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College of Science



**Environment and Sustainable
Development Program**

A Sustainable Framework for Energy Services Contracting on Governmental Premises

A Thesis Submitted in Partial Fulfilment of the Requirements for
the degree of Ph.D. in Environment and Sustainable
Development

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Abstract

Purpose of study: The building sector is an asset that consumes significant energy and contributes to the environmental footprint. In 2018, the globe spent USD 138 billion on energy efficiency in buildings, which could decrease energy intensity by more than 3% annually (Forrester & Reames, 2020). Therefore, the building needs to be operated efficiently. Energy Services Companies (ESCO) offer solutions to achieve efficiency in building with high measures. The research aimed to serve the goal since the Kingdom of Bahrain sets its energy efficiency targets in the building as an important part of its sustainability. This study explores the factors that affect the implementation of ESCO projects on government premises. Also, the study emphasizes the decision-maker's role in considering a proper strategy to implement ESCO on governmental premises. The study focuses on ESCO's experts from different industries.

Methodology and Design: Quantitative and qualitative research methods were used to answer the questions presented in the study. The data used in the study comes from pre-set questionnaires tackling the benefits and challenges of implementing the ESCO project on governmental premises. Research Primary data is collected through semi-structured questionnaires and online surveys based on a rating scale (1/9–9 point rating scale) through questionnaire design. The sample size is 25 energy efficiency project experts from the government, industrial, private, and academic sectors. The sample was selected based on their involvement in ESCO and energy efficiency in buildings. Google Forms and Teams are used to conduct surveys, and Microsoft Excel is used to study the results and analyze the data. Many mathematical and analysis techniques were used to provide a comprehensive evaluation of data, such as Fuzzy, Fuzzy AHP, sensitive analysis, Fuzzy

TOPSIS, and hypotheses, and merge them with SWOT analysis techniques to find the best strategy for implementing ESCO projects on governmental premises.

Finding: The study revealed that strengths are the most critical factors when selecting a proper strategy to implement ESCO projects on governmental premises. It also found four strategies to promote and implement successful ESCO projects.

Keywords: ESCO – Governmental Premises –SWOT Factors –SWOT Sub-Factors – Fuzzy AHP – Fuzzy TOPSIS

Dedication

This work is a result of countless and tedious sacrifices. Through the researchers' efforts, this work is heartily and proudly dedicated to the people who serve as an inspiration. From my late parents and guardians to classmates and circle of friends who extended their support during the COVID-19 pandemic while doing the work. To the experts who supported the thesis and dedicated their time to communicating, meeting, and clarifying all the questions while conducting the research.

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CHAPTER ONE

Introduction

1.1 Research Background

Bahrain is one of the Small Island Developing States (SIDS), and its economy depends mainly on crude oil and natural gas, which are primary energy sources. In 2002, Bahrain decided to diversify its economy from oil dependence by attracting foreign investment to the island. During the past two decades, the government of Bahrain has intensified the structural reforms to improve the infrastructure and developed several facilities and projects; hence, the building stock has drastically increased. Like most developing countries, the increase in electricity demand, population, and anthropogenic activities make the Kingdom of Bahrain face environmental challenges. One of the challenges is the steady increase in CO₂ and greenhouse gas emissions; World Economics reported that Bahrain produced a high methane emission level, reaching 18.55 million MtCo₂e and 10.61 mtCO₂e per capita in 2019 (World Economics, 2020).

On the national level, the final energy consumption is divided into four primary premises in Bahrain. Residential buildings represented the most significant sector that consumed electricity at 76.5%, and commercial buildings (including governmental premises) were the second largest consumer at 16.4% (EWA, 2021) (Krarti & Dubey, 2018a). Nonetheless, the increase in energy consumption in commercial buildings will likely continue to increase considerably following the increasing demand for urban infrastructures to sustain economic growth. To achieve economic development and protect the environment, we must move expeditiously toward energy efficiency in operating buildings.

Energy efficiency (EE) controls energy consumed without negatively affecting the amount demanded, using the latest technology and resources. In our research to find energy efficiency on-premises, we examined energy service companies (ESCOs) with the resources and technology to implement on-site energy efficiency projects and guarantee electricity savings. Since ESCO projects are a very emerging concept in the Kingdom, we needed to evaluate the drivers and challenges of the project among different ESCO experts in a scientific framework and identify the most influential factors among the experts.

Implementing a successful energy efficiency project in a significant sector such as buildings has to start with energy planning to ensure the best strategy for successful projects toward sustainability. Many decision-makers are involved in selecting the best strategy, and each decision-maker has insights and perceptions. Therefore, in this study, we examined the implementation of ESCO projects quantitatively in buildings using a framework of SWOT factors (Strengths, Weaknesses, Opportunities, Threats) and analyzed the factors using two Multi Decision Criteria Analysis (MDCA) models and quantitatively evaluated the importance of the drivers and challenges to obtain the most influential factors. One of the models is called Fuzzy AHP (Analytic Hierarchy Process), and the second is called TOPSIS (Technique for Order Performance by Similarity to Ideal Solution).

This study is the first attempt to study and evaluate the implementation of ESCO projects on governmental premises and to research and review the drivers and challenges of ESCO projects. On a national level, the study will contribute to the national energy efficiency target of the Kingdom of Bahrain.

1.2 Research Problems

Energy planners and policymakers face a complex challenge in formulating and implementing effective energy policies. These challenges include the difficulty of endeavour in contemporary literature and the practical approach leading to multiple scenarios or strategies. The process is critical, where complex procedures are reviewed before making a final decision.

Deciding on specific energy efficiency solutions and projects by several decision-makers is complicated because the process involves uncertainties, intuition in determining, and subjectivity in judgments (Bressane et al., 2020). People involved in decision-making have different experiences and responsibilities, which makes selecting the best-influencing factors a fuzzy process and often delays project implementation. Decision-makers and experts must refer to a clear, structured framework for quantifying and comparing influencing factors. A ranking of decisions is needed before deciding on the project.

Because ESCO projects are a relatively new and emerging concept in Bahrain, the implementation of the projects needs to be evaluated and analyzed systematically and scientifically to reach the best strategy for implementing ESCO projects and fulfilling Bahrain's energy efficiency action plans.

In this study, the determinant factors of the SWOT analysis framework are used to identify and categorize four factors in the Strengths area, four factors in Weaknesses, four factors in Opportunities, and four factors in the Threats area. In the analysis stage of the study, we used a mathematical method for

solving complex Multi-Criteria Decision-Making (MCDM) problems by deploying Fuzzy AHP (FAHP) and Fuzzy TOPSIS techniques.

1.3 Research Questions

The research questions aim to investigate the best strategies that can be proposed to promote the development of ESCO projects in government buildings. It also examines the importance of SWOT factors in formulating strategies. The following research questions were asked to achieve the objective of the study:

1. What internal strengths factors positively affect the implementation of ESCO projects based on governmental premises in the Kingdom of Bahrain? What internal weakness factors negatively affect the implementation of ESCO projects based on governmental premises in the Kingdom of Bahrain?
2. What external opportunity factors positively affect the implementation of ESCO projects based on governmental premises in the Kingdom of Bahrain? What are the external threats and factors negatively affect the implementation of ESCO projects based on governmental premises in the Kingdom of Bahrain?

3. What are the most significant SWOT factors that influence the implementation of ESCO projects based on governmental premises in the Kingdom of Bahrain? And what are the most significant sub-factors in SWOT that influence the implementation of ESCO projects based on governmental premises in the Kingdom of Bahrain?
4. What strategies can be suggested to the decision-makers to promote the implementation of ESCO projects based on governmental premises in the Kingdom of Bahrain Using Multi-Criteria Decision Making?

1.4 Research Objectives

Our study used a mathematical method for solving complex multi-criteria decision-making problems. The method is called the Analytic Hierarchy Process (AHP) model. The AHP model considers qualitative and quantitative criteria for evaluating decision-making options (Namin et al., 2019). The Fuzzy AHP (FAHP) and Fuzzy TOPSIS are models used as extensions of the AHP methodology. The FAHP and TOPSIS models provide a suitable mathematical framework incorporating experts' subjective judgment and approximate reasoning. It also performs better in practical applications than rugged computing statistical models (Bressane et al., 2020).

The Energy Services Companies (ESCO) projects are emerging in Bahrain, and literature reviews proved that ESCO could run the operation on premises efficiently. Proposing the best strategy to implement on-site ESCO projects as one of the energy efficiency plans can solve Bahrain's energy intensity problem and contribute to long-term environmental sustainability.

1.5 Significance of Research

- The building sector is one asset that consumes significant energy and contributes to the environmental footprint. Buildings are a relevant source of CO₂ emissions (Franco & Leccese, 2020). In 2018, the world spent \$138 billion on building energy efficiency, which could reduce energy intensity by more than 3% annually (Forrester & Reames, 2020). Another global primary target is achieving energy efficiency and reducing CO₂ emissions by 80% in 2050 compared to 1990 (Wong et al., 2020).
- In Bahrain, as in most Gulf States, almost 100% of the energy is consumed through oil and gas combustion. The fuel and electricity sell at low rates, reducing energy efficiency incentives. Uncontrolled energy use, in turn, increases the burden of costs on the government yearly as it pays for increased power generation capacity and covers the expenses of regressive subsidies. Moreover, CO₂ is rising with the increased energy used (Lahn & Preston, 2013)
- The increase in electricity and buildings is justified by the economic growth witnessed in Bahrain over the past decades. Hamdi et al. (Hamdi et al., 2014) tested the relationship between electricity consumption, capital, foreign direct investment, and economic growth in the case of Bahrain. Their results supported the positive causality between electricity consumption and economic growth. Similar results from a study conducted specifically on GCC by Salahuddin et al. (Salahuddin et al., 2015) implied that electricity consumption and economic growth stimulate CO₂ emissions in GCC countries. The results reveal a bidirectional causal link between economic growth and CO₂ emissions and a unidirectional relationship between electricity consumption and CO₂ emissions. Therefore, economic growth and

buildings are relevant sources of CO₂ emissions. In 2019, Bahrain produced a high methane emission level, reaching 18.5 Million MtCO₂e, and was reported to be the 63rd methane emitter worldwide (Ritchie et al.,2020).

- We need energy efficiency in the building sector to support economic growth without compromising the environment. In 2020, a study agreed that studying the energy consumption of buildings is important and contributes to energy sustainability (Franco et al., 2020). The commercial building (including government premises) must be designed and operated to have less environmental impact during its estimated lifetime while achieving performance efficiency premises.

One of the solutions to achieve efficiency in a building with high-efficiency measures is implementing Energy Service Companies (ESCOs) projects. Marion et al. (Marino et al., 2011) stated that Energy Service Companies (ESCOs) provide solutions to limit the increasing energy demand, decrease energy costs and control CO₂ emissions.

However, the absence of strategy causes the project to face several obstacles in the implementation process. Despite the benefits the ESCOs provide to institutions, adapting such an institutional strategy is still limited. The limitation is justified by significant challenges such as cultural, corporate, and regulatory obstacles (Hannon et al., 2015). Governments must consider the best strategies to implement ESCO projects based on governmental premises through scientific approaches. Moreover, analyzing the importance of factors (internal and external) related to Strengths, Weaknesses, Opportunities, and Threats (SWOT) in implementing such projects will lead the pave to propose the best strategies to promote the implementation of ESCO projects. In this research, we aim to find the best

factors to formulate the best strategies to contribute to achieving efficiency on governmental premises in Bahrain.

Through this study, we realized that information related to governmental premises is limited. However, the lack of information should not be an excuse for not taking actions extracted from proper strategies to support the ESCO project on governmental premises.

The present thesis provides insights into unexplored areas explained in the novelty of the research section. Figure 1.1 explains the importance of research in different areas.



Figure 1.1 The importance of Research in Different Areas.

The cost reductions offered by ESCOs motivate state agencies to use ESCOs. Generally, owners and managers of private buildings are profit-driven and benefit from cost reductions through greater energy efficiency. However, implementing energy efficiency programs in public buildings is difficult because the people who use the energy do not directly benefit from

the savings. Private sector workers know that their jobs depend to some extent on companies making a profit, so they are more willing to accept austerity measures. Research suggests that public sector workers have less incentive to do so.

For this reason, establishing an energy efficiency strategy as part of energy planning in public buildings will guide employees to gather and direct their efforts to achieve energy efficiency and develop the necessary approach. Private building owners and managers are profit-driven and typically profit from lower costs resulting from energy efficiency. The management and employees in the private sector are more willing to adopt cost-saving initiatives since they know their jobs depend partly on businesses making a profit. Contrary to the government's premises, several studies have shown that government employees are less motivated to achieve energy efficiency because they do not benefit directly from reducing energy costs. For this reason, establishing an energy efficiency strategy as part of energy planning in government facilities will guide employees to rally and direct their efforts to achieve energy efficiency goals.

Setting a proper strategy on governmental premises can motivate other buildings to implement a similar project in commercial and private buildings. The governmental building can be a leader and a role model in energy-efficient buildings.

Such projects will leverage the government's and ESCO's efforts to increase savings. ESPCs allow agencies to partner with energy services companies (ESCOs) to finance the upfront costs of retrofit projects through their long-term energy savings. This approach requires no upfront capital costs or special government appropriations, making it attractive to agencies. The ESCO's guaranteed energy cost savings are used to pay back the initial cost of implementing the measures.

In 2020, the pilot projects conducted on four government facilities in Bahrain placed a significant emphasis on a combination of direct responsibilities (funds appropriated by the government), energy savings performance contracts (ESPCs), and utility energy service contracts on four premises to enhance building performance and save approximately 23% of the amount of electricity and water consumption. Energy services companies (ESCOs) and Tatweer Petroleum and National Oil and Gas Authority in the Kingdom of Bahrain (National Oil and Gas Authority, 2020) collaborated to cover the up-front expenses of retrofit projects. The upfront expense of the ESCO project is surrounded by the energy cost savings guaranteed to the ESCO.

Due to the age of most governmental premises, attaining energy efficiency often requires facing various problems. Inefficient HVAC systems, inadequate insulation, and other factors in older buildings may make it more challenging to adapt them for efficiency. Yet, these characteristics suggest that certain ESCOs can significantly impact efficiency measurements. As a result, premises retrofitting offers more financial advantages than disadvantages.

1.6 Novelty of the Research

In Bahrain, ESCO projects are a relatively new concept. Proposing strategies to accelerate the implementation of ESCO projects will add value to the country's national energy goal and energy efficiency plans (SEU, 2017). (SEU,2017). To the best of our knowledge, no study has been conducted to study ESCO-based projects on governmental premises in Bahrain and analyze the influencing factors (internal and external). This study is considered a first attempt to identify and analyze EE-related factors in premises and examine them in scientific and structural models.

This study aims to suggest the best strategies which capitalize on the strengths and opportunities factors and limit the weaknesses and threats in ESCO projects on governmental premises. Proposing proper strategies for Bahrain to promote such projects has been neglected in previous studies. We aim to provide an academic framework to analyze the SWOT factors and sub-factors for ESCO projects in governmental premises for better strategic management in energy efficiency.

The possibility of adopting similar studies to commercial and private buildings in Bahrain is considerable. Further, the results can guide other GCC countries. The study utilized qualitative and quantitative methodologies to assess the importance of SWOT factors in improving the understanding and incorporation of policymakers' and experts' insights.

- Studying the drivers by identifying the SWOT's positive and negative factors will ensure the study's balance. The SWOT factors are relevant to Bahrain and can be the base for building strategies for energy efficiency on governmental premises and other projects in private or residential premises. The SWOT study factors can be considered as drivers for financial implications and improve decision-makers' awareness regarding the implementation of the ESCO projects since ESCO projects are an emerging concept in Bahrain.
- This research investigates ESCOs-based projects on governmental premises through a structured framework of Strengths, Weaknesses, Opportunities, and Threats (SWOT) analysis to represent the analysis in comprehensive, balanced criteria and overcome the limitations of previous studies. After identifying the factors in SWOT, we evaluated the importance of each factor by using two models of Multi-Criteria

Decision Making (MCDM) to assess the significance of the identified SWOT factors and sub-factors.

- Finally, finding the best strategies fit ESCO projects on governmental premises.

1.7 The Research Importance to Decision Makers

The key factors influencing ESCO projects on governmental premises are based on the acceleration of energy efficiency implementation.

- The better our understanding of ESCO projects in buildings and related drivers, the higher the potential for implementation success. The success of this research depends on understanding the major government strategies for energy efficiency in Bahrain and other authorized agencies.
- The study is an empirical study aimed at gathering and analyzing all decision-makers preferences to participate in proposing strategies and recommendations for such a project.
- It might also serve as a foundation for energy policymakers, stakeholders, and scholars to promote the implementation of ESCO project-based in governmental sectors. And it is increasing the understanding and incorporation of policymakers' and experts' insights.

This study can serve the decision-makers in the financial sector interested in green-funded solutions with limited financial and operational risk and economists supporting economic growth away from environmental degradation.

1.8 Research Theoretical Framework

The research will build on the Fuzzy Theory. Human judgments are usually sourced from the stored information and perception in the man's brain; the decisions are typically vague, unclear, and difficult to measure by numbers. The uncertainty of Multi-Criteria Decision Making and the ambiguity of human judgments are known as epistemic uncertainty (Wicksonon et al., 2020). In other words, epistemic uncertainty is sourced from the human belief system resulting from inadequate knowledge, misunderstanding of the process, and incomplete information and data (Basu, 2017). The fuzzy theory can be effectively applied to investigate epistemic uncertainty.

The uncertainty of multi-criteria decision-making can be solved by the AHP model, in which the element of the decision-making arrangement starts from the action's goal and illustrates all the related criteria to consider in the decision-making process. We plan to apply two models for the research problem: the FAHP and AHP TOPSIS models (explained in detail in Chapter 4). The criteria and attributions related to the problem are structured by following the SWOT framework. Understanding the strengths, weaknesses, opportunities, and threats of implementing ESCO projects in buildings can help explore the best governmental strategies. The SWOT framework is one of the strategic tools used for research in several fields. This study used main 4 sub-factors in each SWOT area to accurately measure their significance among each other. Using the SWOT approach to analyze strategies can better qualitative analysis of pre-studies issues extracted from similar projects (Fertel et al., 2013).

1.9 Research Setting

This study will use qualitative and quantitative techniques to measure the experts' insights and perspectives and the outcomes of the techniques processed in two different methods. A group of industry, government, and academia experts will perform an assessment scale by filling out 'Google forms' during the semi-structured interviews. The study is very focused and approached only audiences familiar with energy efficiency projects or involved in ESCO based-projects in buildings and ESCO Pilot projects in Bahrain.

The interest in the research started with the author attending several workshops and conferences, meeting experts in energy efficiency and building retrofits, and exploring their perceptions about implementing ESCO projects in buildings.

1.10 Research Approach

The research study is categorized into phases as follows.

1.10.1 PHASE I: Literature Review

The increasing energy intensity, CO₂ emissions, and economic growth are the main goals behind the increasing attention on ESCO projects in buildings. In Chapter 2, the importance of ESCO projects in governmental premises is thoroughly reviewed to identify how the ESCO-based project can face challenges in energy consumption and operational costs in building sectors. The Services Contracting (SC) Energy Performance Contracts (EPCs), ESCOs, and the related benefits in building sectors are explained in-depth in Chapter 2. The discussions led up to the unexplored area in ESCO barriers and motives in governmental premises in Bahrain for preliminary research. Chapter 2 also reviewed the importance of strategies and decision-makers' roles in such a project.

In Chapter 3, the literature review discusses the SWOT analysis framework and methodology of the Fuzzy-AHP-TOPSIS empirical framework used for the research and several studies of previous studies related to ESCO projects conducted in different industries, including the buildings sector. The final section of Chapter 3 reviewed previous studies using SWOT analysis and combined it with MCDM methodologies to identify the best factors in SWOT for better strategies.

1.10.2 PHASE 2: Preliminary Research

The discussion in several studies led to some common barriers to ESCO project-based implementation and similar barriers identified in our initial meeting with experts. A better-structured framework is needed to identify and organize the key influence of ESCO implementation. In Chapter 3, SWOT quantitative analysis is explained with a literature review designed to determine SWOT factors and sub-factors for the primary research. A conceptual framework of SWOT analysis for ESCO projects will be presented in Chapter 3. Chapter 4 explained the process and procedures of the research and how the factors and sub-factors of SWOT were formulated and identified. At the end of the chapter, we added five relevant to the research questions before conducting the methodologies and analysing the data.

Chapters 5 and 6 are structured to find the answer to the following research questions: “What are the strengths and factors affecting the implementation of the ESCO project- based on governmental premises?” “What are the weak factors affecting the implementation of ESCO project based on governmental premises?” “What are the opportunities factors affecting the implementation of an ESCO project based on governmental premises?” “and

“What are the threat factors affecting the implementation of an ESCO project based on governmental premises?”

1.11 Research Analysis – Fuzzy AHP

A gap was found in reviewing the SWOT analysis literature, which presented quantitative models in this research in Chapter 3. We reviewed techniques in MCDM to implement hybrid methods merging quantitative and qualitative models for the preliminary research in the ESCO implementation project. Semi-structured interviews were conducted with 25 experts in the field. Fuzzy AHP is deployed in Chapter 5 as a research methodology structured by SWOT to analyze the data collected in the interviews. We also used sensitivity analysis to test the reliability of the results obtained by Fuzzy AHP. The results are discussed with an in-depth explanation of ESCO implementation's identified significant factors and sub-factors.

1.12 Research Analysis – Fuzzy TOPSIS

In Chapter 6, we will deploy a different MCDM model, FAHP TOPSIS methodology, to analyze similar data collected in the interviews. The results of the ESCO implementation's most significant factors and sub-factors are discussed in depth. The results for both methodologies (FAHP and TOPSIS) will answer the research's sixth and seventh questions: ‘What are the most significant SWOT factors that influence the implantation of ESCO projects based in governmental Premises in the Kingdom of Bahrain? ‘What are the most significant sub-factors in SWOT that influence the implantation of ESCO projects based in governmental Premises in the Kingdom of Bahrain?

1.13 Research Terminology

This research uses the following terms to provide consistent and accurate information to the reader. Energy efficiency is a term used to control the energy consumed without negatively affecting the amount demanded using the latest technology in electrical equipment and renewable energy sources.

Literature review definitions for ESCOs cover different types of companies ranging from small companies, which provide simple energy efficiency solutions such as installing LDE lights and equipment, to large companies, which are specialized energy efficiency companies handling different sizes of projects conducting full or partial activities in energy efficiency projects.

In this research, Energy Services Companies (ESCOs) only refer to accredited specialized companies. Many ESCOs are accredited companies that fit the international institution's standards; in the USA, the ESCO accreditation system is set by the National Association of Energy Service Companies (NAESCO). European Union (EU) also established a Code of Conduct for ESCOs to develop an accreditations system for ESCOs to ensure the quality of service (Vine, 2005). Those ESCOs are qualified companies and have experts in human resources and guarantee a 25%-50% return on investment and undertaking projects in buildings called in this study ESCOs Project Based or ESCO projects. ESCO projects have the following characteristics in their operations:

1. ESCOs use a cost-effective mechanism to deliver energy efficiency in buildings (Hansen et al., 2009). Also, ESCOs refer to companies with several energy efficiency activities under services contracting formalities.

2. The companies which provide complete energy-efficiency solutions and technologies, including identifying, developing, and designing projects related to energy efficiency and CO₂ reduction, installation and maintenance of energy-efficient equipment, and verification (M&V) of the project's energy savings, and also guarantee the energy saving for the beneficiaries (clients) in the public, industrial, commercial, or residential sectors (Fang et al., 2012).
3. ESCOs guarantee savings in energy in the form of services contracting formalities through ESPs; in the contracts, ESCOs may also provide financing for energy efficiency projects under different resilient models (explained in Chapter 2). Servicing Contracts (SC) and Performance Contracting" (EPC) are contractual arrangements between parties. Usually, ESCO must deliver energy efficiency improvement measures, and the beneficiary pays for the savings that result from the energy (Hansen et al., 2009). ESCOs also take the financial and technical risks associated with the projects (Goldman et al., 2005). In this study, we used energy services contracting and energy performance contracting interchangeably, leading to similar meanings and purposes.
4. The companies with the potential facilities can arrange for any required financing models for the beneficiaries to implement the energy efficiency projects and investments and take full responsibility for contracted loan payments against different financial arrangements with financial banks (Winther & Gurigard, 2017). Super ESCOs are energy service companies (ESCOs) that provide traditional energy services and supply the beneficiaries with gas, electricity, and other energy resources. The Super ESCOs are expected to be key players in providing energy and energy-efficiency services to utility beneficiaries, and utility companies

are expected to compete or partner with Super ESCOs. The Super ESCO act is critical in solving complicated and multiple issues for electricity beneficiaries, and identifying Super ESCOs will be considered technology integrators, resource managers, and supporting financial tools (Vine et al., 2000).

