the tool's adaptability across projects, but its inherent flexibility allows adjusting criteria, weights, and usage over time, ensuring its relevance throughout reconstruction projects.

Overall, while this study has made steps in advancing the field of post-conflict reconstruction decision-making through the integration of MCDM techniques, it is important to acknowledge the obstacles and challenges encountered during the research process. One notable obstacle relates to data availability. The accuracy and effectiveness of the developed MCDM tool heavily rely on the quality and quantity of data inputs. In some cases, data scarcity or conflict posed challenges, which may have influenced the precision of the results. Additionally, the applicability of the developed tool may vary across different types of public building projects, and its generalizability to diverse post-conflict contexts should be approached with caution. Another limitation is the reliance on expert opinions. While engaging local experts enriched the

study's outcomes, subjectivity and biases could have influenced the weightings assigned to criteria and the ranking of alternatives. Balancing these subjective factors with objective data is an ongoing challenge in decision-making research.

5.3 Recommendations

Considering the findings and insights generated from this study, several recommendations are put forth to enhance the utilization of the developed MCDM tool in post-conflict reconstruction decision-making:

1. It is recommended to establish mechanisms for obtaining accurate and up-to-date data relevant to various criteria.
2. Given the specialized nature of MCDM techniques, capacity-building initiatives and training programs for relevant stakeholders should be developed.
3. Active involvement of government officials, local communities, and experts should be prioritized throughout the reconstruction decision-making process.
4. Test MCDM techniques in smaller pilot projects to identify challenges and refine the approach before full-scale implementation. Emphasize adaptability in MCDM application to respond to changing circumstances and evolving project requirements.
5. Continuous assessment of reconstruction projects, incorporating stakeholder feedback, ensures success and informs future decisions. Share successful case studies and best practices to promote knowledge exchange and effective decision-making.
6. Leveraging technologies such machine learning, and predictive analytics can enhance the predictive capabilities of the MCDM tool.
7. The tool should be integrated as a part of the broader decision-making process rather than being used in isolation.
8. While the current version of the tool integrates the TOPSIS algorithm for decision analysis, future work could involve the inclusion of additional multi-criteria decision-making methods, such as Analytic Hierarchy Process (AHP), Weighted Sum Model, or Electre.

5.4 Future Work

In terms of future research, avenues for enhancement are manifold. Some of future work are listed below:

1. Conduct a comparative study of MCDM methods, such as AHP, TOPSIS, PROMETHEE, etc., to identify the most suitable technique for different types of public building reconstruction in Iraq.
2. Explore the transferability of MCDM techniques and lessons learned to aid reconstruction efforts in other post-conflict regions.
3. Incorporating enhanced visualization options, such as interactive charts and graphs, could provide users with more insightful ways to understand and compare results.
4. Introducing user profiles and the ability to save and load projects would enhance user convenience and enable them to reconsider and modify analyses over time.

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APPENDICES

Appendix A: Interview with Expert 1

Appendix B: Interview with Expert 2

Appendix C: Interview with Expert 3



Appendix A: Interview with Expert 1

1. What types of decision-making tools or methodologies are currently used in the field of reconstruction projects, if any?

Ans: Traditional decision-making tools like cost-benefit analysis and expert opinions are commonly used in reconstruction projects. Some also rely on basic checklists to evaluate project feasibility.

2. What are the key challenges and obstacles faced during the decision-making process for reconstruction projects in Iraq?

Ans: Key challenges in reconstruction decision-making include inadequate funding, security concerns, lack of access to technical documents, and time constraints for thorough evaluations.

3. What criteria or factors are typically considered when making decisions regarding reconstruction projects of public buildings in Iraq?

Ans: Commonly considered criteria in reconstruction decisions include cost, technical feasibility, and resource availability. However, social and environmental factors are often overlooked.

4. How are these criteria or factors currently assessed or evaluated in the decision-making process?

Ans: Currently, the assessment of criteria involves simplistic calculations based on historical data and expert judgments, often lacking a systematic approach.

5. What are the typical intervention methods or approaches currently used in reconstruction projects of public buildings in Iraq?

Ans: In Iraq, common intervention methods include rebuilding from scratch, retrofitting damaged sections, and partial demolition followed by reconstruction.

6. What are the strengths and weaknesses of the existing intervention methods?

Ans: Strengths of existing methods lie in their familiarity and ease of implementation. However, they often lead to suboptimal results due to neglecting broader impacts and long-term sustainability.

7. In your opinion, what would be the key benefits or advantages of implementing a multi-criteria decision-making supporting tool for reconstruction projects in Iraq?

Ans: Implementing a multi-criteria decision-making tool can lead to more informed decisions, considering diverse factors like cost, social impacts, and environmental sustainability.

8. What potential challenges or barriers do you foresee in implementing such a tool in the context of Iraq?

Ans: Challenges in implementing the tool might involve resistance to change, lack of awareness, and initial learning curves for stakeholders unfamiliar with the MCDM approach.