5. Services Contracting (SC): Refers to Energy-Contracting as a proven 'delivery mechanism' to implement demand-side energy efficiency and (renewable) supply projects in buildings and industries. Under energy contracting, we have different performance contracts, such as energy performance contracts, guaranteed savings, and shared savings. Specialized ESCO specialized performance contracting submitted projects take the form of performance contracts.
6. Governmental Premises: Governmental premises refer to any public buildings and facilities operated under the authority of the government of the Kingdom of Bahrain. The operational expenses are paid through the Ministry of Finance in Bahrain. Any building projects are conducted through the Tender Board in the Kingdom of Bahrain.
7. SWOT Factors: SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis refers to techniques used in this research. According to Esra Bas's (Bas, 2013) definition, SWOT is a well-structured analysis method used to assess an organization's internal and external factors. Other researchers, such as Kanten and Ulker (Kanten & Ulker, 2013), stated that SWOT analysis is based on identifying the internal and external evaluation criteria, and the institutions could build strategies based on those criteria.

8. SWOT Sub-factors: SWOT sub-factors refer to the sub-factors, criteria, attributes, or preferences and, in some other articles, called attributes. In this study, the maximum number of factors in each SWOT factor is four to avoid negligence and overlapping when constructing SWOT lists. On the other hand, the limitation of the SWOT list is not so strict (Bas, 2013).
9. Analytic Hierarchy Process (AHP) is a strategic technique using a mathematical model to solve complex (MCDM) problems. The AHP considers qualitative and quantitative criteria for evaluating the decision-making options (Namin et al., 2019). In this study, we used a hybrid method to combine two strategic techniques (SWOT and MCDM) to view the analysis factors and quantitatively evaluate the importance of the factors. To strengthen the study and make it more solid, we applied two models from MCDM; one is called Fuzzy AHP (FAHP), and the second one is called Technique for Order Performance by Similarity to Ideal Solution (TOPSIS).

CHAPTER TWO

Literature Reviews

2.1 Introduction

The increasing energy consumption, CO₂ emissions, and economic growth are the main goals behind the increasing attention on ESCO projects in buildings. Therefore, we reviewed different aspects related to the research problem in the literature, which we organized in this chapter, as shown in Figure 2.1.

Studying ESCO projects conducted on the literature on small project scales such as energy meters and electric monitoring systems (Augustins et al., 2018), financial benefit of ESCOs (Goldman et al., 2005) and heat and solar systems (Bustos et al., 2016). However, rare studies were conducted on large-scale projects such as governmental buildings and premises. The benefits of ESCO extended to building sectors. Although Liu (Liu et al., 2018) and Hannon (Hannon et al., 2015) studies highlighted the benefit of ESCO in buildings in China and the UK, which operated in matured markets, not emerging markets like Bahrain, in both countries. The current thesis focuses mainly on government premises (schools, hospitals, sports stadiums, government institutions) with unique drivers and challenges that differ from other commercial buildings and profit-driven sectors and cutting the energy within their operational plan and targets.

The first part of this chapter reviewed the importance of ESCO projects on governmental premises and buildings by highlighting how ESCO project-based projects can face challenges in energy consumption and the operational cost of buildings. The related benefits of EPCs and ESCOs are

explained in-depth in the following section, highlighting the financial models of EPCs. We also explained the first pilot of the ESCO Project conducted on four Government buildings in Bahrain. The studies led us to some common barriers to ESCO projects-based implementation and some common barriers identified in our meeting with the experts at an earlier study stage (explained in Chapter 4). The barriers and supportive factors of ESCO projects are also reviewed in the following section. The last section of the chapter focused on the importance of strategic planning for projects and decision-makers involvement in the projects.

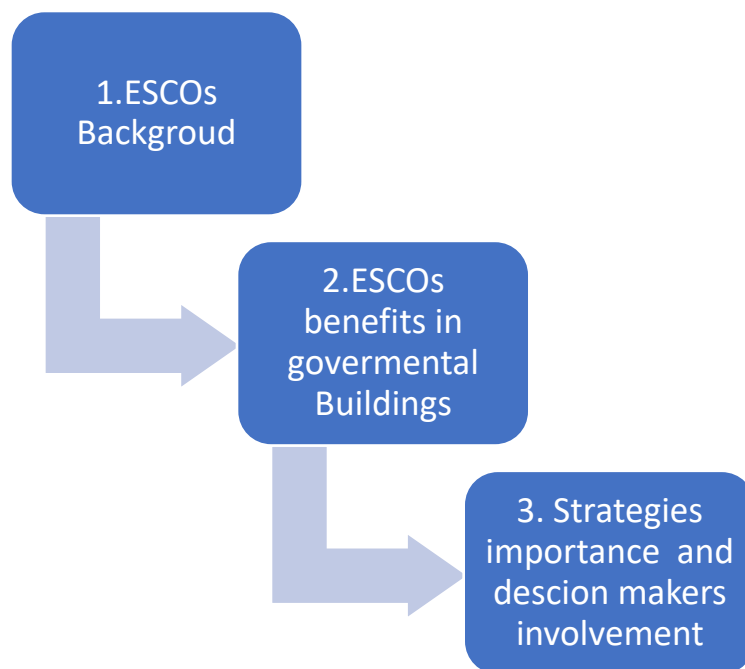


Figure 2.1: The flowchart of Literature Review

2.2 Energy Services Companies (ESCO) Background

The first Energy Services Companies (ESCOs) emerged in Europe more than 100 years ago (Winther & Gurigard, 2017) (Ürge-Vorsatz et al., 2007) and emerged in the United States (U.S.) in the 1980s, when they experienced the oil crisis and the tremendous increase in energy prices. The government energy program in the USA supported ESCOs, unlike other European

countries such as Denmark and the Netherlands, which selected ESCOs in demand-side management (DSM) bidding to achieve energy demand savings (Agency, 2006). The concept was revisited in Europe, where the ESCO industry has successfully developed in some countries such as Germany. Today, the concept of ESCO has spread and succeeded in most industrialized countries, many economies in transition, and other developing countries. ESCO was implemented successfully in the European Union (E.U.) and other countries to promote energy efficiency (Nurcahyanto et al., 2020).

ESCO refers to a specialized company that mainly delivers energy-efficiency-related services. According to The United Nations (U.N.), ESCO is a company that provides a range of energy efficiency and financing services. The U.N. considers ESCO a key instrument for implementing successful large-scale energy efficiency programs targeting the existing stocks of buildings, premises, facilities, or other energy services systems (UN, 2019).

ESCOs deliver projects in energy efficiency and renewable energy projects in buildings to cut the quantity of energy without negatively affecting the quantity demanded in energy. They conduct several operational activities including, but not limited to, Energy Efficiency (E.E.), Green Buildings (G.B.), Energy Performance Contracting (EPC), and Renewable Energy (RE) projects. ESCO's activities included a full-scale service of the project, such as auditing, identifying, developing, designing, monitoring, and funding energy efficiency projects. In the retrofitted buildings, ESCOs install and maintain the new types of equipment, measure, monitor, and verify the project's energy savings while assuming the risk involved in the expected energy savings. Some ESCOs provide energy to end users. In Estonia and Hungary, they took the role of financial providers, and in

Denmark, they were considered managers for the projects (Bertoldi & Boza-Kiss, 2017). Also, ESCOs approached business opportunities in electricity and natural gas markets, combining commodity procurement with energy price risk management and energy-efficiency services in a single, bundled product (Goldman et al., 2005).

There are apparent differences in ESCO markets among regions. These included the scope of EPC, the policies ESCOs are affected by, and technical capability. On average, ESCO projects save 25% of energy. Most ESCO projects are conducted in the non-residential building sectors, followed by industry, with limited numbers in the transport sector (IEA, 2018).

2.3 Services Contracting (SC) and Energy Performance Contracting (EPC) as Financial Model

ESCOs take risks associated with financial and technical areas of the projects through Services Contracts (SC), including Energy Performance Contracting (EPC). The EPC is an agreement between the beneficiary and ESCO, and the investment amount is paid according to a contractually agreed stage of improvement in energy efficiency. The EPC can be organized via guaranteed energy savings or shared energy costs. In the Shared Saving (SS) model, both parties (ESCO and the beneficiary) share energy cost savings according to a pre-calculated percentage for a fixed period. In the Guaranteed Saving (GS) model guaranteed energy cost savings model, ESCO guarantees the beneficiary a specific percentage of energy cost savings and thus assumes the project performance and the credit risk (Suhonen & Okkonen, 2013), (Carvallo et al., 2019). ESCO projects are revenue-neutral because energy cost savings are paid for by capital investment in energy improvements (Pearce & Miller, 2006).

According to Marion et al., he argued that energy service contracts provide comprehensive solutions for improving energy efficiency and increasing the utilization of renewable energy sources and help to overcome financial constraints to energy efficiency investments by paying off investment costs through future energy cost savings resulting from reduced energy consumption (Marino et al., 2011). About 80% of ESCOs offer contract energy management, and ECPs dominate projects in public infrastructure (such as street lighting), industrial facilities, and residential buildings. The projects are small- to large-scale, and public buildings are one of the operational targets for energy performance contracts (Marino et al., 2011).

In 2018, Liu et al. considered EPC a financing mechanism that includes energy savings guarantees, associated designs, and installation services for energy efficiency retrofit projects (Liu et al., 2018). U.N. explained that the company finances the services under the EPC and guarantees the specified energy-saving results (UN, 2019). International institutions accredit many ESCOs; in the USA, the ESCO accreditation system has been implemented by the National Association of Energy Service Companies (NAESCO). European Union (E.U.) also established a Code of Conduct for ESCOs to develop an accreditations system for ESCOs to ensure the quality of service (Vine, 2005).

2.4 The investment scale of Services Contracting (SC) and Energy Performance Contracting (EPC)

The investment scale Services Contracting (SC) and Energy Performance Contracting (EPC) in ESCOs are growing sectors and have the potential for further growth. In 2012, ESCO-implemented projects in the U.S. delivered energy savings (electricity, gas, water, and other resources) of

approximately 224 million MMBtu or about 1% of total annual energy consumption for all U.S. commercial buildings (Carvallo et al., 2019). In 2018, the world spent \$138B on energy efficiency (E.E.) in buildings, which can reduce energy by over 3% annually (Forrester & Reames, 2020). The World Bank estimated that developing countries could reduce energy consumption by 30—60% through profitable investments in energy efficiency. The value of the goods and services needed to meet these targets could be as high as the U.S. \$100 billion per year (Strickland & Sturm, 1998). The Global Environment Facility (GEF) has allocated more than \$90 million over the past ten years to eight projects promoting energy-efficient products in developing and transition countries (Birner & Martinot, 2005). Based on the International Energy Agency (IEA) and World Energy Investment Outlook Report, to unlock energy efficiency's economic and environmental advantages, a considerable increase in finance is required, with estimates projecting a need to mobilize over \$550 billion a year by the 2030s (IEA, 2022). At the 21 Conference of Paris (COP 21), national governments and multilateral development banks (MDB) announced a considerable increase in funding for climate mitigation, with some pledging to double the investment amount. The members officially affirmed their post-Paris commitment to scaling up green financing (Retallack et al., 2018).

2.5 Sustainability environment in governmental premises

Incorporating sustainability policy for governmental premises has gained momentum in recent years as the public sector recognizes the importance of reducing its environmental impact. Scientific journals have published various studies on this topic, examining different aspects of sustainable building design and construction. Here are some critical findings concerning maintaining a sustainable environment on governmental premises.

In Energy Efficiency, Pérez-Lombard et al. (Pérez-Lombard et al., 2008) argued that improving energy efficiency on government premises can help reduce greenhouse gas emissions and save energy costs. They suggested strategies for operating premises, including lighting, heating, cooling, and ventilation systems, as well as using energy management systems and building automation.

In renewable energy, Hernández et al. (Hernández et al., 2010) supported the efficiency of government premises powered by renewable energy sources such as solar, wind, and geothermal energy. The study's outcomes aimed to reduce dependency on fossil fuels and contribute to a more sustainable energy future.

Green roofs and walls contribute to building sustainability by providing insulation, reducing the heat island effect, improving air quality, and promoting biodiversity. Oberndorfer et al. (Oberndorfer et al., 2007) mentioned several sustainability benefits of green roofs for different buildings, including governmental premises. Water Efficiency is another important factor in green buildings. Domènech & Sauri (Domènech & Sauri, 2011) confirmed that water-efficient fixtures and appliances, rainwater harvesting systems, and greywater recycling could significantly reduce the water consumption of governmental premises.

In 2016, Kibert (Kibert, 2016) explained in his book that using sustainable building materials such as recycled materials, locally sourced, and low-carbon impact materials can help reduce the environmental footprint of government buildings. Also, enhancing indoor environmental quality through proper ventilation, air filtration, and low-VOC materials can improve occupant health and productivity (Wargocki et al., 2007). By implementing these sustainable strategies, government buildings can

significantly reduce environmental impact while promoting healthier and more productive workspaces for employees and occupants.

2.6 ESCO Projects- Based in Buildings and Government Premises

Historically, municipalities, universities, schools, and hospitals accounted for the most significant share of U.S. ESCO projects. They accounted for the most significant share of US ESCO projects. Total ESCO revenues reached about 69% of the total revenue of ESCO, an increase of over 10% since 2006, according to researchers at Lawrence Berkeley National Laboratory in Berkeley, California (Pentland, 2011).

In Europe, the growth of ESCO projects in governmental sectors from 2014 to 2020 reached 79.6 million euros, funded by the European Regional Development Fund (ERDF) through loans and guarantees. The public organization's involvement in funding ESCOs increased, and the Europe Energy Efficiency Fund (EEEF) reached 125 million euros and was funded by the European Energy Programme for Recovery. The EEEF offers risk finance for several projects, including energy efficiency, renewable energy, and clean urban transport projects (at market rates) to target public entities, municipal, local, and regional authorities, and private organizations acting on behalf of those authorities (Fiona et al., 2017).

2.7 The Importance of ESCO Projects in Governmental Premises Buildings and Its Advantages

The advantages of ESCO are addressed in several kinds of literature and approved in different projects. The advantages of the ESCO project reached different sectors and fields. The author highlighted the most important advantage linked to the building's stocks in this section. Buildings are considered a high energy consumption asset. According to the IEA, the potential to save energy in the facilities and buildings is huge (IEA, 2018).

The following section elaborates on the advantages of the ESCO projects in the buildings.

2.7.1 Limit the Rapid Increase in Energy Consumption on Premises

One of the benefits of ESCOs is controlling the increasing energy demand in the GCC, including the Kingdom of Bahrain. The peak in electricity loads is expected to increase by 46% in Bahrain and Qatar and 125% in Oman between 2017 and 2017 (UN, 2019). Krarti and Dubey (Krarti & Dubey, 2018) argued that Bahrain has the potential to cost-effectively decrease its energy consumption in buildings by 62%, with a reduction of 55% in its electrical peak demand compared to the business-as-usual scenario. The energy cost is also related to the number of power plants installed in Bahrain to satisfy the continued increase in electricity demand and economic growth. Bahrain is installing more power plants to cope with the future demand (Oxford, 2017), a burning cost for governments.

Moreover, expanding the operation of ESCO in Bahrain can uplift the scale of ESCO activities to operate as Super ESCO, which can act as a Virtual Power (VP) plant to eliminate the need to install more power plants, which are considered a burning cost for countries, (UN, 2019). Therefore, this advantage could solve the relevant problem of increasing energy demand due to the increase in population, which is explained thoroughly in the next section.

2.7.2 ESCO Offers a Solution to Control Energy Intensity and CO₂ Sourced from Economic Growth

Energy consumption is linked to economic development, and several studies (Hien, 2019), (Shahbaz & Lean, 2012), (Agboola et al., 2021), (Patlitzianas

et al., 2008) conducted to test the relationship and concluded that there is a causality relationship between economic development and energy consumptions.

Over the last two decades, the government of Bahrain has launched several structural reforms to accelerate economic growth and implement intensive structural projects to improve the infrastructure and create an open economy with liberalized trade and Foreign Direct Investment (FDI).

The government of the Kingdom succeeded in increasing the FDI inward in 2017 to USD 519 million from around USD 364 million in 2000, despite the global FDI trend falling to 23% in the same year (Hamdi et al., 2014). The increase in FDI is considered one of the main factors needed for economic development and GDP, but, unfortunately, it contributed to environmental pollution, too (Lin & Benjamin, 2018). However, Díaz et al. (Díaz et al., 2019) confirmed in their study that energy efficiency is essential to protect the environment and reduce CO₂.

In this context, the Kingdom of Bahrain is reported to be one of the largest CO₂ emitters (Ritchie et al., 2020), and the problem persists in a higher trend and continues over the years. The CO₂ emissions of Bahrain are calculated at 2.3 metric tonnes per capita, representing a high increase compared to 20.8 metric tonnes per capita in 1990) (The World Bank, 2019). Per-capita CO₂ e emissions in Bahrain are considerably high because of the country's high reliance on fossil fuels (Alsabbagh, 2019). Also, the lack of inefficiency due to energy intensity (2.72kWh/\$) caused the Kingdom to face high energy inefficiency, as reported by the World Bank. According to Alsahlawi (Alsahlawi,2013), the Kingdom of Bahrain is considered one of the most inefficient GCC countries with high energy intensity.

Some studies (Akdag & Yıldırım, 2020) and (Wongsapai et al., 2016) agreed that improving energy efficiency is one of the most cost-effective ways to reduce energy use and protect the environment from greenhouse gas emissions. Other studies, such as those (Wasti & Zaidi, 2020), were widely conducted to prove the links between energy consumption, economic growth, and CO₂ emissions regionally and globally.

The above reasons make us emphasize energy efficiency solutions offered by ESCOs. We agree that the resources available in ESCO operations can contribute to reducing the energy consumption needed for economic development without compromising environmental sustainability.

2.7.3 ESCO offers a secured Return on Investment (ROI) for Buildings Sector

ESCO represents an industry that can cost-effectively reduce pollution and bring sustainability goals closer in the communities. At the same time, the ESCO industry provides a 25–50 % return on investment (ROI) (Hansen, et al., 2009). The operational activities of ESCOs offer different financing models, where customers can often reduce their energy costs and install new equipment without up-front payment. The ESCOs guarantee savings and thus take the investments and financial risks associated with the project implementation. The payment for the services delivered is based on the efficiency improvements achieved, reduced energy costs, or other agreed performance criteria (Suhonen & Okkonen, 2013). The arrangement assures the return on investment (ROI) to cover the investment cost over time. The appeal is enormous, so it is not surprising that the Energy Performance Contracting (EPC) industry has been snowballing and continues to grow.

2.7.4 An Approach to Reduce Government Expenditure in Buildings

Usually, governmental premises need regular retrofit and maintenance. In Bahrain, a considerable budget is allocated for yearly maintenance and retrofit of government premises, according to the Ministry of Work and Building Maintenance Directorate in Bahrain (MOW, 2014). For example, in 2014, the government received retrofit and maintenance requests to cover 2199 buildings, mainly for a government school, and completed 41 schools for BHD 2.4 Million. (Al Ayam Newspaper, 2014). Moreover, in 2022, the total maintenance requests reached BHD 14.7 million. The total approved amount was BHD 12.1 million, including the retrofit and maintenance projects in The Supreme Council for Environment, Ministry of Health, University of Bahrain, Ministry of Justices, Ministry of Labour and Social Development, and Ministry of Finance (Alayam, 2020).

Most buildings need regular maintenance, and some government buildings are energy-intensive due to peculiar usage patterns and sprawling campuses with large-scale buildings, such as schools, hospitals, and Universities. Un-moderated methods and old installed equipment are considered high energy consumption and, in turn, increase the burden of costs yearly (Lahn & Preston, 2013). The vast and regular expenses paid for those national buildings are outside the financial sustainability strategies focused on reducing inefficient governmental expenditure (Bahrain Gov. 2021), propelling the 2030 vision toward achievements.

In Kuwait, Saudi Arabia, the UAE, and Qatar, energy subsidies accounted for 15%, 32%, 28%, and 15% of all government expenditures, respectively. However, the GCC region has been accelerating the trend of developing

more open energy markets with fewer subsidies to reduce the burden cost justified by the prolonged global oil price slump. The Kingdom of Bahrain offers a generous subsidy for electricity, water, and energy (diesel and fuel), and consumers (Bahraini and non-Bahraini pay only 11% of the actual cost of the kWh (Alnaser, 2015). Like other countries to control the burden cost in the government's book, Bahrain announced in early 2016 that electricity rates would be gradually increased and doubled to \$0.077/kWh by March 2019 for industrial, commercial, and most residential customers (Blashke et al., 2018).

Several studies have mentioned ESCO as a solution for several problems in energy and water waste in buildings. A ton of information and data are considered to find a suitable analysis.

2.8 The Pilot ESCO Project for 4 Government Facilities in Bahrain

Bahrain undertook many actions toward promoting energy efficiency projects and sustainable development with Bahrain Petroleum Company (BAPCO), the Gulf Petrochemicals Industries Company (GPIC), and Bahrain's national gas company (Banagas) (Elrahmani et al., 2021). The ESCO project started in 2020 on four governmental buildings.

The project focuses on retrofitting public buildings with energy-efficient technologies to save energy and reduce greenhouse gas emissions. The Pilot Project arranged by Bahrain National Oil Gas Authority (NOGA), Tatweer Petroleum, and Electricity and Water Authority (EWA) acted toward realizing the National Energy Efficiency Action Plan (NEEAP).

The project has made significant strides in promoting sustainability in government buildings in Bahrain. These buildings have undergone a detailed energy audit to determine the potential energy and cost savings that can be achieved. Based on the audit results, ESCOs have been invited to submit proposals for implementing the recommended energy efficiency measures. The project was undertaken by one of the specialized ESCO projects, which included the following scope:

1. Upgrading the lighting system with energy-efficient LED lights
2. Installing an energy-efficient HVAC system
3. Improving insulation and sealing of building envelopes
4. Implementing energy management system and controls
5. Installing solar panels and other renewable energy technologies

As per some officials in NOGA, the implemented ESCO project is expected to reduce the energy consumption level by 24% in five years, estimated to be 1.8 million USD (the saving recognized in the first few months post-implementation). The pilot project documentation was provided to help us with the study, including energy performance, including energy services, energy performance contracting (EPC), EPCs, measurement and verification (M&V), financial arrangements, market regulation process, ESCO prequalification, bid evaluation criteria, and certification of ESCOs studied by the researcher.

According to a report by the Bahrain News Agency, the ESCO Pilot Project is expected to reduce energy consumption in government buildings by up to 30%. Reducing energy consumption will promote sustainability and cost savings for businesses and government entities.

In conclusion, the ESCO Pilot Project in Bahrain has made significant progress in promoting sustainability in government buildings in Bahrain. In this study, we aim to deliver scientific results to implement the projects on other governmental premises.

2.9 SWOT Factors and Sub-Factors

We explored the literature reviews, which focused on the drivers and challenges in EE projects in buildings. We considered the factors in different lectures and studied the drivers and motives of the studies. In our study, we consider internal drivers as strengths factors of our studies, internal barriers as weaknesses, and external factors as threats and opportunities.

ESCO project in buildings is a relatively new concept in the Kingdom, and proposing strategies to expedite the implementation of ESCO projects-based will add value to the national energy target and the country's energy efficiency plans. Several studies investigated the factors and sub-factors. However, limited studies rank the factors and sub-factors in the structured analysis framework. Therefore, we decided to follow the SWOT and MCDM model's framework for analyzing the project implementation's current motivates and challenges.

2.10 The Barriers and Challenges in EE Projects in Buildings

Despite the number of benefits and opportunities that can be gained from implementing ESCO projects in buildings, the adaptation of such strategies to support the implementation is still minimal due to significant challenges and weakness factors such as cultural, corporate policy, and regulatory reviewed in the study conducted by Hannon (Hannon et al., 2015).

Human resources' involvement and compliance in energy efficiency projects in the building are imperative. They should cover not only supply teams (buildings developers and designers) and the regulatory teams (buildings control offices and surveyors) but also the decision-makers who are responsible for putting and selecting the best strategies and managing the implementation of the project (Pan & Garmston, 2012).

Vine (2005) gives details on the most essential barriers facing the ESCO industry in various countries, such as the unfamiliarity of companies and customers with ESCO and EPC, lack of financial solutions, low energy prices, and lack of government support to lead by example (Fang et al., 2012).

The upfront investment is one of the main barriers in ESCO retrofit projects in the building because the upfront investment needs to be secured by the building occupants at an earlier stage of the project (Delgado & Shealy, 2018), (Forrester & Reames, 2020), (Hannon et al., 2015).

2.11 The Importance of Strategies for ESCO Projects in Buildings and Strategy Planning

The world has faced challenges since the early 1970s, such as high-energy prices, greater energy demand, climate change, global warming, emerging carbon markets, environmental concerns, and international agreements. Those challenges created opportunities for developing ESCO businesses (Fang et al., 2012). A meaningful energy efficiency strategy must be formulated to capture the opportunities and maximum advantages. A meaningful energy efficiency strategy is needed to be in place to reduce fossil fuel consumption and transition toward a decarbonized energy system (Bleyl et al., 2019) and toward zero carbon and renewable energy policy.

In the USA, congress passed laws to reduce energy use in federal facilities by 30% by 2015, new efficiency programs were enacted, and significant retrofits to existing facilities were completed. Unfortunately, the federal government could only achieve a 9% reduction in energy use. Despite the continuous effort, actions, and executive orders, facilities still consume 34% of all energy used by the government. Delgado and Shealy ((Delgado & Shealy, 2018b) argued that the cause of the not reaching the potential of the energy efficiency program was the decision-making process and the cognitive biases that prevented the government from meeting its goals in energy reduction.

That was mentioned in the meeting we conducted with decision-makers at the initial stage of the thesis. We learned that managing the energy in buildings needs a strategy from top government authorities to fully utilize the potential of ESCO projects and expedite the implementation. Therefore, selecting the best strategy to implement ESCO projects must be linked to the energy sustainability strategy.

The foundation of strategies can be traced back to Alfred Chandler (b.1918), who stated in his book *Strategy and Structure* that a corporation should develop its strategy before deciding its structure (Richard, 2006). Since the ESCO industry is an emerging concept in Bahrain and many developing countries have started sustainability plans by defining the right strategy to achieve the goals, it will be wise to thoroughly study ESCO projects in buildings from the beginning as one of the energy planning strategies of the Kingdom.

Strategy guides the achievement of economies of scale (ES) and helps generate a higher return on projects, service offers, and investments related to ESCO projects (Marino et al., 2011). Developing a successful strategy

can help overcome several key challenges to financing ESCO's projects. Strategies proposing become a must to benefit from the advantages of the ESCO project against all the challenges experienced. In this study, we propose the best factors involved in strategies and use different methodologies to confirm the analysis results.

2.12 The Decision-Makers Involvement in ESCO projects

Decision makers play a crucial role in ESCO projects, and the success of energy retrofits (ER) depends on the right stakeholder's involvement at the rights stage of the projects. A study investigated the roles and functions of stakeholders in ESCO-led ER. Fasna (Fasna et al., 2020) conducted an in-depth case study on some of the hotel buildings to study the roles and functions of stakeholders in different stages of ESCO projects. The study collects the required data from face-to-face semi-structured interviews with seven selected stakeholders within the case. The results of this study ensure the importance of the proactive involvement of stakeholders in different stages of the ESCO ER project in the hotel sector.

We started exploring the literature reviews, which focused on the drivers and challenges energy efficiency projects face in buildings. We considered the factors in different lectures and studied the drivers and motives of the studies. Our study considers internal drivers as strengths, internal barriers as weaknesses, and external factors as threats and opportunities. Several studies investigated the factors and sub-factors. However, limited studies allocate the factors and sub-factors in the structure analysis framework. Therefore, we decided to follow the structure framework of SWOT for analyzing the current motivations and challenges facing the implementation of the project. ESCO projects in buildings are relatively new concepts in the kingdom. Proposing strategies to expedite the implementation of ESCO-

based projects will add value to the energy plan for energy efficiency in buildings.

CHAPTER THREE

A Fuzzy-AHP-TOPSIS Empirical Framework for ESCO Projects

3.1 Introduction

This chapter reviews the theoretical models used in the study that helped the decision-makers to build the study framework. In the study, the fuzzy theory was the theoretical framework on which the study was built, and the research analysis is based on the Multi-Criteria Decision Making (MCDM) model. In MCDM, we selected two models named fuzzy AHP and fuzzy TOPSIS to be applied to the primary data. We also reviewed the SWOT as a structured framework and its advantages as a compelling method for strategic energy planning. The third section explained the purpose of deploying hybrid methods, combining SWOT and FAHP and SWOT and F-TOPSIS, and the literature gap of SWOT, which we aim to bridge for our analysis. The final part of the chapter covers the literature reviews of previous studies on energy efficiency projects in Buildings and the discussion results. The theoretical framework and literature reviewed in this chapter are arranged as shown in Figure 3.1.

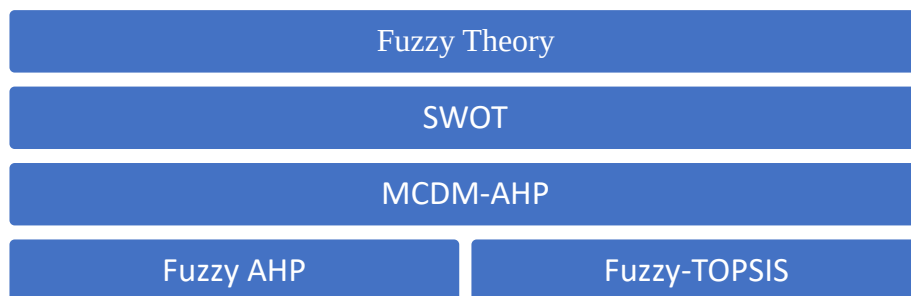


Figure 3.1 Theoretical Framework of the Study

3.2 Fuzzy Theory

Human judgments are usually sourced from the stored information and perception in the man's brain, and the judgments are sometimes vague, unclear, and difficult to measure by numbers. Several theories deal with unclear and ambiguous situations (Zimmermann, 1934). The theories address the problems of uncertainty from different angles. Each theory is differentiated in terms of purpose, methodologies, and scope.

The uncertainty of multi-criteria decision-making and the ambiguity of human judgments are known as epistemic uncertainty (Hanss et al., 2010). The epistemic uncertainty comes from the human belief system that builds on inadequate knowledge, misunderstanding of the process, and incomplete information (Basu, 2017). The uncertainty is recognized as reducible because it can be reduced by new information and data (Lee., 2005). The uncertainty in the judgments needs a fuzzy theory to investigate epistemically. A fuzzy theory is commonly used to investigate a small uncertainty sample (Tsai et al., 2017). The fuzzy theory is based on the fuzzy set, membership function, and boundary data; Zadeh (1965) suggested the fuzzy theory for the first time to solve the judgments' uncertainties. The theory describes fuzzy features by defining a membership function in which each member takes a membership degree from zero to one (0-1) (Guo and Wong, 2013).

Many fuzzy functions represent unclear data, and one of the fuzzy functions is called the Triangular Fuzzy function, which can measure particular linguistic terms and provide straightforward interpretations (Thaker and Nagori, 2018).

A triangular fuzzy number (TFN) is shown by (l, m, u) for the smallest (l), medium (m), and largest (u) possible values, and their function ($\mu_{\tilde{A}}$) is defined as follows (Meng and Chen, 2016).

3.3 Fuzzy Set in Theory and Distance between Fuzzy Triangular Values

A fuzzy set links a set of real numbers (X_i) into membership values (U_i) that lie in the range of (0,1). In the fuzzy model, a fuzzy set is represented by pairs U_i/X_i , and U_i is the membership value of the real number of X_i . (Kore et al., 2017) (Aydin et al., 2012). In the fuzzy model, a fuzzy set is represented by pairs U_i/X_i , and U_i is the membership value of the real number of X_i . (Kore et al., 2017) (Aydin et al., 2012). As shown in the drawing, $a=1$, a_2 represents the maximal grade of U , and a_1 represents the minimal grade of U . Therefore, a_1 and a_3 represented the lower and upper areas for the evaluation data.

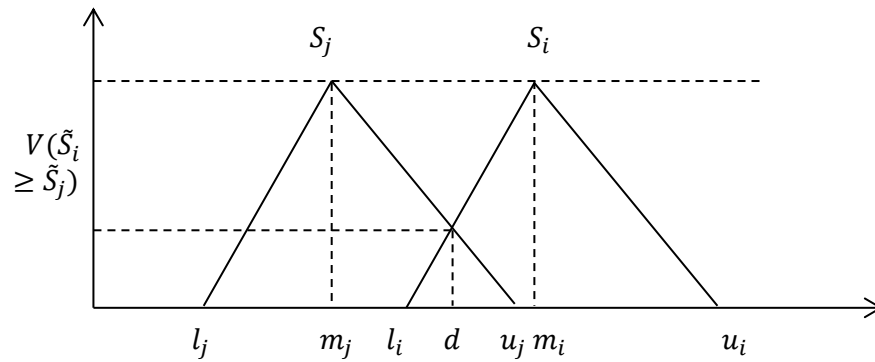


Figure 3.2 The Graphical Representation of $V(\tilde{S}_i \geq \tilde{S}_j)$ Chang (1996)

The values represented as $\{ u_1/x_1 \ u_2/x_2 \ ... \ u_n/x_n \}$. The x values in the brackets are represented in increasing order ($x_1 \leq x_2 \leq ... \leq x_n$). Values before x_1 have the same membership value as x_1 , and values after x_n have the same value as x_n . The value determines values between x_i and x_{i+1} on the straight line between the two consecutive points. The distance between Fuzzy Triangular values according to vertex methods is as follows:

If $\bar{a} = (a_1, a_2, a_3)$ and $b = (b_1, b_2, b_3)$ be two triangular Fuzzy numbers. The distance between them is given using the vertex $d(\bar{a}, b) = \sqrt[3]{\frac{1}{3} [(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]}$.

3.4 Theoretical and Empirical Framework of the Research

There are several models used to structure the analysis framework of the study. The selected models are related to solving strategic research problems using quantitative and qualitative methodologies. The first technique is SWOT, which is qualitatively used to identify the factors. The other methodologies were quantitative, Fuzzy AHP and Fuzzy TOPSIS, both used to solve MCDM problems.

3.5 SWOT Analysis Framework

To build a scientific case for the study, we started the research by reviewing and studying several frameworks and analysis tools before we decided on the SWOT analysis. Several reviews have been conducted on conceptual frameworks for the circular green economy (Kazancoglu et al., 2018). Sustainable development in productions (Saha, 2018) and sustainable projection (Tiwari, et al., 2020), as well as frameworks, cover energy resources such as waste management (Zorpas, 2020), water resource management (Apostolaki et al., 2019) and electricity supply chain (Bas, 2013).

The SWOT framework analysis is one of the well-structured strategic techniques to assess the current status or practice by evaluating its four factors, including Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T). The analysis assesses the internal and external evaluation criteria and attributes. The internal factors are used to analyze the strengths

and weaknesses of the project. In comparison, external factors identify the project's opportunities and threats not within the decision-maker's control. The goal is to help identify strategies (Fertel et al., 2013) and developing Industries et al., 2021) by describing the current situation or status of the project.

The advantages of deploying SWOT for strategy are as follows :

1. It allows better-structured qualitative analyses of pre-studied issues extracted from a similar project in literature reviews.
2. SWOT analysis provides the framing of essential and relevant strategies.
3. SWOT analysis helps significantly identify and analyze the factors and sub-factors for the energy efficiency ESCO building projects.
4. SWOT can be used to study the policies that encompass several parallel objectives.

The SWOT analysis is a powerful tool for strategic energy planning subjects (Fertel et al., 2013), which allows decision-makers to evaluate an issue by defining the parameters to set direction and strategic decisions for energy efficiency projects. Several related studies agreed that SWOT analysis is a convenient technique for strategically evaluating issues and practices (Liu et al., 2018). Scientific researchers broadly utilized SWOT for energy planning and analysis. In this context, the importance of the SWOT for energy efficiency is to utilize the strengths factors, adjust the weaknesses, utilize the opportunities, and minimize the threats. The SWOT analysis is very suited for this study because SWOT analysis is a compelling and effective method for strategic energy planning issues (Solangi et al., 2019). This study identifies the four SWOT factors (S, W, O, and T) from pertinent

literature and by local and regional energy efficiency experts. The ESCO-based project in the building is a relatively new concept in the Kingdom of Bahrain. Hence, SWOT analysis is appropriate for analyzing the building's ESCOs and energy efficiency projects. SWOT can favourably follow a proper strategy at the project's beginning stage.

However, the key disadvantage of SWOT analysis is that the factors cannot be assessed quantitatively (Solangi et al., 2019) and not able to reflect the importance of each factor (Lee et al., 2021), (Kanten & Ulker, 2013), (Namin et al., 2019), (Kurttila et al., 2000). The parameters or subfactors are not quantified to determine the degree of importance of each factor in the proposed strategy. Therefore, the SWOT framework cannot be considered a comprehensive assessment tool for strategy identification and project implementation.

Based on the above explanation, we need to add a quantitative measure to the study to strengthen the obtained results away from subjectivity and unclear judgments of the experts. Indeed, as decision-making processes become more complex by increasing the number of interdependent subfactors, the usefulness of using SWOT is decreased. Therefore, the quantitative measures of each SWOT factor can be achieved by deploying AHP models (Solangi et al., 2019). It can be concluded that the SWOT analysis is an effective tool for strategy, but merging it with qualitative techniques such as FAHP and F-TOPSIS can provide accurate analysis and results.

3.6 The Multi-Criteria Decision Making (MCDM) - Analytic Hierarchy Process (AHP)

The Multi-Criteria Decision Making (MCDM) and Analytic Hierarchy Process (AHP) model is among the energy sector's most popular and common assessment models. The MCDA model provides a flexible approach to solving multi-attribute (e.g., political, economic, social, technical, and environmental) problems by helping decision-makers (e.g., investors and managers) make clear and consistent decisions (Marzi et al., 2019). The Analytic Hierarchy Process (AHP) is one of the models used to address issues in MCDA.

Thomas Saaty developed the concept of AHP in the 1980s (Karayalcin, 1982), and it is one of the most widely and frequently methods used to resolve complex MCDM problems in diverse research areas (Zare, Mehri-Tekmeh, & Karimi, 2015). The AHP represents one of the most suitable methods experts use in energy planning because of its simplicity and transparency (Solangi et al., 2019).

The AHP model applied both tangible and intangible criteria based on the judgments of knowledgeable and expert people (Kurttila et al., 2000). The AHP arranges the study into a hierarchy so that each level contains elements that depend on its higher level in a linear form to show its dependency on the highest level. In Figure 2.3, we illustrated the levels of arrangement of the quantitative factors used in the analysis process in the research.

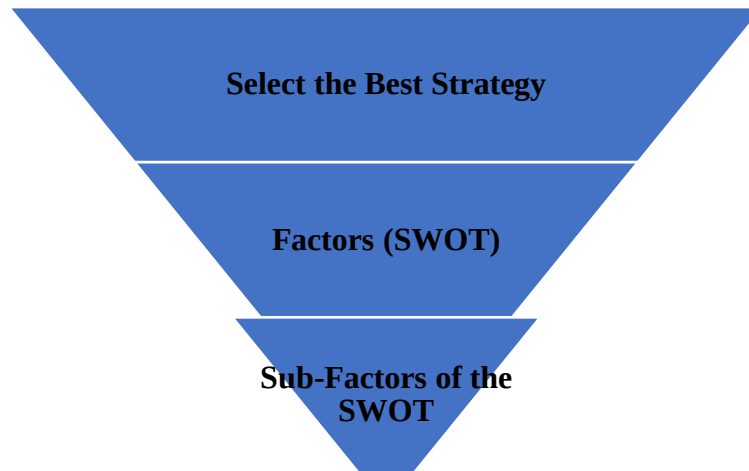


Figure 3.3 AHP of SWOT Factors and Sub-Factors

The values used in the quantitative interview questions were those explained by the linguist terms in the AHP importance scale—the values of AHP range from 1 to 9 (Berdie et al., 2017). Saaty’s scale ranges from 1/9 to 9 (Solangi et al.,2019). The descriptive terms in both tables solve the fuzziness in the information and knowledge in the experts' decisions. We used Saaty’s scale (1/9 to 9) in the study for our questionnaires.

AHP Scale (1 to 9)		Saaty’s Scale (1/9 to 9)			
		Scale	Definition	Reciprocal	Definition
Equally important	1	1	Equally important	1	Equally important
Moderately more important	3	3	Moderately important	1/3	Moderately less important
Strongly more important	5	5	Strongly important	1/5	Strongly less important
Very strongly more important	7	7	Very strongly more important)	1/7	Very strongly more important
		9	9 Extremely more important	1/9	Extremely less important

Table 3.1 The AHP importance Scale (Berdie et al., 2017) and Saaty’s point scale (Solangi et al.,2019)

3.7 Fuzzy Analytical Hierarchy Process (FAHP)

The first Fuzzy Analytical Hierarchy Process (FAHP) method was introduced by van Laarhoven and Pedrycz in 1983 (Kubler et al., 2018) and is viewed as one of the practical and popular methodologies for dealing with fuzziness and uncertainty. The Fuzzy Logic, combined with AHP, is more commonly known as Fuzzy AHP or FAHP. Kubler and his team (Kubler et al., 2016) argued that FAHP is the second most widely used technique in a stand-alone mode after AHP.

The main advantage of FAHP methods is that they allow comparing the factors using linguistic values, which helps select the most optimal one among a group of SWOT factors (Adar et al., 2016). The weights obtained from the FAHP method were used to achieve the weighted normalized fuzzy decision (Ligus & Peternek, 2018).

Several studies on energy efficiency used Triangular Fuzzy and Triangular Fuzzy Reciprocal Scale Analysis Models to conclude a proper decision among the experts and decision-makers and to avoid bias in human judgments when conducting pairwise comparison among assessment factors. The Triangular Fuzzy and Triangular Fuzzy Reciprocal (TFR) Scale Analysis Model is an accepted alternative to AHP, uses a fuzzy number and can reflect the accurate as possible, rather than an entropy number to represent the degree of relative importance (Delgado & Shealy, 2018).

The fuzzy numbers include the fuzzy interval number, the triangular fuzzy number, and the trapezoidal fuzzy number. In this study, we used triangular fuzzy number-based AHP (TFN-AHP) as a practical popular method for dealing with fuzziness and uncertainty; the TFN-AHP has been used to evaluate the key factors of some policies (Ma et al., 2021). The medium

value of the triangular fuzzy number represents the largest possibility of the assessment model. In contrast, the minimum and maximum values refer to the fuzzy degree corresponding to the largest possibility (Ma., 2021).

Therefore, the study used the Triangular Fuzzy and Triangular Fuzzy Reciprocal (TFR) AHP Scale Analysis Model to provide decision-makers and stakeholders with a solid foundation for accurate evaluation to identify the importance of factors for proper strategies to implement ESCO projects-based in governmental buildings in Bahrain.

3.7 FUZZY TOPSIS MODEL

The model Fuzzy TOPSIS is related to AHP models, which evaluate the alternatives in systematic steps on multiple criteria. A Fuzzy TOPSIS refers to the Techniques for Order of Preferences by Similarity to Ideal Solutions, and it's related to the MCDAM. The techniques brought by Hwang and Yoon (Hwang and Yoon, 1981) help in rating the alternative against several factors and weights the criteria evaluated in linguistic terms (Qin et al., 2017). The model TOPSIS was used to rank the alternative based on the geometric distance from the positive ideal solutions (PIS) and negative ideal solutions (NIS) and used the aggregation to compare a set of alternatives and the weights for each criterion (Kore et al., 2017).

The fuzzy TOPSIS approach is a powerful tool for MCDA, and it can be used in a wide range of decision-making contexts, including SWOT analysis. By providing a systematic and rigorous approach to decision-making, fuzzy TOPSIS can help decision-makers make informed and effective choices in complex and uncertain situations.

3.9 Hybrid Methodology: SWOT-FAHP and SWOT-TOPSIS

In this study, merging SWOT with Analytic Hierarchy Process (AHP) models can quantify the importance of each factor for decision-making and determine the weight of the SWOT factors and sub-factors in numeric values. The hybrid methodology SWOT-AHP offers a systematic approach to proposing and evaluating energy strategies for policies related to sustainable energy planning. The integrated SWOT-AHP technique has been used in different fields, including manufacturing companies (Görener et al., 2012), prioritization strategies in e-government (Lee et al., 2021b), electronic industry (Zare et al., 2015), Turkey airlines services (Büyükoçkan et al., 2021) and space and satellite field (Lee et al., 2021). The SWOT-AHP techniques have been utilized in several energy studies across many countries, as illustrated in Table 2.2.

Although SWOT analysis is the qualitative model used to identify the alternatives and organize the factors to assess the situation through a different dimension, it does not allow one to evaluate the degree of importance of the factors. This shortcoming can be overcome by using the Analytical Hierarchy Process (AHP) in both models, FAHP and F-TOPSIS, which provide a ranking advantage for SWOT factors according to their relevance and importance to the decision makers (Brudermann et al., 2017)

In 2017, Kahraman used SWOT-AHP to analyze e-government services in Turkey, and in his article, he used the model to evaluate alternative strategies for a government electronic application. The articles have since been cited more than 193 times and received online views 529 times as of 5 August 2022 (Kahraman et al., 2017).

In 2018, another study utilized a different Multi-Criteria Decision Making (MCDM) model called the Analytic Network Process (ANP) to determine the strategy for increasing the building ESCO industry and rank the most important factor in SWOT. A study by Liu et al. (Liu et al., 2018) presented the status of the building ESCO industry in China and proposed an alternative strategy. The results showed that ANP-SWOT provides invaluable insight for strategic management decisions in the building ESCO industry and proposed set strategies for the growth of ESCO in the buildings sector.

However, the most thoughtful and incredible blueprints for the methodology flowchart and contracture of the SWOT-AHP were found in an article published in 2020 by Nurcahyanto (Nurcahyanto et al., 2020). They studied the opportunities and barriers experienced in running the energy efficiency program in buildings by identifying and understanding the SWOT for the development market for ESCO in Indonesia. The study depends on surveying the key stakeholders in the industry, policymakers, and financial organizations and identifying important factors that can help improve the implementation of ESCO, such as regulatory financial, and increase awareness among the decision-makers. The study's results revealed that solid policy regulations and financial incentives could improve the development of ESOs.

In the study, we selected both models for the analysis: the Fuzzy AHP Model, deployed in Chapter 5, and the Fuzzy TOPSIS, deployed in Chapter 6. The purpose of selecting those methodologies is to obtain accurate results, strengthen the comprehensive assessment, and select the best SWOT factors to implement ESCO projects based on governmental buildings and premises in the county. It is worth mentioning, and to our current knowledge, no

similar hybrid methodologies have been utilized for the same projects to achieve the purpose of the study.

3.10 Literature Reviews: SWOT-FAHP and SWOT-TOPSIS on Energy Efficiency Projects in Buildings

Several information and data are studied in the literature to find a suitable analysis, and qualitative information is collected based on the types of analysis in energy efficiency fields. The limitations in the analysis of each technique were identified. However, the limitation for energy efficiency in each analysis is concentrated on a single element, such as PV for Energy (Lüthi, 2010), or a single project, such as a microgrid project (Brahim, 2020) at University Abdelmalek Essaâdi in Morocco.

A case study published by Guan (Guan et al., 2016) used long-term, real-time data on energy used in the Norwegian University campus for heating and water, which were analyzed using statistics and coincidental rates. On this base, the coincidence factors showed that energy usage was like water usage. The study identified an enormous potential for energy saving.

On an industrial level, different factors were tested in energy efficiency projects. A study conducted by Garbuzova and Madlener (Garbuzova & Madlener, 2016) explores the common risk factors and causes of risk associated with EPC projects executed in three Russian sectors: industrial, housing, communal services, and public. They conducted a qualitative risk assessment by using (AHP) approach. Brunnhofel et al. (Brunnhofel et al. 2020) assessed and prioritized the factors for implementing biorefinery in the European Pulp and Paper Industry (PPI) by conducting an empirical study.

Likewise, a study was tested in Latvia by Augustins and other researchers (Augustins et al., 2018) to analyze a dataset collected from energy meters in multi-buildings retrofitted by ESCO to analyze an energy monitoring system. The results show that structured energy management keeps designed energy efficiency guaranteed indoor temperature during the heating season.