9. What are your recommendations or suggestions for establishing an effective and sustainable multi-criteria decision-making supporting tool for reconstruction projects of public buildings in Iraq?

Ans: To establish an effective tool, it's crucial to involve stakeholders in its development, ensuring it aligns with their needs. Regular training and support can address challenges in tool adoption.

Appendix B: Interview with Expert 2

1. What types of decision-making tools or methodologies are currently used in the field of reconstruction projects, if any?

Ans: Decision-making in reconstruction projects is often informed by subjective judgments and historical practices rather than structured tools. Some methodologies integrating financial assessments and engineering expertise are employed.

2. What are the key challenges and obstacles faced during the decision-making process for reconstruction projects in Iraq?

Ans: Decision-making faces challenges related to a shortage of experienced personnel, limited availability of accurate data, and varying stakeholder interests.

3. What criteria or factors are typically considered when making decisions regarding reconstruction projects of public buildings in Iraq?

Ans: Decision-makers primarily focus on cost and technical aspects while the broader impacts on environment, community needs, and long-term sustainability are inadequately addressed.

4. How are these criteria or factors currently assessed or evaluated in the decision-making process?

Ans: Evaluation mostly relies on qualitative assessments, with limited utilization of quantitative data. Technical and financial aspects are often prioritized over social and environmental factors.

5. What are the typical intervention methods or approaches currently used in reconstruction projects of public buildings in Iraq?

Ans: The prevailing approaches involve complete demolition and reconstruction or simple repairs, often failing to consider innovative methods that balance costs and long-term benefits.

6. What are the strengths and weaknesses of the existing intervention methods?

Ans: Existing methods prioritize immediate fixes but may ignore long-term implications. They lack systematic evaluation, hampering effective decision-making.

7. In your opinion, what would be the key benefits or advantages of implementing a multi-criteria decision-making supporting tool for reconstruction projects in Iraq?

Ans: The tool could enhance transparency, stakeholder engagement, and ensure comprehensive consideration of criteria, resulting in more robust and well-balanced decisions.

8. What potential challenges or barriers do you foresee in implementing such a tool in the context of Iraq?

Ans: Implementing the tool may require capacity-building efforts to enhance stakeholders' understanding and adaptation. Technical limitations and data availability might also pose hurdles.

9. What are your recommendations or suggestions for establishing an effective and sustainable multi-criteria decision-making supporting tool for reconstruction projects of public buildings in Iraq?

Ans: Recommendations include piloting the tool on smaller projects, promoting awareness about MCDM benefits, and fostering collaboration among relevant agencies to overcome implementation barriers.

Appendix C: Interview with Expert 3

1. What types of decision-making tools or methodologies are currently used in the field of reconstruction projects, if any?

Ans: In certain cases, reconstruction projects might involve rudimentary cost estimation tools, while others employ limited scenario analysis to assess various alternatives. However, a systematic and comprehensive decision-making framework is lacking.

2. What are the key challenges and obstacles faced during the decision-making process for reconstruction projects in Iraq?

Ans: Challenges encompass inadequate resources, lack of comprehensive post-conflict policies, and difficulties in coordinating multi-agency efforts.

3. What criteria or factors are typically considered when making decisions regarding reconstruction projects of public buildings in Iraq?

Ans: Project duration, financial resources, local community needs, environmental impacts, technical feasibility, and safety measures are typically considered when evaluating reconstruction options.

4. How are these criteria or factors currently assessed or evaluated in the decision-making process?

Ans: Assessments are mostly subjective, relying on expert opinions and qualitative analyses. Quantitative tools are underutilized, leading to suboptimal decision outcomes.

5. What are the typical intervention methods or approaches currently used in reconstruction projects of public buildings in Iraq?

Ans: Current practices include full reconstruction, repair, or limited retrofitting. However, holistic approaches considering both structural integrity and functional needs are often missing.

6. What are the strengths and weaknesses of the existing intervention methods?

Ans: The established methods may provide quick solutions, but they may overlook social and environmental dimensions, leading to missed opportunities for holistic improvement.

7. In your opinion, what would be the key benefits or advantages of implementing a multi-criteria decision-making supporting tool for reconstruction projects in Iraq?

Ans: This tool's key advantage lies in its ability to provide a structured approach, aiding decision-makers in making well-rounded choices that align with the project's broader objectives.

8. What potential challenges or barriers do you foresee in implementing such a tool in the context of Iraq?

Ans: Barriers could include resistance from traditional decision-making practitioners, the need for substantial data input, and potential complexities in adapting the tool to varying project scales.

9. What are your recommendations or suggestions for establishing an effective and sustainable multi-criteria decision-making supporting tool for reconstruction projects of public buildings in Iraq?

Ans: Suggestions encompass continuous updates of the tool's criteria, incorporating user feedback for improvements, and developing user-friendly interfaces to enhance its accessibility and usability.

CURRICULUM VITAE

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