Countries encountering different social, economic, and industrial barriers looked for relevant factors. For example, a study on Iceland and Sweden has embraced green resources because of their topography. In contrast, China, India, and the USA must consider them as solutions for their growing energy demand (Madurai et al., 2020). Other literature presented the drivers of the study based on the unique geological landscapes and energy intensity of specific countries. Their energy efficiency and renewable projects are priorities based on different scenarios and situations of each country and region. For example, the drivers are considered strengths in some countries or projects; similar factors are considered weaknesses or opportunities in other projects. Therefore, the importance of the drivers or factors viewed uniquely differed in different energy-efficiency building projects and different types of buildings. A balance must be placed between multiple performances and motives reflected in the complicated system of influencing factors (Pan & Garmston, 2012).

A study conducted in Saudi Arabia by Banani (Banani et al., 2016) assessed and summarized the criteria weights and priorities for evaluating sustainable non-residential factors in buildings, including the following: water efficiency and energy efficiency; materials selection; indoor environmental quality; effective management and land and waste. The surveys were conducted with various construction experts, and AHP methods were

employed to evaluate the data. The results indicated that the water and energy efficiency criteria represent the highest priority criteria for the study.

In 2018, a study published by Bleyl (Bleyl et al., 2019) revealed the economic and financial benefits of retrofitting office buildings by analyzing the projects' cash flow. The results showed that deep retrofit project cash flow built on 25 years achieved an IRR of below 2% and that heat saving costs reached 100EUR/MWh. The second part of the paper uses Multiple Project Benefits (MPB) to identify other benefits of the projects related to productivity. Table 4 shows several studies that used SWOT and AHP techniques in energy efficiency fields and strategies. However, limited studies discuss the drivers and weaknesses in the structural framework to analyze the implementation of ESCO projects in governmental premises or studies that analyze the factors in ESCO implementation in the Kingdom of Bahrain.

Year	Purpose/ Focus	Results	Country
2018	(Liu, Zheng, Xu, & Zhuang, 2018). Propose the strategy to expand the ESCO project in the building sector.	The research offers a quantitative analysis to identify the SWOT factors and select the most appropriate strategy to increase ESCO projects in buildings in China. The research applied the ANP-SWOT method to set strategies for ESCO for buildings.	China
2013	(Fertel et al., 2013). They applied SWOT to achieve energy security, efficiency, and technological innovation. The study focused on	The study highlighted the lack of Canadian strategy considering energy and climate and recommended cooperation between intergovernmental agencies and jurisdictions.	Canada

	energy and climate policy.		
2015	(Posch, Brudermann, Braschel, & Gabriel, 2015).They applied SWOT with AHP on paper and pulp sectors to analyze the internal and external factors in energy management systems towards competitiveness.	The study identifies the most important and direct factors in the paper and pulp industry related to energy cost, energy market, and energy efficiency. They agreed that SWOT-AHP provided an effective tool for the management in the energy field.	Austria
2017	(Allasseri, Rajeev Tripathi, Ashish Joji Rao, T. Sreekanth and K. J, 2017).Using SWOT analysis, explore the suitable Demand Side Management (DSM) measures to maintain the growth per capita electricity consumption.	An incentive program to control electricity demand is considered one of the most appropriate solutions to solve the increase in per capita consumption of electricity in Kuwait.	Kuwait
2016	(Garbuzova-Schlifter & Madlener, 2016). The study highlighted the most prioritized risk factors associated with EPC projects related to housing and industry in Russia by deploying the AHP approach.	The study's results illustrated the regulations and financial risk in implementing Energy Performance Contracts (EPC) projects. It recommended some changes in EPC policy and the business market.	Russia

2020	(Nurcahyanto, Simsek, & Urme, 2020). They applied the SWOT factors to expand the markets for ESCOs in Indonesia.	Solid regulations and financial incentives are needed to develop the ESCO industry, and the availability of financial opportunities in the same industry can add value to such development.	Indonesia
2019	(Stojčeto, Nikolić, Živković, & Bogdanović, 2019). They defined the current status of electricity in the municipality of Štrpce and found potential energy security strategies.	The article ranked the best strategies in energy security considering legal models, financial, and energy networks. Set up energy management in the different sectors and establish an office for municipal energy.	Serbia

Table 3.2 Literature Reviews on Energy Efficiency in Buildings Used Merged SWOT-FAHP and SWOT-TOPSIS

3.11 TOWS Analysis

The TOWS matrix is a framework to identify strategies based on the results obtained from SWOT and AHP analysis and TOPSIS (Gottfried et al., 2018). TOWS matrix provides four different combinations of strategies SO, ST, WO, and WT. The strategies developments in TOWS analysis are built based on the identified strengths, weaknesses, opportunities, and threats (Alpar, 2007); (Audenhove, 2007), (Baker & Edwards, 2012). Hence, the best strategies are determined by optimizing the strengths and opportunities and minimizing the weaknesses and threats of the expert's opinions. Energy sustainability is one of the fields that used the TOWS matrix in proposing strategies (Stojčeto et al., 2019), and (Kurttila et al., 2000).

CHAPTER FOUR

Research Methodology

4.1 Introduction

The objective of Chapter 4 is to explain the steps and procedures to formulate and identify SWOT factors and sub-factors used for the study. The data used in the study were primary and collected from semi-structured interviews through questionnaires shared with experts during the interviews. The respondent was focused and limited to 25 experts, selected carefully based on their experience in ESCO projects and building energy efficiency. The SWOT factors and sub-factors merged with the methodology used in Chapters 5 and 6 to analyze and categorize the results by applying F-AHP and F-TOPSIS.

The chapter is organized as follows. The coming section introduces the study design and procedures in stages. The first section includes the data-collecting process and highlights a group of SWOT factors. The following section explains the process of configuration and identification of SWOT factors and sub-factors. In the third section of the chapter, each factor and sub-factor is reviewed and explained about the energy efficiency project and buildings in Bahrain. The final part highlighted and linked the study's development to the literature.

4.2 Research Design and Procedures

ESCOs-based energy efficiency project is a new concept in Bahrain, and the subject lacks relevant historical data and published information. Therefore,

we utilized several sources to study and understand some related data and information collected from different sources.

4.3 Collecting and Configuration Data

The research information depends on the primary and secondary formations and data related to the drivers and challenges of implementing ESCO on governmental premises of the collected studies. Then, we configure the data and information in two sections; one lists the challenges, and the second configures the motivations for implementing ESCO projects in buildings. Collecting and configuring data is conducted in two stages, as explained in the following sections and Figure 4.1.

4.3.1 Stage One: Collecting Data and Information

At the initial stage of the study, we started meeting with different energy efficiency experts involved in ESCO and energy efficiency projects in Buildings so we could set up the scope of the study and explore the challenges and motives in implementing ESCO projects from their practical perspective. We also studied secondary sources of information such as articles and white papers. The following section explains, in detail, the sources of collecting data we used before formulating the research questions and identifying relevant SWOT factors:

4.3.1.1 Literature Review

A review examined the literature (Chapters 2 and 3) on ESCO approaches in developed and developing countries. We extracted the SWOT factors of similar energy projects and highlighted the negative and positive factors.

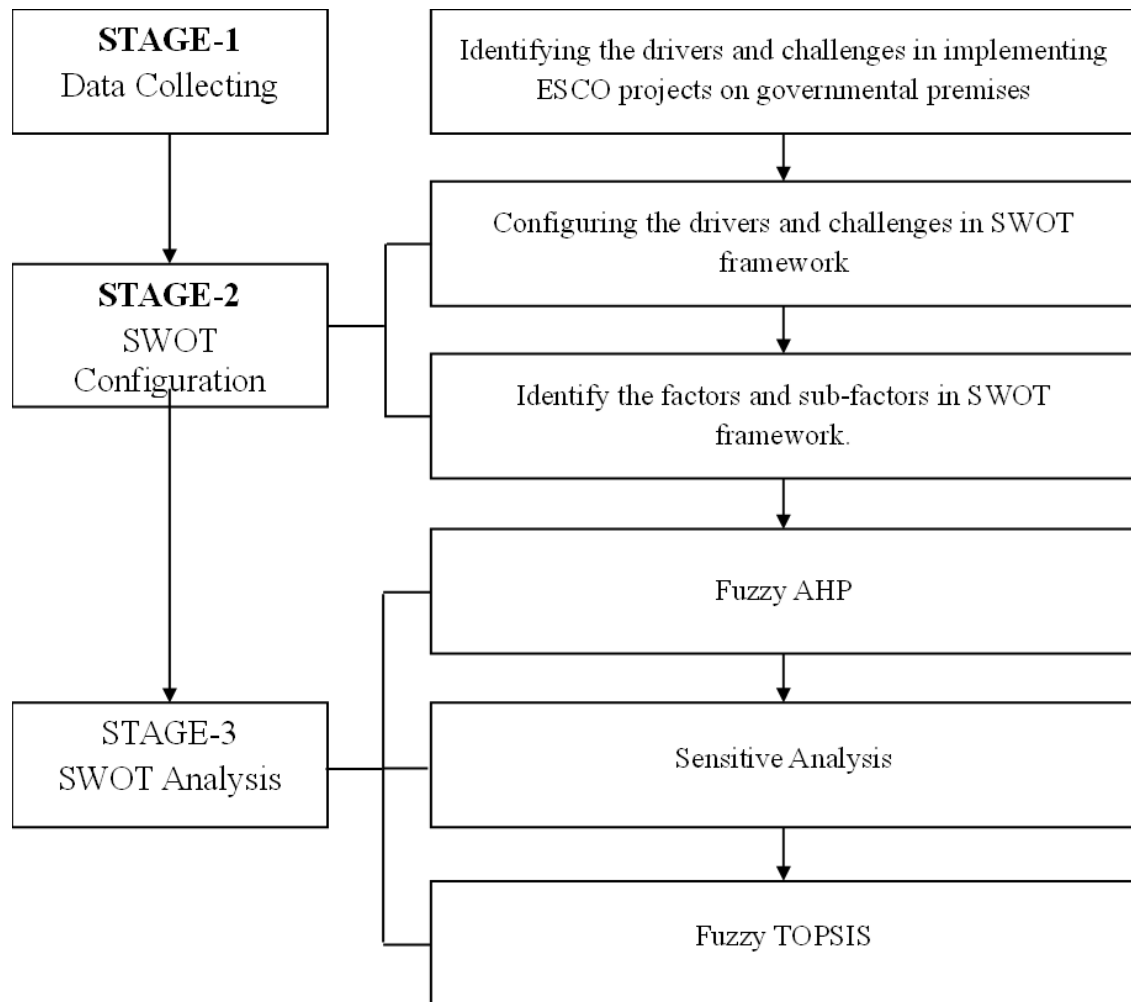


Figure 4.1 The Process of Collecting and Configuring Data - In Stages

4.3.1.2 Meeting Experts in Government Sectors

In 2019, a meeting was arranged with the National Oil and Gas Authority (NOGA), currently the Ministry of Oil. The meetings were held with three experts in the governmental sections and four from Academia. The experts discussed the importance of ESCO in governmental buildings in Bahrain.

Later, we conducted several meetings with the private sector in 2020 to discuss the obstacles facing ESCO projects, such as Elite Hotel and another project held with a private energy company called Capital Energy Company. The meetings aimed to investigate the motivation (strengths) and practical challenges (weaknesses) in ESCO projects in buildings. During the

meetings, we could identify several factors. For example, there is a lack of formal legal contracts and arrangements for such projects, limited social awareness of the benefits of ESCO projects, and no incentive to implement ESCO projects in governmental buildings. At the end of the meetings, we captured many insights into the current study, which helped us to formulate the study questions related to the subject (Tiwari et al., 2020) and (Au et al., 2018).

4.3.1.3 Meeting Experts from ESCOs

We met experts from the international ESCO to assess the University of Bahrain (UOB) building as part of this study in cooperation with the maintenance team in the Sakir Campus. The desktop analysis conducted by the ESCO company showed that there would be a 24% to 29% annual reduction in energy consumption, which will be reflected in electricity bills over 5 to 7.5 years. Universities are governmental institutions considered energy-intensive due to peculiar usage patterns and sprawling campuses with many (and often large) buildings and facilities.

4.3.1.4 ESCOs Reports

We reviewed the white paper and reports related to ESCO projects. Most are related to Europe, the USA, and the Gulf County Council (GCC), such as the United Arab Emirates and Saudi Arabia. It has been noticed that ESCO is a very mature market that started in the 1970s in the USA and Europe and faced many challenges at an earlier stage, which are similar to the challenges currently facing in Bahrain.

4.3.2 Stage Two: Configuration and Identification of SWOT Factors and Sub-Factors

In this stage, we configure, identify, and categorise the factors between motivation and barriers for the ESCO projects on governmental premises. And The following section will explain the process.

4.3.2.1 Configuration of SWOT Factors

In this research procedure, we segregated the factors between internal and external factors following the SWOT framework. Then, we created samples of the SWOT factors and discussed them with three experts from 3 sectors (Appendix 1). We selected the four most related and important factors to establish relative priorities (4X4 =16 sub-factors). Saaty (1980) recommends using only a limited number of factors to make comparisons manageable, the exact condition that Brudermann agreed upon in his study (Brudermann & Sangkakool, 2017). The SWOT sub-factors are limited to each area's most common and important subfactor. We selected the main factors in weaknesses, opportunities, and threats.

4.3.2.2 SWOT Identification

We eliminated factors with relatively low priority and focused on the four most relative factors to facilitate the analysis process. This reduction process left us with four main strengths, four main weaknesses, four main opportunities, and four main threats. We assessed the current status of the ESCO-based project on governmental premises by evaluating the internal factors related to strengths and weaknesses. The external factors are used to identify opportunities and threats that are not within the control of the project's decision-makers.

We identified the important advantages and strengths factors of the SWOT. We chose the challenges and barriers of the ESCO projects to represent the weak factors of the SWOT. In contrast, the external encouraging factors and future advantages gained from the ESCO projects were identified as opportunity factors. The external factors limiting ESCO project promotion are identified as threat factors. Table 4.1 represents the SWOT framework of the study.

	Strength Factors (S)	Weakness Factors (W)
Internal	S1: Reduce the electricity consumption and cost in buildings	W1: High upfront capital cost/limited access to fund
	S2: Contribute to achieving the national target in energy efficiency – (6% reduction by 2023)	W2: Business-as-usual mentality slows the acknowledgement of the benefits related to ESCO based Energy Efficiency projects
	S3: Reduce CO2 emission and contribute to environmental improvement	W3: lack of knowledge in technical and legal formalities for ESCO-based Energy Efficiency projects, i.e., EPC
	S4: Technical knowledge sharing between ESCO and employees	W4: Operational interruption in the buildings
External	Opportunity Factors (O)	Threat Factors (T)
	O1: The downturn in the Economy encourages governmental institutions to cut operational costs and invest more in energy efficiency	T1: Lack of incentive from the government to reduce the energy cost in buildings
	O2: Banks' capability to provide financial solutions for energy efficiency and green finance projects	T2: Energy costs are allocated and paid for by the government budget.

	O3: Huge building energy conservation potential	T3: Absent of regulations to support ESCO based-projects in governmental buildings
	O4: Benefiting from lessons from other countries experience	T4: Bureaucracy constraints - bureaucracy required at different levels of government authority

Table 4.1 The SWOT Framework

4.4 Experts Selection

SWOT factor identification is crucial. The selection of samples or stakeholders must be unbiased and balanced (Haque et al., 2020). Although the sample size is relatively small (experts), a similar study was conducted with only 8 experts (Liu et al., 2018). Moreover, the ESCO projects are an emerging concept in Bahrain and relatively new. The people involved in such a project are small, and the sample was very limited to the experts involved in practical projects. A group of industry, academia, and government experts assessed the factors and sub-factors using Microsoft Teams and Zoom through online interviews (due to the COVID-19 lockdown). Most have over 10 to 15 years of experience and a strong background and experience in energy efficiency implementation projects in Bahrain and other countries (Appendix 5). The Distribution details of the experts are shown in Table 4.2.

Gender		Education level			Sector				Year of Experience in Energy Efficiency Projects			
Male	Female	Post-graduated	Under-graduated	Certified	Government	Private	Academia	Other	1-5	6-10	11-20	>20
22	3	14	10	1	7	10	5	1	6	5	6	8

Position					Years of Experience in Energy Efficiency Project				Experience in ESCO Project Implementation		
Consultant	Decision-Maker	Manager	Researcher	Other	1-5	6-10	11-20	>20	Aware -of ESCO, No Implementation	Limited Implementation	
3	8	4	4	6	6	5	6	8	7	16	2

Table 4.2 Descriptive Details of the Experts

The selection of the experts was highly focused based on their involvement in ESCO-based projects in Bahrain and other GCC regions. We employed snowball sampling techniques in which the interviewed experts with desired traits or characteristics suggested names of other experts for the interviews (Hannon et al., 2015), (Haque et al., 2020). Such a technique aims to make the study's results highly focused on ESCO projects (as per the characteristics explained in Chapter 1). Therefore, we interviewed experts directly involved in the pilot project and ESCO in buildings in the MENA region.

4.5 Structuring AHP Pair Comparison Questionnaires

Based on the above, we formulated questionnaires to be answered by experts. Hence, the final AHP questionnaire included 30 pairwise comparison questionnaires (four sub-factors 4 X 6 pairwise questionnaires of each SWOT area =24) and the 6 pairwise comparison questionnaires that compared the SWOT factors. All comparisons were made based on the scale Saaty (1999) suggested, ranging from 1/9:9 (Appendix 2), meaning that factor one is much more important, to 1:9, meaning that factor two is much more important. The even numbers were deliberately left out, and the centre

of the scale (1:1) indicates a position where the respective factors are equally important Table 4-1.

4.6 Conducting Semi-Structured Interviews

Semi-structured interviews are one methodology used to collect the expert's weights (primary data) from competent experts. The questions below in tables (4.3 - 4.7 appendix 3) have been converted into pairwise comparison questionnaires and used 1/9-9 scales (Saaty, 1999) to allow the expert to assess the importance of SWOT factors and sub-factors from their perspectives and opinions. We used the questions in tables (4.3 to 4.7- Appendix 3) and set up the 30 questionnaires in pair-comparison format (Appendix 2) in Google Form. Then, we shared the form with the experts during the interview and asked them to compare the sub-factors of SWOT. We provided linguistic terms (important, very important, moderately important, etc.) as shown in Table 3.1 and asked the expert to select the best rates that match their thoughts. Sharing the forms of questionnaires during the semi-structured interviews allows us to clarify the mechanism of questions and rating scales and explain the sub-factors whenever required. Next, we collected all the values, transferred them from Google Forms to Microsoft Excel, and converted Saaty's scale rating (Table 3.1) in the questionnaires to 3-digit numbers (Table 4.8) to conduct the analysis. Finally, we analyze the values by implying the formulas in the Fuzzy AHP and Fuzzy AHP TOPSIS models explained in the coming Chapters.

Scale in Linguistic Terms	Triangular Fuzzy Scale	Reciprocal Scale in Triangular Fuzzy
Important extremely	(9,9,9)	(1/9,1/9,1/9)
Very, very strong	(7,8,9)	(1/9,1/8,1/7)
Very strong or demonstrated important	(6,7,8)	(1/8,1/7,1/6)
Strong plus	(5,6,7)	(1/7,1/6,1/5)

Strong important	(4,5,6)	(1/6,1/5,1/4)
Moderate plus	(3,4,5)	(1/5,1/4,1/3)
Moderate important	(2,3,4)	(1/4,1/3,1/2)
Weak or slight	(1,2,3)	(1/3,1/2,1)
Equal Important	(1,1,1)	(1,1,1)

Table 4.8 Triangular Fuzzy and Reciprocal Scale in Triangular Fuzzy rating (3 Digits Numbers)

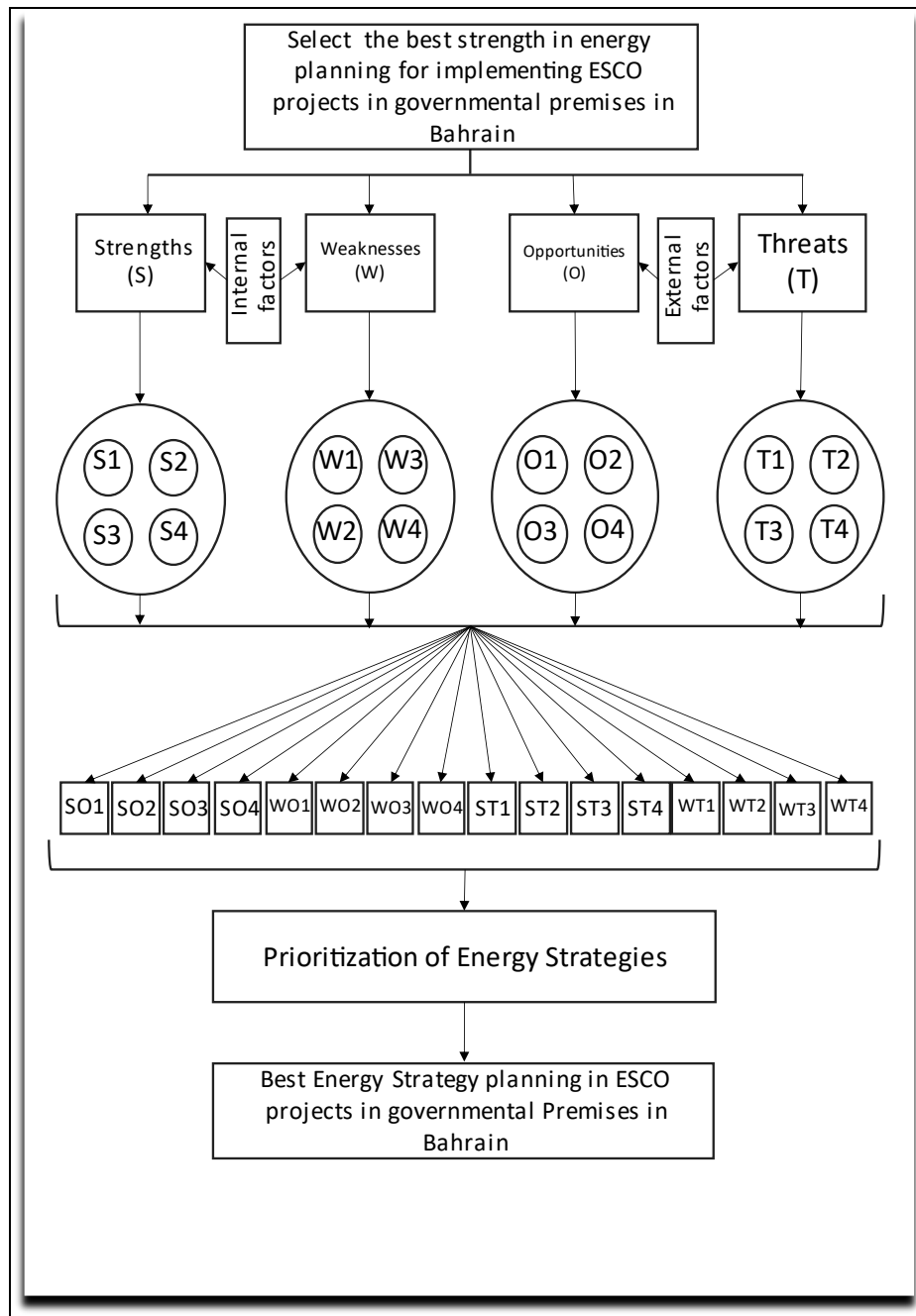


Figure 4.2 Hierarchy of the SWOT-AHP Factors and Sub-Factors

4.7 SWOT Factors Analysis

The section below explains the study's SWOT factors and sub-factors in detail. The sub-factors reviewed independence in a separate section. Figure 4.2 explains the hierarchy of the SWOT-AHP factors and sub-factors.

4.8 Strengths Factors

The strengths factors are the internal factors that assess the current implementation of the ESCO base project on the governmental premises in Bahrain and represent supportive factors for such implementation.

4.8.1 Reduce the electricity consumption and cost in buildings (S1)

The strengths factors related to ESCO and buildings are widely addressed in the literature (Chapter 3). One of the main factors is controlling the increasing energy consumption. As per The International Energy Agency (IEA), the energy consumption in Bahrain has witnessed a dramatic increase over the period 2000–2016; over 6300 kTOE was consumed in 2016 compared with 3000 kTOE in 2000 (Alsabbagh, 2019). The energy demand continues to increase in Bahrain. The residential sector was responsible for 48% of total energy consumption, and the commercial sector was responsible for 36% of total energy consumption in 2014 (Pillai & Naser, 2018). The buildings (commercial and residential) consumed a high portion of the total energy. Therefore, it has become an exciting and adequate area to be tackled toward efficiency targets. (Radhi, 2009).

The Kingdom of Bahrain has the potential to cost-effectively decrease its energy consumption in buildings by 62%, with a reduction of 55% in its electrical peak demand compared to the ‘business as usual scenario’. Implementing a retrofit program in Bahrain found to pay for itself when applied to the existing residential building stock and eliminate the need to develop new power plants while achieving savings of 495 GWh/year in electricity consumption, 116 MW, in electrical peak demand, and 377 Million tons/year in carbon emissions (Krarti & Dubey, 2018).

Energy costs represent a large part of the total operational cost in institutions; energy efficiency must be viewed as a motivated approach to cutting costs (Chai & Baudelaire, 2015). Hansen et al. (Hansen et al., 2009) agreed that the ESCO project is the most cost-effective way to gain increased energy security, improve industrial profitability and reduce costs.

Several studies (Nurcahyanto et al., 2020a), (Hannon et al., 2015), (Hou, Liu, Yang, Liu, & Qiao, 2017), (Suhonen & Okkonen, 2013), (Augustins et al., 2018), (Fang, Miller, & Yeh, 2012) agreed that reduction in electricity consumption is one of the most advantages of ESCO energy efficiency projects.

An institution reported a high percentage of total operation cost, the institutions hence, is likely to be more encouraged to reduce costs of energy consumption and be more energy efficient (Chai & Baudelaire, 2015), (De Groot et al., 2001) (Schleich and Gruber, 2008) and (Schleich, 2009). High energy costs can trigger top management support for energy efficiency (Cooremans, 2011).

4.8.2 Contribute to achieving the national target in energy efficiency – (6% reduction by 2023) (S2)

The Kingdom of Bahrain is committed to energy efficiency targets without compromising the energy supply and environmental sustainability. The effort has continued to overcome many challenges in energy efficiency, and one of the significant challenges is efficient and green buildings. The government in Bahrain and the regulatory authorities are open to adopting newly developed projects to achieve energy efficiency, proved by supporting the implementation of the Pilot ESCO projects in 4 premises.

The Economic Vision 2030 of Bahrain focuses on shaping the vision of the government, society, and economy based on sustainability, fairness, and competitiveness. The three guiding principles are heading in the same direction as the Sustainable Development Goals 2030 (SDGs). The Kingdom of Bahrain proposed targets and standards for fuel conservation and undertook several energy policy reforms to cope with geopolitical tension and oil depletion challenges. These goals are considered the government's current priorities and are linked to the executive actions of the Government Action Plan (2019-2022).

National initiatives and the energy efficiency target of Bahrain to reach 6% in energy efficiency by 2030 (which is very close) can trigger the support of decision-makers in government premises to implement ESCO-based projects and follow government direction to achieve the energy efficiency target.

4.8.3 Reduce CO₂ emission and contribute to environment improvement (S3)

The scientific community agrees that CO₂ emissions are the reason the earth's average temperature has increased over the past centuries. Energy intensity is a vital factor that impacts environmental sustainability and produces CO₂; producing electricity has a role in increasing CO₂ emissions and harming the environment. There are research studies on the causality relationship between energy consumption and carbon dioxide emissions (Wasti & Zaidi, 2020a), (Bang et al., 2019), (Lahn & Preston, 2013) and prove the relationship. Other studies also agreed with the causality relationship explained in Chapter 2. Therefore, ESCO projects based on

buildings can limit the impact of CO₂ on environmental sustainability and contribute to reducing pollution in Bahrain.

Bahrain was ranked as the world's 76th largest CO₂ emitter in the online scientific publication based at the University of Oxford called 'Our World in Data' (OWID), which published that CO₂ emissions (production-based emission) of Bahrain calculated at 31.06 million tonnes in 2018. That is an increase of 18.65 million tonnes (150%) compared to 1990, which was reported as 12.41 million tonnes (Janahi & Shams, 2020). In 2015, the World Bank reported Bahrain had a high energy inefficiency (2.72kWh/\$) compared with other countries at different income levels (The World Bank, 2013).

Limiting energy intensity and improving energy efficiency have been provided as one of the most cost-effective ways to reduce carbon dioxide CO₂ emissions (Saidur et al., 2010) without affecting the level of energy demanded in society. Since ESCO project-based can offer this advantage, theoretically (S3), the factor represents the outcomes of the (S1) factor, as most factors are interrelated.

4.8.4 Technical knowledge sharing between ESCO and employees (S4)

ESCO projects in buildings are an emerging concept in Bahrain, and technical knowledge is limited among employees in the government sector. Implementing energy efficiency by qualified ESCO companies on governmental premises increases the interaction between human resources in ESCO and employees in the different departments (maintenance, technical, accounting, and project management) in a government building.

The high level of human capacity (knowledge) and technical capabilities of ESCOs (Nurcahyanto et al., 2020a) will minimize the knowledge risk of such a project. Also, ESCOs offer several structured business models that guarantee saving energy, measure cost reduction (Bleyl et al., 2019), and limit technical risk. Sharing such experiences among the team in both sections will reduce the possibility of errors during the implementation.

4.9 Weakness Factors

The weakness factors are the internal factors that assess the current implementation of the ESCO base project on the governmental premises in Bahrain and represent factors that might adversely affect the implementation of the projects. Most weaknesses factors are interrelated, which will be explained in the coming sections.

4.9.1 High upfront capital cost/limit access to funding (W1)

The high upfront capital is one of the problems in most energy projects (Madurai et al., 2020). Upfront investment needs to be secured by the building occupant at an earlier stage of the project (Delgado & Shealy, 2018b), (Forrester & Reames, 2020), (Hannon et al., 2015), which is usually considered a significant barrier (Retallack et al., 2018) in project implementation. Also, securing high funds for an energy performance contract (EPC) project is crucial (Garbuzova et al., 2016) for some ESCO projects because ESCOs need to be partially funded to ensure the client's commitment throughout the project.

EPC provided by ESCOs is a performance mechanism for retrofitting buildings' energy. ESCOs in China have limited access to financing,

representing a key challenge for realizing large-scale energy efficiency projects in the building sector (Zhang et al.,2020).

In many cases, the decision-makers in government buildings in Bahrain lack access to investment capital due to the nature of the financial structure, which is centralized at the Ministry of Finance (Alayam Newspaper, 2014) of Bahrain, and this type of capital investment is not within the annual allocated budget of the government's financial books.

4.9.2 Business-as-usual mentality slows the acknowledgement of the benefits related to ESCO-based Energy Efficiency projects (W2)

Shifting to energy transformation and innovation proved difficult and faced individual resistance (Zaynullina, 2020). Several examples have been found in various industries where incumbent firms have suffered financial losses and technical obstacles as they have failed to adopt energy transformation in their operational business. The business model of innovation in sustainability projects is an explorative process that consists of a trial-and-error process (Kindström & Ottosson, 2016). The trial and error led the institution to a failure process and a learning experience. The existing energy policy does not support such risk (Hall & Roelich, 2016). Therefore, the government considers business-as-usual mentality a saving mindset, making them avoid taking an operational risk. This mindset adversely affects ESCO projects to be promoted in different local government entities and benefits from its advantages.

4.9.3 lack of knowledge in technical and legal formalities for ESCO-based Energy Efficiency projects, i.e., EPC (W3)

The bureaucracy is required at the different levels and between different ministries to comply with statutory requirements, such as legal formalities, tender writing, detailed audits, official form-filling, and report writing, the other increasing requirement/documentation/formalities (Posch et al., 2015). The legal requirements make initiating ESCO projects in government sectors a lengthy and challenging process compared to commercial buildings, whose business model is profit-driven and needs fewer legal formalities. Lack of knowledge in the legal formalities, technical solution documentation, and complicated administration procedures leads to inflexibility in decision-making and is usually hit by bureaucratic obstacles.

Several experts interviewed while collecting the data raised the issue of collaboration in reviewing the documents. They agreed that finding specific professionals in the local authority to review documentation related to the project and tenders was a challenging task. Professionals' legal views from experienced people in energy efficiency and buildings are needed for this project.

4.9.4 Operational interruption in the buildings (W4)

Operational disruption is when a firm experiences unexpected events interrupting a smooth flow of operations in energy capacity and implementing energy efficiency projects, sometimes affecting the operation inside the governmental buildings and shutting down the operation, which is a problem in most cases (Chai & Baudelaire, 2015). The frequent interruption in the operational flow of the buildings results in a technical risk to electricity assets (Thollander and Ottosson, 2008). Also, physical

constraints, such as lack of space, may hinder the ease of implementation. Most governmental buildings are considered service sectors for society, including hospitals and health centres, schools, universities, and ministries. To consider the process of operation with ESCO, a Ministry of Electricity, Ministry of Labour, Municipal Affairs and Urban Planning (EWA, Bahrain) must be involved in the process of operation of producers hired by ESCO to arrange the disconnection or shifting of the load of the buildings in case of sharing of electricity services and emergencies.

4.10 Opportunity Factors (O)

The opportunity factors are the external factors that assess the current implementation of the ESCO base project on the governmental premises in Bahrain and represent external supportive factors for such implementation.

4.10.1 Downturn in the economy encourages governmental institutions to invest more in Energy Efficiency (O1)

The Kingdom of Bahrain has a relatively diversified economy, with oil manufacturing (including aluminium and petrochemicals) and a financial sector, but there is a high dependence on oil revenues. Due to the collapse of global oil prices in 2014-2016 (World Bank, 2022), they were followed by the negative effect of the COVID-19 pandemic in 2020, leading most of the GCC countries, including Bahrain, to look for a strategic method to cut the cost. The government of Bahrain launched several initiatives to achieve fiscal balancing by 2024, mainly based on reducing operational expenditure in the government sector and resource optimization (Bahrain Vision, 2030). The Kingdom of Bahrain started investing in several projects related to energy efficiency in industries such as electronic cars and oil (Elrahmani et

al., 2021). The building can be one of the sectors to invest in and save money.

Using resources to cut the energy cost in governmental utility bills is necessary to face the increasing trends in energy expenses, especially in summer. Energy costs typically increase in the Kingdom of Bahrain during the long months of hot weather. The maximum temperature of the month in Bahrain was 40.5°C, recorded as the eighth-highest mean maximum temperature for August since 1946. August's highest mean monthly maximum temperature was 41°C in 2021(MOTT,2022). Similarly, the world has faced the problem of weather conditions since 2016, and almost a fifth of the increase in global energy demand as average summer temperatures in some regions exceeded historical records and pushed up the electricity demand (Zedalis, 2017). The empirical findings in a study published by Abbasi et al. (Abbasi et al., 2021) revealed that heating degree in days and investment in fixed assets are all positive indicators of electricity usage and electric cost. Therefore, the Investment in energy efficiency is a reason to face the energy intensity and environmental pressure (Wang et al., 2020) which the Kingdom of Bahrain both factors (explained in Chapter 3).

The principle of cutting costs through future savings in electricity expenses in buildings such as government buildings is represented in the financial mechanism of EPC (Energy Performance Contract), which covers the investment cost technology through future savings in energy costs and guarantees the saving (Winther & Gurigard, 2017). ESCO pays the Capital Expenditure (CAPEX), providing clients with an energy and cost-saving mechanism (Boza-Kiss et al., 2015). In other cases, ESCOs provide a return on investment through guaranteed savings arrangements.

Therefore, the principle of ESCO and EPC allows the governmental buildings to pay back investments through saved future costs and cut operational costs on their premises without compromising the energy supply needed for economic growth in the country.

4.10.2 Banks' capability to provide financial solutions for energy efficiency and green finance projects (O2)

The financial sector in Bahrain has the potential to utilize the increasing demand in the energy field and turn it into credit lending opportunities. Banks in Bahrain are considered one of the most vital sectors and have contributed to Bahrain's economic development for many years. The banking sector comprises over 85% of financial assets (Buchari et al., 2015). The Central Bank of Bahrain reported on its website that the total of Bahrain financial institutions reached 376 as of the end of September 2020, including 31 retail banks, 62 wholesale banks, 17 branches of foreign banks, and eight representative offices of banks, in addition to insurance companies and investment firms. As of July 2020, banking sector assets stood at over US\$212 billion, more than five times the annual GDP of Bahrain (Central Bank of Bahrain). The banking sector in Bahrain has the potential to allocate assets for energy efficiency projects, achieve the bank's implementation policy for green finance strategy (SEA, 2013), and follow the world's movement toward investment in energy efficiency.

The Intergovernmental Panel on Climate Change (IPCC) fifth report stated that the annual investments in energy efficiency across the sectors are expected to increase dramatically from 2010 to 2029 compared to other alternatives, such as renewable energy. Research (Nurcahyanto et al., 2020b), (Brudermann & Sangkakool, 2017), (Liu and Ren, 2020), (Hannon

et al., 2015) and (Pantaleo et al., 2014) agreed that the energy efficiency project provides a huge investment opportunity. More than 60% of cost-effective opportunities in the energy efficiency field are located in developing countries. The energy demand is increasing drastically in developing countries (including Bahrain), and the opportunities for energy efficiency are also increasing (Janahi & Shams, 2020)

The banks in Bahrain have the potential to provide an opportunity by being a financial player in energy efficiency projects for the government sector and obtain a secured credit benefit for their assets. The government sector is considered a secured client to the bank because fixed deposits and current accounts secure the credit facilities with the government. Government entities consider a low risk in the bank's books.

The regulatory Central Bank of Bahrain also encourages investment in green financial lines toward environmental sustainability objectives. In recent years, many banks in Bahrain have launched regulated frameworks to meet sustainable development goals (SDGs). Applying ESCO financial models for governmental projects with the banks can be an attractive opportunity for all parties.

4.10.3 Huge Building Energy Conservation Potential (O3)

As in most Gulf States, electricity is the primary energy source in Bahrain. The final energy consumption is divided into four primary sectors, as shown in Figure 1. Commercial buildings, which include governmental premises, are the second largest sector consumer of electricity and account for 16.4% of total electricity consumption (Krarti & Dubey, 2018), as shown in Table 4.4 and Chart 4.1. The increase in energy consumption in commercial buildings is likely to continue to increase considerably. As countries

develop, the fraction of energy consumption in facilities devoted to commercial buildings may increase too and contribute to more excellent production of CO₂ and greenhouse gas emissions.

Type	Number of Customers	Percentage of total
Residences	205,315	76.51%
Commercial buildings	44,189	16.47%
Industrial facilities	18,358	6.84%
Agricultural units	474	0.18%
Total	268,336	100.00%

Table 4.9 Types of Customers for Electricity in Bahrain (Krarti & Dubey, 2018)

Based on the above, there is a considerable potential to save energy in buildings by implementing ESCO projects to offer the needed demand efficiently and save the energy for other potential expansions or increases in the demand for electricity to achieve sustainability. Frano and Leccese (Franco & Leccese, 2020) agreed that studying the energy consumption of buildings is essential to energy sustainability, and Marzi et al. (Marzi et al., 2019) agreed that energy efficiency is crucial for energy conservation.

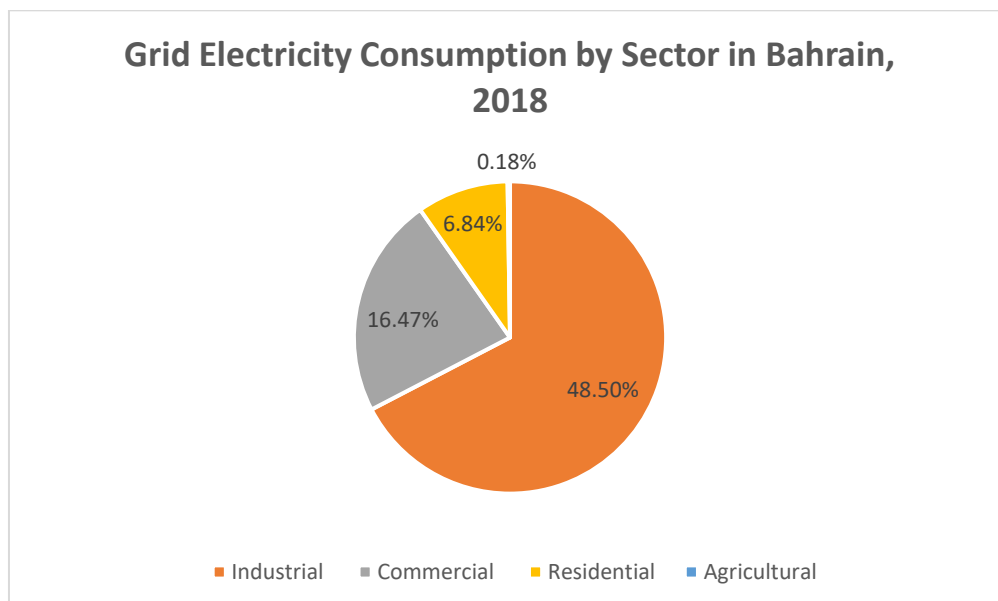


Figure 4.3 Grid Electricity Consumption by Sector (Krarti & Dubey, 2018)

4.10.4 Benefiting from Lessons from other Countries Experience (O4)

The lessons learned from implementing ESCOs in developed and developing countries would help the promotion of ESCOs in the Kingdom of Bahrain. The initial ESCO concept started over 100 years ago and moved to North America in the 1970s (Hansen et al.,2009). The development of ESCOs in western developed countries is far more advanced compared with other parts of the World. During long-term development, ESCOs in these advanced countries faced several barriers, such as low energy prices, conflicts with other government outcomes and policies, short repayment requirements, high transaction costs, and so on (Hansen, 2011). In the foreseeable future, Bahrain might face the same barriers. Thus, many lessons about preventing or coping with barriers of ESCOs in their developmental process are worth learning.

It has been observed that the GCC has scaled up some of its renewable energy projects based on the knowledge and experience gained from older projects. For example, utilizing solar power means has increased over the years. Mohammed bin Rashid Al Maktoum Solar Park has witnessed a yearly increase in its installed capacity for Dubai. Between the period from 2017 to 2020, the project has expanded its capacity to a total installed capacity of 1288 MW. Moreover, such large-scale projects may have influenced other GCC countries to learn from such experience to implement their large-scale solar projects since all GCC countries experience almost the same conditions (Elrahmani et al., 2021).

Several lessons can be learned as an opportunity to synthesize and establish the priority factors for implementing such projects in the Kingdom of

Bahrain. Also, to study and learn different ESCO approaches in different countries to glean best practices to be adopted by local policymakers.

4.11 Threat Factors (T)

The Threat factors are the external barriers effect the implementation of the ESCO base project on the governmental premises in Bahrain and represent challenges for the project.

4.11.1 Lack of Incentive from the Government to Reduce the Energy Cost in Buildings (T1)

The oil and gas sector represented the most substantial component of Bahrain's economy. Hence, Bahrain ranked 66 globally in oil reservations and 57 in gas reservations. Fossil fuels represented 73.1% of total exports, which accounted for 26.2% of GDP (Tsai & Mezher, 2020). The economic position allowed Bahrain, over past years, to provide highly subsidized electricity prices and consume energy with few conservation traditions.

Bahrain and other GCC regions have been accelerating a trend to develop more open energy markets with fewer subsidies to ease the burden on government budgets already strained by the prolonged global oil price slump (Sabouni R. et al., 2018). Therefore, in early 2016, Bahrain announced that electricity rates in Bahrain would gradually increase from 2016 to 2019, eventually doubling to \$0.077/kWh by March 2019 for industrial, commercial, and most residential customers (Nurcahyanto et al., 2020b).

The energy rate is still low compared to other non-oil countries, so the incentive to reduce energy expenses is still limited. Thus, there is no incentive towards the energy efficiency of government-building energy systems – and it would not lead to a significant change in behavior. It would

have limited motivation to implement energy efficiency projects and rebound effect (Dubey & Krarti, 2017).

The ESCO industry is a new market in the country, and to promote ESCO activities, an incentive program needs to be embedded in the policy support (financial and non-financial incentives) for the ESCO implementation project. The absence of targeted policies and programs is a threat and limits the ESCO projects in buildings.

A study concluded by Allasseri et al. (Allasseri et al., 2017) that an incentive-based demand program for energy efficiency could be considered one of the most suitable solutions to address the increased energy consumption in buildings. The absence of incentive demand programs and demand side management (DSM) solutions such as energy efficiency (EE), demand response (DR), price-based DR program (PBDRP), and incentive-based demand response program (IBDRP) do not motivate the buildings sector to reduce the energy consumption and search for energy efficiency solution. This threat can be minimized by implementing ESCO projects, which have proven to lead the shift toward selling “energy solutions” as part of their operational model (Goldman et al., 2005).

4.11.2 Energy cost is Allocated and Paid by the Government Budget (T2)

The daily decision process for government facility stakeholders is full of challenges, such as limited operating budgets and bounded rationality about energy consumption and savings (Delgado & Shealy, 2018). One threat that affects the promotion of ESCO projects in governmental buildings is the mechanism of cost allocation in the government sector. In Bahrain, the

‘Ministry of Finance’ allocates the electricity expense in governmental buildings at the beginning of each fiscal year as one of the operation costs of the building. Therefore, empowering resources inside the facilities to conduct energy efficiency projects in the governmental buildings is very limited and is not considered a priority for many public institutions in Bahrain, unlike commercial buildings where the institution is profit-driven and has a strong appetite to take any initiative to cut the operational cost to be reflected on their bottom line.

The discussion with the key stakeholders of the pilot project confirmed that government buildings need to put a strategic action plan for existing governmental buildings supported by allocated budget and energy-saving measurements.

4.11.3 Absent of Regulations to Support ESCO-based Projects in Governmental Buildings (T3)

Literature on the ESCO market in Bahrain is limited as the ESCO market is still in its early stages of development. Interviews with Key Informant Interviewees were conducted at the initial stage and part of this research to understand the current state of the ESCO market and the needed steps for its growth moving forward. Significant gaps focused on the need for a stringent regulatory framework and project financing and the absence of certifications in the field despite the presence of engineers.

The existing regulations do not support energy efficiency projects in buildings. Thus, ESCO energy efficiency projects compete with other technologies, such as solar PV, and with proponents of traditional simple solutions in the building industry. An energy efficiency policy framework is needed at numerous political levels, and there is a lack of financial support for the projects. More consideration must be given to subsidizing energy efficiency projects or integrating energy efficiency with renewable energy technologies.

In several countries, including GCC, establishing substantial ESCO markets has emerged from a combination or package of basic ESCO models through dedicated finance, enabling policies, regulatory actions, and rising public sector demand. Simpler models combined with legislative support and dedicated financing boost markets in South Africa (utility-based standard offer program), Armenia (Super ESCO providing energy service agreements), India (Super ESCO, accreditation scheme, and deemed savings), and China (aggressive energy efficiency policy, public pilot ESCOs, and equipment leasing) (Hofer et al., 2016). The absence of strong

energy efficiency policy regulations, regulatory actions, and financial incentives will threaten the development of ESCOs.

4.11.4 Bureaucracy constraints - bureaucracy required at different levels of government authority (T4)

The bureaucracy in approving and drafting all administrative formalities and documents delays the implementations and delays gaining the related benefits of ESCO energy efficiency projects. In Bahrain, several national authorities (such as the Ministry of Finance) study and evaluate such projects (Alayam, 2019). The obstacle makes the investment in such a project less attractive for investors and financial sectors. This type of project requires a top-down policy to minimize the risk of time constraints. Delays in formatting and adopting an energy policy were partly due to the institutions' cumbersome, procedural, and bureaucratic nature (Maistry & McKay, 2016).

Unfortunately, it took years to get the policy drafted and ratified as it was delayed by conflicting priorities and bureaucratic procedures (Maistry & Makay, 2016). Governance processes could be more convenient and complex, with numerous administrative steps and approval levels required for a long time. It took time to get authorized people to sign off the documents, but the tender processes are also very long, as is the evaluation period and appointing the contractor. In the meeting, one of the experts mentioned that the delay in processing could reach 12 months or more. The bureaucracy constraints are a threat that can adversely affect the increase in energy efficiency projects. Absent of proper policy effect policy traditional investment in Bahrain makes valuing and lending for energy savings

complex, leading to different weakness areas explained above.
(Nurcahyanto et al., 2020).

4.12 Hypothesis Development

Five hypotheses were developed with the help of a literature review. Two models of Multi-Criteria Decision Analysis (MCDA), FAHP and F-TOPSIS Analysis, were used with the help of Microsoft Excel to test these hypotheses.

4.12.1 Hypothesis 1

Hypothesis 1 (H1): Strengths of ESCO projects are more important in the SWOT than weakness, opportunity, and threat factors.

Hypothesis 1 (H1) was developed by considering the strengths factors in implementing ESCO projects on governmental premises as the most critical factors. Since we are collecting data from experts who believe in the strengths and motives of the ESCOs, we assumed the strengths factor is the most influential and dominant in the SWOT framework. A study in Pakistan reveals the importance of considering the strength factor in the strategic energy planning process among SWOT factors (Solangi et al., 2020). Another study was conducted on developing markets for ESCO in Indonesia and concluded that experts had given their opinion regarding the SWOT factors, which were equal for each SWOT category (Nurcahyanto et al., 2020). A case study conducted in Turkey reveals that the strengths and success of the energy services market are around 58% (Acuner et al., 2021).

4.12.2 Hypothesis 2

Hypothesis 2 (H2): The reduction in the electricity consumption and cost in buildings (S1) is more important than strength than contributes to achieving the national target in energy efficiency (S2), S3 Reduce CO₂ emission (S3)

and technical knowledge sharing between ESCO and employees (S4) in strength Factors of SWOT.

A study in Indonesia by Nurcahyanto et al. confirmed that the potential to reduce energy consumption in buildings to save money is one of the most substantial factors in SWOT analysis (Nurcahyanto et al., 2020). Hannon et al. argued that ESCO in buildings contributed to cost reduction in electricity under EPC, which guaranteed the reduction in final energy consumption. Commonly, this translates into cost savings in the institution's accounting books (Hannon et al., 2015). Hou et al. also researched considerably large public building stocks. They found out that cost saving from a long-term perspective is of major importance in retrofitting building projects (Hou et al., 2017).

Suhonen et al. explained in their study that, in the model of guaranteed energy cost saving offered by ESCOs, the client obtained a certain level of energy cost savings (Suhonen & Okkonen, 2013). We also learned from the experience in Latvia that Augustins et al. agreed that ESCO energy monitoring is an essential tool for planned energy savings and maximum energy efficiency (Augustins et al., 2018).

In 2018, Liu et al. considered EPC a financing mechanism that includes energy-saving guarantees, associated designs, and installation services for energy efficiency retrofit projects (Liu et al., 2018).

Based on the above literature and the Kingdom of Bahrain's strategy to reduce the operational cost in buildings, we are hypothesizing that a reduction in the electricity consumption and cost in buildings (S1) is more important than a contribution to achieving the national target in energy

efficiency which is a 6% reduction by 2023 (S2) and more important than a reduction in CO₂ emission and contribution to environmental improvements (S3) and also more important than the technical knowledge sharing between ESCO and employees (S4). The hypothesis is expressed as follows:

4.12.3 Hypothesis 3

Hypothesis 3 (H3): The upfront reduction in the electricity consumption and cost in buildings (W1) is a more significant weakness than the Business-as-usual mentality (W2), lack of knowledge in technical and legal formalities (W2), and Operational interruption in the buildings (W3) in the weakness area of SWOT.

Hypostasis No. 3 is based on a study by Forrester & Reames (Forrester & Reames, 2020) and Hannon et al. (Hannon et al., 2015), who agreed that upfront investment is a barrier in ESCO projects. Ming et al. also categorized the high upfront cost and poor economic feasibility as important weakness factors in their SWOT analysis to evaluate energy efficiency technology called Carbon Capture and Storage (CCS) (Ming et al., 2014).

Additionally, Hannon et al. (Hannon et al., 2015) highlighted that ESCO projects face difficult access to finance, with the necessary capital to cover the upfront costs of energy service contracts. Some other authors have recommended economic incentives to cover the upfront costs of ESCO activities (Tukker et al., 2008) (Bilsen et al., 2013).

In the same context, several experts confirmed during the interview that the high upfront investment and limited access to investment capital for governmental premises slow the implementation of energy efficiency. Delgado et al. stated that the procurement process in a government facility

is complex due to the institutional barriers that over-emphasize upfront costs against long-term savings (Delgado & Shealy, 2018).

Therefore, we hypothesize that the high upfront capital cost and limited access to funding for energy efficiency in governmental buildings are the most important factors compared to W2, W3, and W4.

4.12.4 Hypothesis 4

Hypothesis 3 (H4): The Bank's capability to provide financial solutions for energy efficiency and green finance projects (O3) is a more important opportunity than the Economy encourages governmental institutions to invest more in energy efficiency (O1), Huge building energy conservation potential (O2) and benefiting from lessons from other countries experience (O4).

Liu et al. selected huge building energy conservation potential (O3) in their article as one of the opportunity factors in their SWOT analysis in China. They supported the argument with the fact that the total building area in China witnessed a considerable growth of 2 billion m² yearly, more than 90% of buildings have high energy consumption (Liu et al., 2018).

Although several articles encouraged the role of the banking sector to fund energy efficiency projects due to the low credit risk and as part of their commitment to green fundings with low credit risk, for example, Hansen et al. confirmed that the ESCO industry provides a –50 % return on investment (ROI) (Hansen et al., 2015). Suhonen et al. stated that ESCOs guarantee savings and limited financial risks associated with project implementation (Suhonen et al., 2013). Several articles (Nurcahyanto et al., 2020b), (Brudermann & Sangkakool, 2017), (Q. Liu & Ren, 2020); and (Pantaleo et

al., 2014) agreed that the energy efficiency project provides a huge investment opportunity.

Since the financial corporation banks in the Kingdom of Bahrain contributed to 16.8 % of real GDB in the second quarter of 2022 (Ministry of Finance and National Economy, 2022), they represented one of the strongest sectors in Bahrain. There is a huge investment opportunity for the financial sector, hence the public and private sector financing for energy efficiency, approximately USD 0 billion per year (2010–2019), at an annual average of 15 percent of total energy investment. To sustain the demand for energy at today's level, global investment in energy efficiency would need to double by 20 and increase again by 2040 from its 2019 levels (The World Bank Group, 2021).

Therefore, we assumed that banks could benefit from the substantial opportunities offered by ESCOs to effectively fulfil their energy efficiency mandate to develop green funds market opportunities in the Kingdom of Bahrain. Based on the above, we hypothesize that O3 is the most important factor compared to O1, O2, and O4. We formulated the above hypothesis.

4.12.5 Hypothesis 5

Hypothesis 5 (H5) assumes that the Lack of incentive from the government to reduce the energy cost in buildings (T1) is a more important threat than the energy cost allocated and paid by the government budget (T2); the absence of regulations to support ESCO based-projects in governmental buildings (T3) and Bureaucracy constraints (T4).

The incentive is a crucial factor in encouraging the promotion of ESCOs and supporting their rapid development; the government has introduced support

policies to spread shared savings contracts because this can make ESCOs profitable for all parties. In China, the tax cuts policy released in 2010 and the financial incentives policy released in 2011 require shared savings contracting to benefit from such policy and promote the expansion in retrofitting buildings (Qian and Guo, 2014). The same was true in transportation projects. A study found that Italy adopted a new decree supporting the production of organic biomethane in the transportation industry by providing incentives for converting existing biogas plants. He explained the incentives for renewable energy in the transport sector support of 2020 to a minimum reduction of 60% in GHG emissions for biofuels produced in new installations. (D'Adamo,et al., 2020).

Hannon explored how 'the government policies in the UK addressed the barriers in ESCO markets. The case study focused on how regulatory economic incentive policies have supported Energy Service Company (ESCO) activity in the UK. They recommended several policies, including balancing economic incentives and regulatory disincentives (Hannon et al., 2015). Bleyel also agreed that the Office Building Deep Energy retrofit project could offer meaningful monetary contributions to help identify strategic allies for project implementation (Bleyel et al., 2019). Linking financial incentives to energy contracts will promote the development of the ESCO (Zhang et al., 2020).

In Indonesia, the incentives provided by the financial section are considered one of the external opportunity factors for the ESCO market and the most critical opportunity factor that can support the enhancement of the ESCO market. Contrary to our study, the need for incentives to promote ESCO projects is considered an external threat. Particular attention must be given to the incentives of buildings and energy consumption. These incentives will

likely be incorporated into energy efficiency policy regimes for future change.

Therefore, we hypothesize that the (T1) are the most important factors compared to T2, T3, and T4

CHAPTER FIVE

Applying The Model of SWOT -Fuzzy Analytical Hierarchy Process (AHP)

5.1 Introduction

This chapter aims to present proper strategies by analyzing various internal and external SWOT factors (criteria) identified in Chapter 4. In this chapter, we used a hybrid method to combine two strategical assessment techniques to view the analyzed factors and quantitatively evaluate their importance.

In this chapter, we employ the SWOT-FAHP multi-criteria decision model to quantitatively study the judgments of 25 experts obtained from the semi-structured interviews (explained in Chapter 4). We used Microsoft Excel to formulate the equations and produce the values. Then, we evaluate the influential factors via fuzzy set AHP. The steps of analysis are illustrated in the methodology section. The results of the analysis and evaluation are explained in the same section.

We concluded that strength factors in SWOT represent the most important factor among other SWOT factors. Reducing electricity consumption and cost in buildings is one of the most influential sub-factors across all factors in strength factor. Upfront capital cost and limited access to funds are subfactors' most important weaknesses. Reducing operational expenditure in government sectors and investing in energy efficiency are the most influential sub-factors in opportunities. Lack of incentive from the government to reduce the energy cost in buildings ranked the highest sub-

factors in threats. Finally, we used sensitivity analysis to test the reliability of the values obtained in the Fuzzy AHP analysis.

5.2 Mechanism of Fuzzy AHP Combined with SWOT

In stage 1, we assessed the status of ESCO-based projects in governmental buildings and premises by evaluating the influential factors and developing a decision support mechanism using fuzzy set theory and AHP. The first step is identifying factors contributing to a project's strengths, weaknesses, opportunities, and threats. The factors and sub-factors are explained in Chapter 4. In stage 2, we structured a SWOT matrix using a fuzzy triangular scale (mentioned in Chapter 4). Once these factors have been identified, they are assigned a weight based on their relative importance to the experts determined in the interviews. In stage 3, we assessed and prioritized the factors and sub-factors. The mechanism of the Fuzzy AHP is explained in stages, as shown in Figure 5.1. The objective of the analysis is to determine the best factor to consider in selecting the strategy to implement successful ESCO projects on governmental premises and buildings.

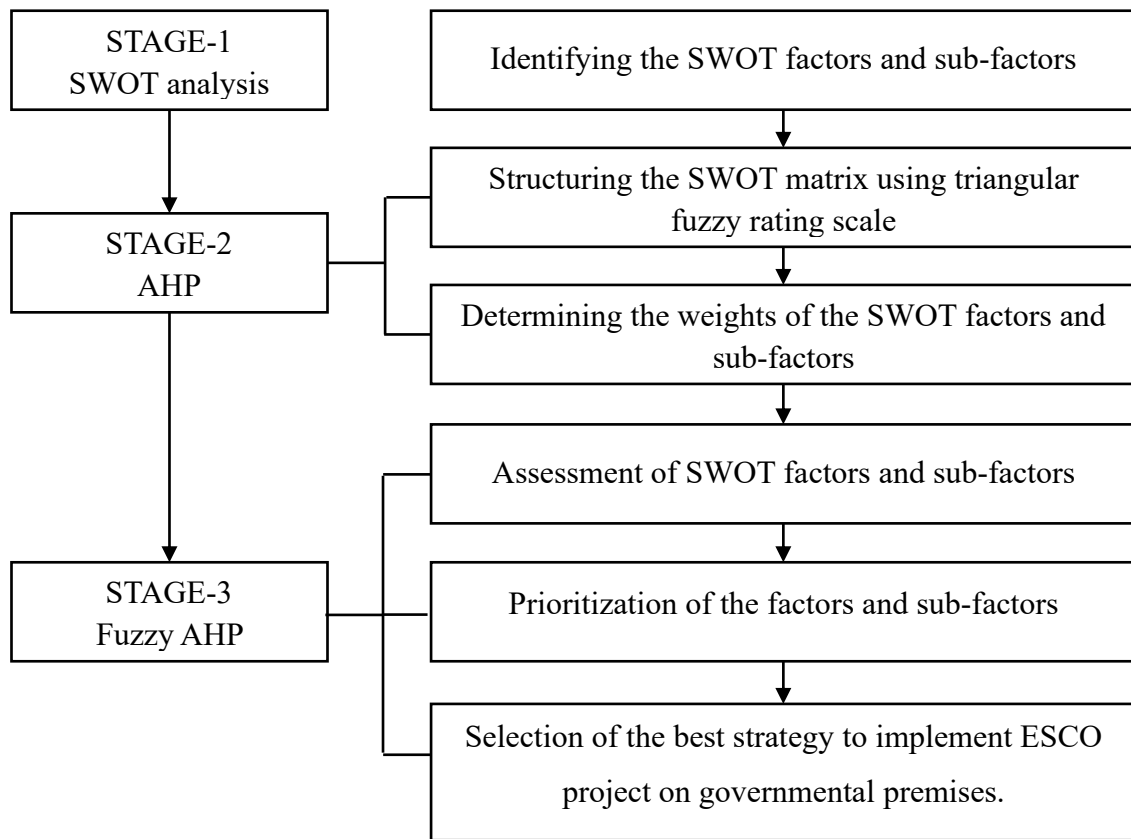


Figure 5.1 Mechanism of Fuzzy AHP in Stages (Solangi et al., 2019)

5.3 implementation of Fuzzy AHP Methodology in Research

FAHP offers a systemic way to select alternatives. This study combined fuzzy and AHP approaches by applying triangular fuzzy values used by Saaty's scale. Triangular fuzzy numbers are applied to rank the importance of each criterion that contributed to the decision-making process. The AHP method is deployed to qualify the importance and priority of such criteria. To find the priorities vector, we follow the following steps:

Step 1: Calculation of TF Criteria

We deployed FAHP to pairwise comparison and weight the priorities in four factors of SWOT and related sub-factors using a fuzzy triangular scale,

shown in Table 4.8. Each decision maker chooses the appropriate linguistic that matches their judgment when comparing the factors or sub-factors. The criteria in the scale are matched with specific values in a fuzzy triangular scale, and three different values define each number. Other literature used different scales of values (Solangi et al., 2019), (Görener et al., 2012), (Tung & Tang, 1998) and (Aghasafari et al., 2020). In our study, we used the scale representing nine linguistic terms ranging from extremely important to weak or slightly important, as shown in Table 5.2.

Scale in Linguistic Terms	Triangular Fuzzy Scale	Reciprocal Scale in Triangular Fuzzy
Important extremely	(9,9,9)	(1/9,1/9,1/9)
Very, very strong	(7,8,9)	(1/9,1/8,1/7)
Very strong or demonstrated important	(6,7,8)	(1/8,1/7,1/6)
Strong plus	(5,6,7)	(1/7,1/6,1/5)
Strong important	(4,5,6)	(1/6,1/5,1/4)
Moderate plus	(3,4,5)	(1/5,1/4,1/3)
Moderate important	(2,3,4)	(1/4,1/3,1/2)
Weak or slight	(1,2,3)	(1/3,1/2,1)
Equal Important	(1,1,1)	(1,1,1)

Table 5.1 Conversion Scale of Triangular Fuzzy

The value of ($\tilde{A}$) represented a triangular fuzzy comparison matrix:

$$\tilde{A} = \begin{bmatrix} 1 & \tilde{a}_{12} & \dots & \tilde{a}_{1n} \\ & & \dots & \\ \tilde{a}_{n1} & \tilde{a}_{n2} & \dots & 1 \end{bmatrix} = \begin{bmatrix} (1,1,1) & \dots & (l_{1,n}, m_{1,n}, u_{1,n}) \\ & \dots & \\ (l_{1,n}, m_{1,n}, u_{1,n}) & \dots & (1,1,1) \end{bmatrix} \quad (1)$$

$$\text{With: } \tilde{a}_{ij} = \tilde{a}_{ji}^{-1} \text{ and } \tilde{a}_{ji}^{-1} = (\frac{1}{u_{ij}}, \frac{1}{m_{ij}}, \frac{1}{l_{ij}}) \quad (2)$$

In each line of $\tilde{A}$ We summed up the values.

$$RS_i = \sum_{j=1}^n \tilde{a}_{ij} = (\sum_{j=1}^n l_{ij}, \sum_{j=1}^n m_{ij}, \sum_{j=1}^n u_{ij}), i=1, \dots, n. \quad (3)$$

Step 2: Fuzzy synthetic extent value (S_i) considering i^{th} criteria is defined by Wang (2008) as follows:

$$\tilde{S} = \frac{RS_i}{\sum_{j=1}^n RS_j} \left(\frac{\sum_{j=1}^n l_{ij}}{\sum_{j=1}^n l_{ij} + \sum_{k=1}^n \sum_{j=1}^n u_{kj}}, \frac{\sum_{j=1}^n m_{ij}}{\sum_{k=1}^n \sum_{j=1}^n mu_{kj}}, \frac{\sum_{j=1}^n u_{ij}}{\sum_{j=1}^n u_{ij} + \sum_{k=1}^n \sum_{j=1}^n l_{kj}} \right) \quad \text{And} \quad k \neq i. \quad (4)$$

Step 3: The degree of possibility of $\tilde{S}_i \geq \tilde{S}_j$ to calculated.

$$V(\tilde{S}_i \geq \tilde{S}_j) = \begin{cases} 1, & \text{If } m_i > m_j \\ \frac{u_i - l_j}{(u_i - m_j) + (m_i - l_j)}, & \text{If } l_j \leq u_i \\ 0, & \text{If not} \end{cases} \quad i, j = 1, \dots, n \text{ and } j \neq i. \quad (5)$$

Figure 5.1 represents the graphical degree of possibility of $\tilde{S}_i \geq \tilde{S}_j$.

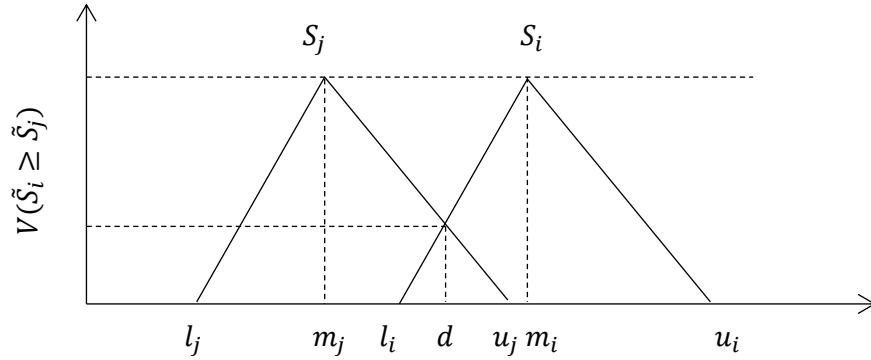


Figure 5.2 Graphical Representation of $V(S_i \geq S_j)$ Chang (1996)

Step 4: Calculation the degree of possibility for specific $\tilde{S}_i$ compared to other fuzzy numbers.

$$V(\tilde{S}_i \geq \tilde{S}_j | j = 1, \dots, n; j \neq i) = \min_{j \in \{1, \dots, n\}, j \neq i} V(\tilde{S}_i \geq \tilde{S}_j), \quad (6)$$

Step 5: Defining the priority vector $W = (w_1, \dots, w_n)^T$ For fuzzy comparison matrix:

$$W_i = \frac{V(\tilde{S}_i \geq \tilde{S}_j | j=1, \dots, n; j \neq i)}{\sum_{k=1}^n V(\tilde{S}_k \geq \tilde{S}_j | j=1, \dots, n; j \neq k)} \quad i = 1, \dots, n. \quad (7)$$

Step 6: Calculating the Consistency Index of the Model

The Consistency Index (CI) measures the inconsistency in the weights of pair-wise comparison, where the eigenvalue λ_{max} is calculated—the eigenvalue λ_{max} obtained by averaging all eigenvalues of the pair-wise comparison in a matrix.

$$CI = \frac{\lambda_{max} - n}{n - 1}$$

$$\text{With } \lambda_{max} = \sum_{j=1}^n a_{ij} \frac{W_j}{W_i}, \quad i, j=1, 2, \dots, n$$

The consistency ratio indicates the reliability of experts' responses, which is reflected in the calculated weights. The weights are reliable and consistent if the obtained value is less than 0.1.

$$CR = \frac{CI}{RI}$$

RI is a random index already given for the specified criteria.

5.4 Results and Discussions of SWOT and Fuzzy AHP Model

Table 4 illustrates the fuzzy comparison between specific pairs of SWOT factors. The pairwise comparison values were used to quantify the expert judgments in linguistic terms during the pairwise selections. The comparison values are presented in the form of (l_{ij}, m_{ij}, u_{ij}) . The study only displays the values above the diagonal. However, equation (2) finds the values below the diagonal (Minwir & Mili, 2019).

The results of this table indicate that strengths factors (S) are the most important factor in SWOT analysis compared to weakness, opportunities, and threats factors since the fuzzy numbers are greater than one (illustrated in the first row).

	S	W	O	T
S	(1,1,1)	3,4,5)	(2,3,4)	(2,3,4)
W	(1/5,1/4,1/3,1)	(1,1,1)	(1,1,1)	(1,2,3)
O	(1/4,1/3,1/2)	(1,1,1)	(1,1,1)	(2,3,4)
T	(1/4,1/3,1/2)	(1/3,1/2,1)	(1/4, 1/3, 1/2)	(1,1,1)

Table 5.2 Fuzzy comparison between each SWOT Factor

After the pairwise comparison, the weights of the FAHP selection criteria are defined. The obtained results are illustrated in Table 5.4. The consistency ratio is less than 0.1, which reveals that the semi-structured questionnaire in interview responses is consistent and appropriate for analysis (Lee et al., 2021), (Zorpas, 2016).

Table 5.4 illustrates the overall priority representing the value of the judgment degree in experts' selection, obtained by multiplying the local priority with the SWOT scaling factors. The pair-comparison analysis of expert judgment was quantified.

SWOT Factors	Local Weights	Sub-Factors	Sub-factor / Local Weights	Overall Weights	Consistency
					0.063
Strengths	0.3374	S1	0.3374	0.282	
		S2	0.1045		
		S3	0.15		
		S4	0.3065		
Weaknesses	0.1045	W1	0.3014	0.261	
		W2	0.2158		
		W3	0.2031		
		W4	0.2795		
Opportunities	0.15	O1	0.3020	0.267	
		O2	0.1788		
		O3	0.2347		
		O4	0.2843		
Threats	0.3065	T1	0.3786	0.276	
		T2	0.1145		
		T3	0.2116		
		T4	0.2951		

Table 5.3 The Weights for the FAHP Selection Factors of SWOT

The overall weights in Table 5.4 show that strength factors in SWOT represent the most important factor among others, with the weight slightly higher than other factors 0.282. The analysis result confirmed the findings of (Nurcahyanto et al., 2020b) and (Liu et al., 2018), who argued that the strengths factors of ESCO in buildings are more important and significant compared to other factors in SWOT analysis.

The weakness factors were the less important factors in SWOT and weighted 0.261. Threats were considered the second important factor in SWOT, followed by opportunities factors with values of 0.276 and 0.267, respectively. Although the weight differences among all factors are relatively small, the strengths factors are the highest priorities, indicating positive experts' perceptions about implementing ESCO-based projects in

government buildings. The aggregated weights of positive factors (strengths and opportunities) at 0.549 slightly exceeded the weakness and threat factors, reaching 0.537.

In the same context, obtaining results was relatively equal, reflecting that all SWOT factors are important tools for studying ESCO-based projects on governmental premises. Lead the decision-makers to evaluate the project holistically and study all SWOT factors for the ESCO project in buildings. The CR was calculated at 0.063, within the reliable range 0.1 (Saaty, 2003). Table 5.5 evaluates ESCO-based projects regarding the strengths factors and prioritizing the strengths area's sub-factors. The results show that a reduction in the electricity consumption and cost in buildings (S1) is considered two times more important than a contribution to achieving the national target in energy efficiency, which is a 6% reduction by 2023 (S2) and three times more important than a reduction in CO₂ emission and contribution to environment improvement (S3) and four times more important than the technical knowledge sharing between ESCO and employees (S4).

	S1	S2	S3	S4
S1	(1,1,1)	(1,2,3)	(2,3,4)	(3,4,5)
S2	(1/3, 1/2, 1)	(1,1,1)	(1,1,1)	(2,3,4)
S3	(1/4, 1/3, 1/2)	(1,1,1)	(1,1,1)	(3,4,5)
S4	(1/5, 1/4, 1/3)	(1/4, 1/3, 1/2)	(1/5, 1/4, 1/3)	(1,1,1)

Table 5.4 Evaluation of SWOT Dimensions Based on the Strengths factors

Table 5.6 reports the weights of the FAHP Strengths Sub-Factors. It is shown that the reduction in the electricity consumption and cost in buildings factor (S1) is one of the most influential sub-factors across all factors in strength factors, which are weighted at (0.337). It was obvious to most experts that implementing ESCO in the building reduces electricity consumption and operational costs (S1) for the buildings. Therefore, the finding is consistent with other research which proved ESCO in buildings contributed to cost reduction in electricity (Hannon et al., 2015), (Hou et al., 2017), (Suhonen & Okkonen, 2013), (Augustins et al., 2018).

The second most influential sub-factor in the strengths area was S4, representing technical knowledge sharing between ESCO and employees, calculated at 0.307. Technical experts run ESCO projects in accredited-companies in which they analyze, identify, and propose a technical solution to achieve the required reduction in energy and cost.

The training and technical resources available in ESCOs (Nurcahyanto et al., 2020b) will minimize the knowledge risk with employees and close the knowledge gap between the employees in the governmental sector and ESCO.

The third place of priorities among the sub-factors allocated for environmental factors in reducing CO₂ emission in Bahrain is represented in S3, which is weighted at 0.252. We concluded that the experts are very

much aware of the environmental improvement that ESCO projects can add to the ecosystem. Limiting energy intensity and improving energy efficiency have been provided as one of the most cost-effective ways to reduce carbon dioxide (CO₂) emissions (Saidur et al., 2010) without affecting the level of energy demanded.

Priorities of all three factors (S1, S2, and S3) will lead to achieving S4, which represents achieving the national target in energy efficiency, which is weighted at 0.105. Developing ESCO-based projects in buildings is an option that would help optimize the national natural gas for other higher value-added activities such as exports. ESCO-based projects can play a role in developing the country's energy sustainability plan. The consistency ratio is 0.071 and shows that the priorities of strengths factors are reasonable.

The results accepted hypothesis 1 (H1), which assessed the importance of S1 as the most important factor among other strengths factors. This means that S1 plays a significant and moderating role in selecting the best strategy for implementing ESCO projects on government premises, among other strengths factors.

Strength Factor	Definition	Local Wights	Ranking	Consistency
				0.071
S1	Reduce the electricity consumption and cost of buildings	0.3374	1	
S2	Contribute to achieving the national target in energy efficiency (6% reduction by 2023)	0.1045	4	
S3	Reduce CO ₂ emissions and contribute to environmental improvement	0.2515	3	
S4	Technical knowledge sharing between ESCO and employees	0.3065	2	

Table 5.5 Weights of the FAHP Strengths Sub-Factors

Table 5.7 shows the weakness sub-factor expressed in high upfront capital cost and limited access to funds (W1) is the most important compared with the business-as-usual mentality slow the acknowledgement of the benefits related to ESCO-based Energy Efficiency projects (W2), the lack of knowledge in technical and legal formalities for ESCO based Energy Efficiency projects (W3) and Operational interruption in the buildings (W4). Therefore, the high upfront capital cost and limited access to funds (W1) are three times more important than W2, W3, and W4, confirmed by raw 1, which allocated the highest number for W1.

	W1	W2	W3	W4
W1	(1,1,1)	(2,3,4)	(2,3,4)	(2,3,4)
W2	(1/4, 1/3, 1/2)	(1, 1, 1)	(1,2,3)	(2,3,4)
W3	(1/4, 1/3, 1/2)	(1/3, 1/2,1)	(1, 1, 1)	(2,3,4)
W4	(1/4, 1/3, 1/2)	(1/4 1/3, 1/2)	(1/4, 1/3, 1/2)	(1,1,1)

Table 5.6 Evaluation of SWOT dimensions based on the Weaknesses factors

Table 5.8 confirms the findings in Table 5.4 and shows the priorities in the weak sub-factors of the SWOT analysis. The sub-factor (W1), representing the high upfront capital cost and limited access to funds, is the most influential factor in the weakness area. One of the biggest weaknesses ESCO projects in governmental buildings face is limited access to funding the upfront capital. High upfront capital is one of the problems in energy projects (Madurai et al., 2020), and securing funds for a servicing contract (SC) and energy performance contract (EPC) for the project is a crucial issue (Garbuzova et al., 2016). Upfront investment in such a project is one of the biggest barriers (Retallack et al., 2018).

ESCO experts mentioned that they are willing to manage the projects for government buildings. They recognized that the upfront capital guaranteed the decision-makers commitment to proceed with the ESCO project. In some

situations, such projects face delays in processing due to the nature of government processing. Normally, the first stage of ESCO projects needs to secure resources to investigate, audit, and study the project's feasibility, and the initial process needs mutual commitment between both parties. The analysis of FAHP confirmed ESCO experts' opinions. This result approved hypothesis 2 (H: 2).

The second priority for weaknesses in Table 5.7 is allocated to the operational interruption in the buildings (W4). Most governmental buildings have been running operations over the years to provide different services for society, such as hospitals, schools, universities, ministries, etc. At some stages, implementing energy efficiency inside the governmental buildings and shutting down the operation represents a weakness (W4) in most cases (Chai & Baudelaire, 2015), and frequency interruption in the operational flow of the buildings results in technical risk in the electricity assets (Thollander and Ottosson, 2008). The interruption in the operational flow of those sectors is considered the highest second priority in weakness and is weighted at 0.280.

The third priority among sub-factors in weak areas was the business-as-usual mentality that slows the acknowledgement of the benefits related to ESCO-based energy efficiency projects (W2), which is 0.216. Unlike the business sector, where the main driver for operations is the financial objectives, the government sector drives by offering services to society within a certain timeframe.

The fourth priority in analyzing the weakness is reserved for the lack of knowledge in technical and legal formalities for ESCO-based Energy Efficiency projects, i.e., EPC. (W3). ESCO projects should go through different formalities since ESCO is an emerging concept in Bahrain. No

single entity can implement the project through systematic processes and formalities. Therefore, the experts agreed that the lack of knowledge in several areas, such as legal and technical projects, causes unneeded delays in implementation, unlike countries that assign an internal governmental entity called Super ESCO operated under a structured system to handle such projects. The consistency ratio is at an acceptable level of 0.079.

Weakness Factors	Definition	Local Wights	Ranking	Consistency
				0.079
W1	High Upfront Capital Cost / Limit Access to the Fund	0.301	1	
W2	Business-As-Usual Mentality Slow the Acknowledgment of the Benefits Related to ESCO-Based Energy Efficiency Projects	0.216	3	
W3	Lack of Knowledge in Technical and Legal Formalities for ESCO Based Energy Efficiency Projects such as EPC	0.203	4	
W4	Operational Interruption in the Buildings	0.280	2	

Table 5.7 The Weights of the FAHP Weakness Sub-Factors

Table 5.9 shows that opportunity sub-factor O1 is the most critical sub-factor compared with O2, O3, and O4. The downturn in the economy encourages governmental institutions to invest more in energy efficiency (O1), which is three times more important than banks' capability to provide financial solutions for energy efficiency and green finance projects (O2), O3, which represents huge building energy conservation potential. The sub-

factor O4 expressed benefiting from lessons from other countries' experience. The results were confirmed by the raw 1 in Table 5.9, which reflected the highest value for O1.

	O1	O2	O3	O4
O1	(1,1,1)	(2,3,4)	(2,3,4)	(2,3,4)
O2	(1/4, 1/3, 1/2)	(1,1,1)	(2,3,4)	(3,4,5)
O3	(1/4, 1/3, 1/2)	(1/4, 1/3, 1/2)	(1, 1, 1)	(3,4,5)
O4	(1/4, 1/3, 1/2)	(1/5, 1/4, 1/3)	1/5, 1/4, 1/3)	(1, 1,1)

Table 5.8 Evaluation of SWOT Dimensions Based on the Opportunity Factors

Table 5.10 shows that O1 represents the highest priority in SWOT analysis, reflected by the government plan and several initiatives to reduce the operational expenditure in government sectors and invest in energy efficiency (EE). The investment in energy efficiency is a reason to face fluctuations in oil price, the cost of energy intensity, and environmental pressure (Wang et al., 2020). During the pandemic, several unplanned expenses were allocated to governmental budgets, and investing in energy efficiency through ESCO allowed for cutting operational costs without compromising the energy demand.

The analysis in Table 5.10 shows that O4 was the second-highest weighted (0.280) opportunity sub-factor in opportunity analysis; O4 represents benefiting from lessons from other countries' experiences. In Bahrain, learning from all the lessons experienced in the region and elsewhere allows Bahrain to avoid shortfalls and unproductive issues in implementing the projects on the premises.

O2 represented banks' capability to provide financial solutions for energy efficiency and green finance projects and ranked the third priority in the analysis. The banking sector in Bahrain has launched several initiatives to support green finance and energy efficiency as one of the funds in their

lending portfolio. Moreover, the S3 sub-factor was the fourth priority among the opportunities represented by the ESCO project's huge building energy conservation potential based on governmental premises and facilities.

Opportunity Factor	Definition	Local Wights	Ranking	Consistency
				0.079
O1	The downturn in the Economy encourages governmental institutions to invest more in energy efficiency	0.301	1	
O2	Banks' capability to provide financial solutions for energy efficiency and green finance projects	0.216	3	
O3	Huge building energy conservation potential	0.203	4	
O4	Benefiting from lessons from other countries' experience	0.280	2	

Table 5.9 The Weights of the FAHP Weakness Sub-Factors

Threat factors considered external factors negatively influence the implementation of ESCO-based projects in the government sector.

Table 5.11 shows that the threat sub-factor related to the lack of incentive from the government to reduce the energy cost in buildings (T1) is the most important sub-factor compared with T2, T3, and T4. The T1 is five times more important than the energy cost allocated and paid by the government budget (T2), two times more important than the absence of regulations to support ESCO projects in governmental buildings (T3), and three times more important than bureaucracy constraints-bureaucracy required at different levels of government authority expressed in (T4).

	T1	T2	T3	T4
T1	(1,1,1)	(4,5,6)	(1,2,3)	(2,3,4)
T2	(1/6, 1/5, 1/4)	(1, 1, 1)	(1,1,1)	(1,2,3)
T3	(1/3, 1/2,1)	(1, 1, 1)	(1, 1, 1)	(2,3,4)
T4	(1/4, 1/3, 1/2)	(1/3, 1/2,1)	(1/4, 1/3, 1/2)	(1, 1, 1)

Table 5.10 Evaluation of SWOT Dimensions Based on the Threat Factors

Table 5.12 analyses the weights and priorities ranking for sub-factors of threats. T1, which represented a lack of incentive from the government to reduce the energy cost in buildings, ranked the highest priority in most experts' opinions. The lack of incentives to reduce energy demand should be linked with defined targets since ESCO is an emerging concept in Bahrain. Therefore, arranging an incentive program across the government sector will increase cultural awareness about the benefits of energy efficiency and encourage society to support the projects and be part of the incentive program.

The second priority among threats sub-factors was T3 and T4, which were evaluated equally at 0.295. The absence of regulations and bureaucratic constraints are considered a threat and slow down the process of ESCO project implementation.

Most experts prioritized T2 (energy cost allocated and paid by the government budget), the least influential sub-factor among the threats, and ranked the lowest among other factors.

Threats Factor	Sub-Factor	Local Wights	Ranking	Consistency
				0.082
T1	Lack of incentive from the government to reduce the energy cost in buildings.	0.295	1	
T2	Energy cost allocated and paid by the government budget)	0.115	3	
T3	Absent of regulations to support ESCO in governmental buildings	0.295	2	
T4	Bureaucracy constraints - bureaucracy required at different levels of government authority	0.295	2	

Table 5.11 The Weights of the FAHP Threats Sub-Factors

We aggregated the local weights for all sub-factors in one diagram to show the ranking among all sub-factors as per the above results.

Sub-Factor	Local Wights	Ranking
S1	0.3374	2
S2	0.1045	16
S3	0.2515	9
S4	0.3065	3
W1	0.3014	5
W2	0.2158	13
W3	0.2031	12
W4	0.2795	8
O1	0.302	4
O2	0.1788	14
O3	0.2347	10
O4	0.2843	7
T1	0.3786	1
T2	0.1145	15
T3	0.2116	11
T4	0.2951	6

Table 5.12 The Ranking Among the Sub-Factors based on the Calculated Local Weigh

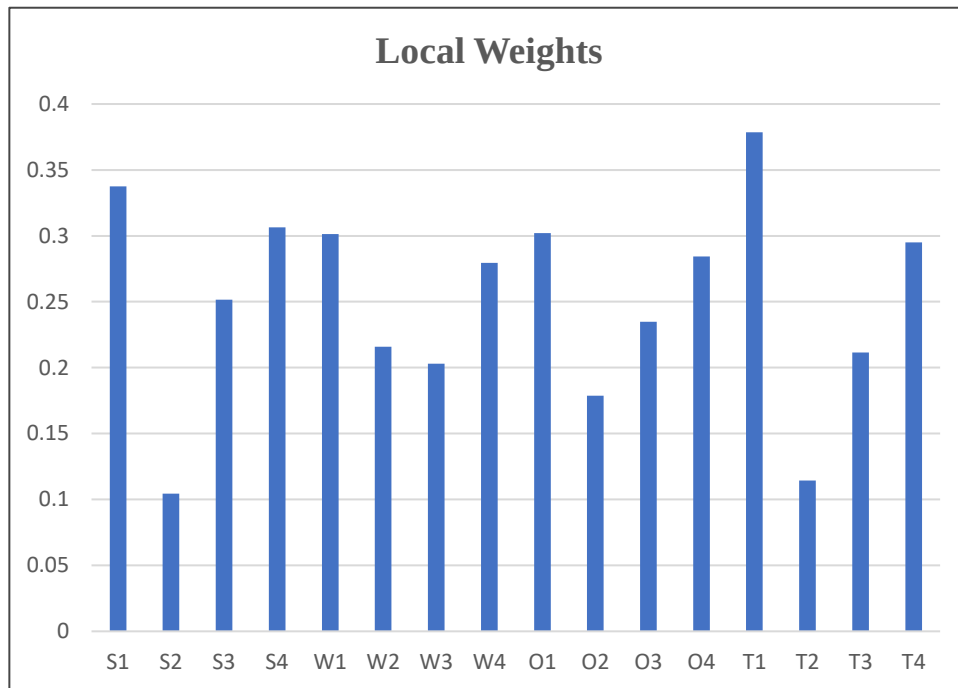


Figure 5.3 The Ranking Among the Sub-Factors Based on the Local Weigh

5.5 Sensitivity Analysis

Sensitivity analysis is employed for SWOT factors selection and is integrated with the development of FHAP methods. Sensitivity analysis was utilized to identify and rank the significance (Fußeder et al., 2022) of SWOT factors in AHP analysis. It formulates several combinations of weights and applies the FAHP module for the factors in SWOT. The results of the classification will test the reliability of the classification generated by the FAHP module. The weights of the different factors of SWOT were allocated to measure the effect of the final ranking of factors.

Table 5.13 illustrates the weight combination of the SWOT factors. The table represents cases to test the relationship between the ranking and the specific sub-factors. The first column reflects the current weights, and the next column (representing Case 1) is where all the weights are equal to 0.2. The rest of the columns show Case 2 to Case 5, which attributed 55% as a

weight to one criterion value. The 55% of the rest are equally divided by all other factors (0.55/3 0.15).

	S	W	O	T
FAHP Weights	0.3374	0.1045	0.2515	0.3065
Case 1	0.2	0.2	0.2	0.2
Case 2	0.55	0.15	0.15	0.15
Case 3	0.15	0.55	0.15	0.15
Case 4	0.15	0.15	0.55	0.15
Case 5	0.15	0.15	0.15	0.55

Table 5.12 Weight Combinations of the SWOT Factors

Table 5.14 illustrates the classification by combinations. Strengths factors are not sensitive to the changes in the weights of the attributes as they are ranked first in 6 cases among 6 cases. Threats are ranked second among 5 cases among 6 cases, and opportunities and weakness are ranked third and fourth, respectively. The results confirm the stability of the classification obtained by the weight. The changes in the weights of the strength factors were most affected in the ranking of SWOT factors.

In cases 1, 2, 3, 4, and 5, strengths factors always ranked 1, while threats factors ranked 2 in cases 1, 2, and 4. On the other hand, opportunities and weaknesses ranked 3 and 4, respectively, in cases 1, 2, and 3. In case 4, opportunities ranked 2, weaknesses ranked 3, and threats ranked 4. In case 5, the threats ranked 2 and 4, and the weaknesses ranked 3. The observation concludes that opportunities, weaknesses, and threats can exchange their ranking relative to a given criteria sensitivity analysis, even if they are stable for a multi-criteria analysis.

Ranked	1	2	3	4
FAHP Weights	S	T	O	W
Case 1	S	T	O	W
Case 2	S	T	O	W
Case 3	S	T	O	W
Case 4	S	O	W	T
Case 5	S	T	W	T

Table 5.13 The Alternative Weight Classifications by Weight Combination

5.6 Conclusions of SWOT and Fuzzy AHP Model

This paper examines the ESCO project based on SWOT analysis. We deployed an integration method of SWOT and FAHP approach to assess the most important areas of SWOT. We conducted semi-structured interviews with 24 experts involved in ESCO projects with local, regional, and global experience. The experts received a questionnaire built on pair-wise comparison for several sub-factors in each SWOT area. The paired comparison converts from AHP into FAHP for an accurate assessment of the importance of alternatives. The FAHP overcame the weaknesses associated with AHP regarding uncertainty and clarity in the experts' judgment. The hybrid approach using SWOT analysis and FAHP provides a qualitative and quantitative approach and deals accurately with subjectivity in experts' selections.

The study's results are consistent with other research conducted in China and Indonesia (Zhang et al., 2020) & (Nurcahyanto et al., 2020), proving that the strengths factors of ESCO in buildings are more important and significant compared to other factors in SWOT analysis, which reflected the positivity in the most decision-makers judgments towards ESCO projects.

Considering the outcomes in planning the energy in buildings, it will have the potential to fulfil some aspects of energy sustainability. Most countries, including Bahrain, have the strategic direction to cut operational costs in governmental and service sectors as a response to the economic pressure resulting from the global pandemic that hit the globe in 2020. Therefore, adding ESCO-based projects to the energy planning agenda will cut the operational cost in buildings and implement energy-efficient solutions without hurting the environmental resources or compromising the energy needed for economic development.

To capitalize on the strengths and opportunity factors of the study and limit the crucial negative effect of weaknesses and threat factors, the decision-makers in energy strategy planning in Bahrain need to consider establishing a single intergovernmental powerful body (Super ESCO) to coordinate with accredited rated ESCOs to execute the strategic projects in energy efficiency with clear objectives and regulations cross all governmental sectors to overall come all the obstacles and challenges faced such projects.

Finally, the current study seems to be the first application of FAHP in prioritizing SWOT factors related to ESCO-based projects in the buildings, and no comparable studies have been conducted on the exact scope of the study before.

CHAPTER SIX

Applying the Model of SWOT- Fuzzy Techniques For Order Of Preference (TOPSIS)

6.1 Introduction

The primary data was collected from the questionnaire and used again in this Chapter to apply the second methodology, SWOT -Fuzzy TOPSIS model. Unless proven otherwise, the Chapter aims to strengthen the results obtained from applying Fuzzy AHP SWOT in Chapter 5. Therefore, Apply Fuzzy TOPSIS was used to confirm the reliability of the results obtained in Chapter 5 and answer the research questions in more depth.

This Chapter presents the Fuzzy TOPSIS approach in steps, including alternative rating by decision-makers, criteria weighting, and fuzzification of linguistic values. These steps are followed by the aggregation of alternative and criteria weightage fuzzy decision matrices, which are then normalized and used to determine the weighted importance of each criterion in the decision-making process. The resulting weighted normalized fuzzy decision matrix provides a valuable tool for evaluating and comparing alternatives, considering their relative importance and performance for criteria. It also helps decision-makers identify the best alternative based on a balanced consideration of all relevant factors.

Based on the analysis, we conclude that 1) The subfactors S1, W1, O1 and T1 are dominant, confirming the results obtained in Chapter 5; 2) Fuzzy TOPSIS helps to find that T4 is the most critical subfactor among all other sub-factors in the study. Therefore, the results in Chapter 5 are reliable.

6.2 Mechanism of SWOT and Fuzzy TOPSIS

Fuzzy TOPSIS is a multi-criteria decision-making methodology commonly used in SWOT analysis to evaluate and rank different alternatives based on their relative strengths and weaknesses. It is often used with other MCDA (Multi-Criteria Decision Analysis) techniques to provide a comprehensive framework for decision-making in complex and uncertain situations. In the TOPSIS approach, a fuzzy decision matrix is constructed that includes both subjective and objective criteria. The matrix is then used to generate ideal and anti-ideal solutions, known as the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS). The FPIS represents the best performance values for each alternative, while the FNIS represents the worst performance values. Figure 6.1 shows Fuzzy TOPSIS's mechanism in steps (Patil, 2017).

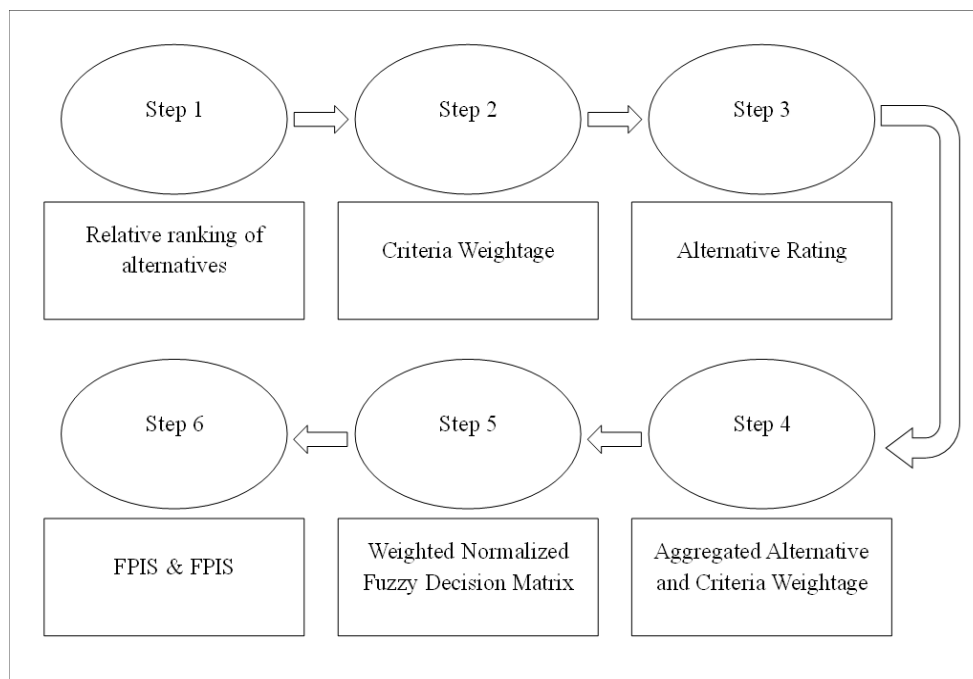


Figure 6.1: Mechanism of Fuzzy TOPSIS (Patil, 2017)

Once the ideal and anti-ideal solutions have been identified, each alternative is evaluated based on its relative proximity to these solutions. The optimal solution is the alternative closest to the FPIS and farthest from the FNIS.

6.3 SWOT FUZZY TOPSIS Methodology

In the coming sections, we explain the methodology of Fuzzy TOPSIS and SWOT analysis in detail, with the relative values and outcomes in different steps.

Step 1: Alternatives Ratings by Decision-Makers

The first step in this study is to gather ratings from the two decision-makers, DM1 and DM2, regarding the two alternatives, A1 and A2, across four evaluation criteria, C1, C2, C3, and C4. The decision-makers use their expert knowledge and experience to evaluate the performance of each alternative on each criterion and assign a rating or score to reflect their level of satisfaction with each alternative's performance.

The ratings provided by the decision-makers are used as the input data for the subsequent steps of the Fuzzy TOPSIS methodology, which is used to evaluate and rank the alternatives based on the collective input of the decision-makers. The ratings are used to determine the weightings assigned to each criterion based on the relative importance of each criterion in the decision-making process. We used Linguistic terms and a Fuzzy scale (Han and Trimi, 2018).

Linguistic Term	Fuzzy Value
Very Poor (VP)	(0, 0, 1)
Poor (P)	(0, 1, 3)
Medium Poor (MP)	(1, 3, 5)
Fair (F)	(3, 5, 7)
Medium Good (MG)	(5, 7, 9)
Good (G)	(7, 9, 10)
Very Good (VG)	(9, 10, 10)

6.1 Linguistic and Fuzzy Value Scale (Han and Trimi, 2018)

Collecting ratings from the decision-makers is a crucial step in the Fuzzy TOPSIS methodology, as it provides the necessary input data to evaluate and rank the alternatives. The ratings reflect the decision-makers preferences and opinions and serve as the foundation for the subsequent steps of the methodology, which determine the optimal solution based on the collective input of the decision-makers.

Criteria	A1		A2	
	DM1	DM2	DM1	DM2
C1	F	F	G	G
C2	VG	VG	G	VG
C3	P	F	P	P
C4	F	F	P	P

Table 6.2: Alternative Ratings

Step 2: Criteria Weightage by Decision-Makers

In the second step of this study, the decision-makers, DM1 and DM2, assign weights to each criterion to reflect their relative importance in the decision-making process. The weights are assigned on a scale of High, Very High, Medium, Low, and Very Low, allowing the decision-makers to express their preferences for each criterion qualitatively.

The weightages assigned by the decision-makers are used to calculate the overall weightage for each criterion, which is used in the subsequent steps of the Fuzzy TOPSIS methodology. The weightages assigned to each criterion are critical, as they determine the relative importance of each criterion in the overall decision-making process. Assigning weightages to each criterion requires the decision-makers to consider the impact of each criterion on the final decision and to balance the competing priorities of each criterion. The weightages assigned by the decision-makers are used to determine the ideal and anti-ideal solutions and to calculate the distance between each alternative and these solutions.

Overall, the second step of this study is essential for ensuring that the weightage assigned to each criterion reflects the preferences and priorities of the decision-makers and that the subsequent steps of the Fuzzy TOPSIS methodology accurately capture the decision-making process.

Criteria	DM1	DM2
C1	H	M
C2	VH	H
C3	VH	H
C4	M	L

Table 6.3: Criteria Weightage

Step 3: Converting Linguistics Values to Fuzzy Rating Scales

In the third step of this study, the linguistic values assigned by the decision-makers in the previous steps are converted into fuzzy ratings using the table provided in the "Fuzzy Ratings" sheet. Fuzzy ratings represent uncertain and subjective information in a quantitative manner, which is necessary for the subsequent steps of the Fuzzy TOPSIS methodology.

The fuzzy ratings are determined based on the linguistic values assigned to each criterion by the decision-makers. They are calculated according to the parameters in the Fuzzy Ratings table. The fuzzy ratings provide a way to

capture the imprecise and subjective nature of the decision-making process, allowing for a more accurate and comprehensive evaluation of the alternatives.

The conversion of linguistic values into fuzzy ratings is an important step in the Fuzzy TOPSIS methodology, as it enables the quantitative evaluation of the alternatives and criteria. The fuzzy ratings were used to construct the decision matrix in the subsequent steps of the methodology to determine the ideal and anti-ideal solutions and calculate the distance between each alternative and these solutions.

	A1						A2					
Criteria	DM1			DM2			DM1			DM2		
C1	3	5	7	3	5	7	5	7	9	5	7	9
C2	7	9	9	7	9	9	5	7	9	7	9	9
C3	1	3	5	3	5	7	1	3	5	1	3	5
C4	3	5	7	3	5	7	1	3	5	1	3	5

Table 6.4: Alternative Rating

Step 4 Aggregating alternative and criteria weightage fuzzy decision matrix

In the fourth step of this study, the aggregated alternative and criteria weightage fuzzy decision matrix is constructed using the fuzzy ratings and weightages assigned by the decision-makers in the previous steps. The fuzzy decision matrix allows for the quantitative evaluation of the alternatives and criteria. It enables the calculation of the ideal and anti-ideal solutions and the distance between each alternative and these solutions.

The fuzzy decision matrix is constructed by multiplying the weightages assigned to each criterion by the fuzzy ratings assigned to each alternative for that criterion. The resulting values are then aggregated to form the fuzzy

decision matrix, which is used to determine the minimum value of the first place, the average value of the middle place, and the maximum value of the last place.

The minimum value of the first place corresponds to the alternative closest to the anti-ideal solution. In contrast, the maximum value of the last place corresponds to the alternative closest to the ideal solution, as shown in the figure below. The average value of the middle place represents the overall performance of the alternatives relative to each other and can be used to determine the ranking of the alternatives. Equation 3 has been applied to all criteria, which can be seen from Table 6.4 to Table 6.11. We obtain the minimum, average and maximum values for each criterion C1-C4 determined with both alternatives, i.e., A1 and A2. The following equations are used for the next step to obtain the criterion.

1. $\bar{x}^{k_{ij}} = (a^{k_{ij}}, b^{k_{ij}}, c^{k_{ij}})$
2. $w^{k_j} = (w^{k_{j1}}, w^{k_{j2}}, w^{k_{j3}})$
3. $a_{ij} = \min_k \{a^{k_{ij}}\}, b_{ij} = 1/K \sum_{k=1}^K b^{k_{ij}}, c_{ij} = \max_k \{c^{k_{ij}}\}$

Using equation 3 as

$$a_{11} = \min\{3, 5, 7\}, b_{11} = 1/3 \sum (3, 5, 7), c_{11} = \max\{3, 5, 7\}$$

$$a_{11} = 3$$

$$b_{11} = 5$$

$$c_{11} = 7$$

C1A1							
DM1			DM2			Aggregated Values	Types
3	5	7	3	5	7	3	Minimum
3	5	7	3	5	7	5	Average
3	5	7	3	5	7	7	Maximum

Table 6.5: Aggregated Form of Alternative and Criteria Weightage for C1 and A1

C1A2							
DM1			DM2			Aggregated Values	Types
5	7	9	5	7	9	5	Minimum
5	7	9	5	7	9	7	Average
5	7	9	5	7	9	9	Maximum

Table 6.6 Aggregated Form of Alternative and Criteria Weightage for C1 and A2

C2A1							
DM1			DM2			Aggregated Values	Types
7	9	9	7	9	9	7	Minimum
7	9	9	7	9	9	9	Average
7	9	9	7	9	9	9	Maximum

Table 1.7 Aggregated Form of Alternative and Criteria Weightage for C2 A1

C2A2							
DM1			DM2			Aggregated Values	Types
5	7	9	7	9	9	5	Minimum
5	7	9	7	9	9	8	Average
5	7	9	7	9	9	9	Maximum

Table 6.8 Aggregated Form of Alternative and Criteria Weightage for C2 A2

C3A1							
DM1			DM2			Aggregated Values	Types
1	3	5	3	5	7	1	Minimum
1	3	5	3	5	7	4	Average
1	3	5	3	5	7	7	Maximum

Table 6.9 Aggregated Alternative and Criteria Weightage for C3A1

C3A2							
DM1			DM2			Aggregated Values	Types
1	3	5	1	3	5	1	Minimum
1	3	5	1	3	5	3	Average
1	3	5	1	3	5	5	Maximum

Table 6.10 Aggregated Form of Alternative and Criteria Weightage for C3 A2

C4A1							
DM1			DM2			Aggregated Values	Types
3	5	7	3	5	7	3	Minimum
3	5	7	3	5	7	5	Average
3	5	7	3	5	7	7	Maximum

Table 6.11 Aggregated Form of Alternative and Criteria Weightage for C4A1

C4A2							
DM1			DM2			Aggregated Values	Types
1	3	5	1	3	5	1	Minimum
1	3	5	1	3	5	3	Average
1	3	5	1	3	5	5	Maximum

Table 6.12 Aggregated Form of Alternative and Criteria Weightage for C4A2

Constructing the aggregated alternative and criteria weightage fuzzy decision matrix is a critical step in the Fuzzy TOPSIS methodology, as it enables the quantitative evaluation of the alternatives and criteria. It also allows for identifying the best alternative based on the distance from the ideal and anti-ideal solutions. For aggregated weightage using equation 4 as below for criteria C1, the values have been taken from Table 6.3 and Table.

$$4. \ w_{ij} = \min_k \{w_j k1\}, = 1/K \sum_{k=1}^K w_j k2, w_{j3} = \max_k \{w_j k3\}$$

$$w_{11} = \min\{3,5,7\}, 1/3(3,7,9), \max\{5,7,9\}$$

$$w_{11} = 3,6,9$$

Equation 4 is used for all the criteria to get the aggregated values, as shown in Table 6.13. Table 6.13 shows the Criteria Weights

Criteria	Aggregated Weightage		
C1	3	6	9
C2	5	8	9
C3	5	8	9
C4	1	4	7

Table 6.13: Aggregated Weightage

Criteria	DM1			DM2		
C1	5	7	9	3	5	7
C2	7	9	9	5	7	9
C3	7	9	9	5	7	9
C4	3	5	7	1	3	5

Table 6.14 Criteria Weightage

Step 5: Fuzzy Multi Criteria Group Decision Making (GDM) and process of normalizing.

In the fifth step of the Fuzzy TOPSIS methodology, the fuzzy multi-criteria group decision-making (GDM) problem is addressed by considering the benefits and costs associated with each criterion. This step aims to maximize benefits and minimize costs by assigning weights to the criteria based on their relative importance. The aggregated fuzzy decision matrix for alternatives is obtained in the coming sections.

Strengths

Aggregated Fuzzy Decision Matrix for Alternatives has been constructed with the help of Matrix D below.

$$\bar{D} = \begin{matrix} & \begin{matrix} C_1 & C_1 & & C_n \end{matrix} \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} \bar{x}_{11} & \bar{x}_{12} & \cdots & \bar{x}_{1n} \\ \bar{x}_{21} & \bar{x}_{22} & \cdots & \bar{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \bar{x}_{m1} & \bar{x}_{m2} & \cdots & \bar{x}_{mn} \end{bmatrix} \end{matrix}$$

Criteria	S1			S2			S3			S4		
C1	1.000	1.000	1.000	0.143	2.393	9.000	0.143	1.796	9.000	0.167	3.236	9.000
C2	0.111	1.132	5.000	1.000	1.000	1.000	0.111	1.207	6.000	0.143	2.928	9.000

C3	0.111	1.441	5.000	0.250	2.578	9.000	1.000	1.000	1.000	0.167	3.848	9.000
C4	0.111	0.983	4.000	0.111	0.907	4.000	0.111	0.923	4.000	1.000	1.000	1.000

Table 6.15 Strengths, Aggregated Fuzzy Decision Matrix for Alternatives

Weaknesses

The aggregated fuzzy decision matrix for alternatives has been constructed with the help of the equation below. Similarly, tables 6.15 to 6.17 were created using matrix D.

$$\bar{D} = \begin{matrix} & \begin{matrix} C_1 & C_1 & & C_n \end{matrix} \\ \begin{matrix} A_1 \\ A_2 \\ \vdots \\ A_m \end{matrix} & \begin{bmatrix} \bar{x}_{11} & \bar{x}_{12} & \dots & \bar{x}_{1n} \\ \bar{x}_{21} & \bar{x}_{22} & \dots & \bar{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \bar{x}_{m1} & \bar{x}_2 & \dots & \bar{x}_{mn} \end{bmatrix} \end{matrix}$$

W1			W2			W3			W4		
1.000	1.000	1.000	0.111	2.972	9.000	0.111	2.055	9.00	0.111	2.606	9.000
0.111	2.367	9.000	1.000	1.000	1.000	0.111	1.249	6.00	0.111	2.620	9.000
0.111	2.367	9.000	0.250	2.986	9.000	1.000	1.000	1.00	0.125	2.589	9.000
0.111	2.125	7.000	0.111	2.511	9.000	0.111	1.681	6.00	1.000	1.000	1.000

Table 6.16 Weaknesses, Aggregated Fuzzy Decision Matrix for Alternatives

Opportunities

O1			O2			O3			O4		
1.000	1.000	1.000	0.125	2.484	9.000	0.111	2.436	9.000	0.167	2.566	9.000
0.143	1.777	6.000	1.000	1.000	1.000	0.143	2.348	9.000	0.111	3.239	9.000
0.143	1.704	9.000	0.143	1.704	9.000	1.000	1.000	1.000	0.167	3.438	9.000
0.143	1.337	4.000	0.111	1.717	9.000	0.143	0.934	4.000	1.000	1.000	1.000

Table 6.17 Opportunities, Aggregated Fuzzy Decision Matrix for Alternatives

Threats

T1			T2			T3			T4		
1.000	1.000	1.000	0.125	4.322	9.000	0.111	1.771	9.000	0.111	1.904	9.000
0.111	0.915	6.000	1.000	1.000	1.000	0.111	1.220	6.000	0.111	1.308	8.000
0.143	2.243	9.000	0.250	3.076	9.000	1.000	1.000	1.000	0.167	2.806	9.000
0.111	2.711	9.000	0.167	3.007	9.000	0.111	1.413	4.000	1.000	1.000	1.000

Table 6.18 Threats, Aggregated Fuzzy Decision Matrix for Alternatives

This step also uses the normalisation matrix to determine the relationships between the criteria. The normalization matrix is constructed by dividing each element in the fuzzy decision matrix by the corresponding column sum.

This results in a matrix of normalized values used to determine each criterion's relative importance in the decision-making process.

$$\bar{W} = (\bar{w}_1, \bar{w}_2, \dots, \bar{w}_n)$$

The normalisation process ensures that the criteria are weighted appropriately based on their relative importance and allows for identifying the best alternative based on the distance from the ideal and anti-ideal solutions. The AHP method is a widely used approach for solving complex decision-making problems and is particularly useful when dealing with quantitative and qualitative criteria.

The formula mainly used for normalization is as follows.

$$5. rij = \frac{xij}{\max(xixij)}$$

$$j = 1, 2, 3, \dots, m; i = 1, 2, 3, \dots, n \text{ (Saifullah, 2019)}$$

The normalisation process is essential for ensuring that the criteria are weighted appropriately and identifying the best alternative based on the distance from the ideal and anti-ideal solutions. We used the analytic hierarchy process (AHP) method to determine the relationships between the criteria. The AHP method allows for comparing criteria pairs, and the resulting ratio scale assigns weights to the criteria.

Criteria	A1			A2		
C1	3	5	7	5	7	9
C2	7	9	9	5	8	9
C3	1	4	7	1	3	5
C4	3	5	7	1	3	5

Table 6.19 Normalization Matrix

After the normalization process, we obtained a weighted normalized fuzzy decision matrix that reflects the relative importance of each criterion in the decision-making process. The matrix is used to determine the strengths and

weaknesses of each alternative based on their distance from the ideal and anti-ideal solutions.

We applied the concept by considering the maximum value of the weighted normalized fuzzy decision matrix for the strength and opportunities criteria, as these represent factors that can positively impact the decision-making process. Based on these criteria, the maximum value reflects the best possible outcome for each alternative.

Conversely, we considered the minimum value of the weighted normalized fuzzy decision matrix for the weaknesses and threats criteria, as these represent factors that can have a negative impact on the decision-making process. Based on these criteria, the minimum value reflected the worst possible outcome for each alternative. We identify the best and worst possible outcomes for each alternative based on all the criteria considered by considering the criterion's maximum and minimum values. The results are crucial for selecting the best alternative based on the specific needs and requirements of the decision-makers.

Criteria		S			W			O			T		
Cost	C1	0.111	0.111	0.111	0.016	0.266	1.000	0.016	0.200	1.000	0.019	0.360	1.000
Benefit	C2	0.022	0.098	0.022	0.111	0.111	0.111	0.019	0.092	0.019	0.012	0.038	0.012
Benefit	C3	0.012	0.160	0.556	0.028	0.286	1.000	0.111	0.111	0.111	0.019	0.428	1.000
Benefit	C4	0.028	0.109	0.444	0.028	0.101	0.444	0.028	0.103	0.444	1.000	0.111	0.111

Table 6.20 Weighted Normalized Fuzzy Decision Matrix

We multiplied the values of the weighted normalized fuzzy decision matrix and the normalization matrix for each criterion to obtain the final weighted normalised fuzzy decision matrix. The normalization matrix is a square matrix that reflects the relative importance of each criterion in the decision-making process. It is calculated through the analytic hierarchy process

(AHP) method and uses pairwise comparisons between criteria to determine their relative importance.

Strengths

The weighted normalized fuzzy decision matrix for strength can be prepared by using the following:

$$5. rij = \frac{xij}{\max(xixij)}$$

We calculated the normalized fuzzy decision matrix for S1 first value and used Table 6. Column S values first and third sub-columns of S1, S2, S3 and S4 in the same table.

$$rij = \frac{1}{\max\{1, 9, 9, 9\}}$$

$$rij = \frac{1}{9}$$

$$rij = 0.111$$

Criteria	S1			S2			S3			S4		
C1	0.111	0.111	0.111	0.016	0.266	1.000	0.016	0.200	1.000	0.019	0.360	1.000
C2	0.022	0.098	1.000	0.111	0.111	0.111	0.019	0.092	1.000	0.012	0.038	0.778
C3	0.012	0.160	0.556	0.028	0.286	1.000	0.111	0.111	0.111	0.019	0.428	1.000
C4	0.028	0.113	1.000	0.028	0.122	1.000	0.028	0.120	1.000	0.111	0.111	0.111

Table 6.21 (Panel 1) Strength, Weighted Normalized form of Fuzzy Decision Matrix

A+					A-		
S1+	5.000	5.000	5.000	S1-	0.016	0.016	0.016
S2+	3.000	3.000	3.000	S2-	0.004	0.004	0.004
S3+	4.000	4.000	4.000	S3-	0.006	0.006	0.006
S4+	1.000	1.000	1.000	S4-	0.014	0.014	0.014

Table 6.21(Panel 2) Maximum and Minimum Value of Strengths Sub-Factor

Weaknesses

The weighted Normalized Fuzzy Decision Matrix can be constructed by applying equation 5.

W1			W2			W3			W4		
0.111	0.292	0.556	0.012	0.867	5.000	0.012	0.600	5.000	0.012	0.760	5.00
0.004	0.049	3.000	0.037	0.116	0.333	0.006	0.093	3.000	0.004	0.044	3.00
0.006	0.334	4.000	0.014	0.421	4.000	0.056	0.141	0.444	0.007	0.365	4.00
0.008	0.028	1.000	0.006	0.024	1.000	0.009	0.036	1.000	0.056	0.060	0.11

Table 6.22 (Panel-1) Weaknesses, Weighted Normalized Form of Fuzzy Decision Matrix

A+					A-		
W1+	5	5	5	W1	0.0123457	0.012345679	0.012345679
W2+	3	3	3	W2-	0.0041152	0.004115226	0.004115226
W3+	4	4	4	W3-	0.0061728	0.00617284	0.00617284
W4+	1	1	1	W4-	0.0061728	0.00617284	0.00617284

Table 6.22(Panel 2) Maximum and Minimum Value of Weakness Sub-Factor

Opportunities

The Weighted Normalized from the Fuzzy Decision Matrix can be constructed using Equation 5.

O1			O1			O3			O4		
0.111	0.292	0.556	0.014	0.725	5.000	0.012	0.711	5.000	0.019	0.749	5.000
0.006	0.065	2.333	0.037	0.116	0.333	0.004	0.050	2.333	0.004	0.036	3.000
0.008	0.240	4.000	0.008	0.240	4.000	0.056	0.141	0.444	0.009	0.484	4.000
0.014	0.045	0.778	0.006	0.035	1.000	0.014	0.064	0.778	0.056	0.060	0.111

Table 6.23 Opportunities, Weighted Normalized Form of Fuzzy Decision Matrix

A+					A-		
O1+	5	5	5	O1-	0.012	0.012	0.012
O2+	3	3	3	O2-	0.004	0.004	0.004
O3+	4	4	4	O3-	0.008	0.008	0.008
O4+	1	1	1	O4-	0.006	0.006173	0.006173

Table 6.23 (Panel 2) Maximum and Minimum Value of Opportunity Sub-Factor

Threats

The weighted normalized from the Fuzzy Decision Matrix can be constructed using Equation 5.

T1			T2			T3			T4		
0.111	0.292	0.556	0.014	1.261	5.000	0.012	0.517	5.000	0.012	0.555	5.000
0.006	0.127	3.000	0.037	0.116	0.333	0.006	0.095	3.000	0.005	0.089	3.000
0.008	0.316	4.000	0.014	0.433	4.000	0.056	0.141	0.444	0.009	0.395	4.000
0.006	0.022	1.000	0.006	0.020	0.667	0.014	0.043	1.000	0.056	0.060	0.111

Table 6.24 Threats, Weighted Normalized Form of Fuzzy Decision Matrix

A+					A-		
T1+	5	5	5	T1-	0.0123457	0.012345679	0.012345679
T2+	3	3	3	T2-	0.0046296	0.00462963	0.00462963
T3+	4	4	4	T3-	0.0079365	0.007936508	0.007936508
T4+	1	1	1	T4-	0.0061728	0.00617284	0.00617284

Table 6.24(Panel 2) Maximum and Minimum Value of Threats Sub-Factor

The values in the weighted normalized decision matrix represent each criterion's overall importance, considering its relative importance (as reflected in the normalization matrix) and its performance for each alternative (as reflected in the weighted normalized fuzzy decision matrix).

Criteria	Aggregated Weightage		
C1	1	2.625833333	5
C2	0.333333333	1.047373016	3
C3	0.5	1.267916667	4
C4	0.5	0.541666667	1

Table 6.25 Aggregation Fuzzy Decision Matrix for Criteria Weights

Using the previous approach, we can ensure that the criteria are appropriately weighted and that the overall decision is based on a balanced consideration of all relevant factors. The resulting weighted normalized fuzzy decision matrix is an essential tool for identifying the best alternative based on the specific needs and requirements of the decision-makers. The formula used for getting the final form of the weighted normalized matrix for fuzzy decision based on calculating the final weighted normalized fuzzy value for C1, the values have been extracted from Table 6.2

$$6. \bar{P} = [\bar{p}_{ij}] \text{ where } \bar{p}_{ij} = \bar{r}_{ij} \times \bar{w}_{ij}$$

$$p_{ij} = 1 * 0.111$$

$$p_{ij} = 0.111$$

Similarly, all other values have been calculated using Equation 6. Multiplying the values of the weighted normalized fuzzy decision matrix and the normalization matrix for each criterion results in a new matrix reflecting each criterion's weighted importance in the decision-making process. This new matrix is called the weighted normalized decision matrix.

Criteria	S			W			O			T		
C1	0.11	0.29	0.56	0.02	0.70	5.00	0.02	0.52	5.00	0.02	0.94	5.00
C2	0.01	0.10	0.07	0.04	0.12	0.33	0.01	0.10	0.06	0.00	0.04	0.04
C3	0.01	0.20	2.22	0.01	0.36	4.00	0.06	0.14	0.44	0.01	0.54	4.00
C4	0.01	0.06	0.44	0.01	0.05	0.44	0.01	0.06	0.44	0.50	0.06	0.11

Table 6.26 Final Weighted Normalized Fuzzy Decision Matrix

Similarly, the W column of the final weighted normalized fuzzy decision matrix is calculated by considering the values in Table 6.2. The O and T of the final weighted normalized fuzzy decision matrix are calculated by using the same equation.

Step 6: FPIS And FNIS

In Step 6, the fuzzy TOPSIS methodology involves finding the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FN) to determine the optimal alternative. The FPIS is a composite of the best performance values for each criterion, while the FNIS consists of the worst performance values.

To find the FPIS and FNIS, we selected the maximum value from each row of the weighted normalized fuzzy decision matrix as p^+ and the minimum value from each row as p^- . These values measure the distance between each

alternative and the FPIS or FNIS. The equations used for finding FPIS and FNIS are as follows:

$$A^+ = (p^+_1, p^+_2, \dots, p^+_n)$$

where

$$1. p^+_j = \max_i \{p_{ij}\}, i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

$$2. A^- = (p^-_1, p^-_2, \dots, p^-_n) \text{ where } p^-_j = \min_i \{p_{ij}\}, i = 1, 2, \dots, m; j = 1, 2, \dots, n$$

The Euclidean distance formula calculates the distance between an alternative and the FPIS. In contrast, the distance between an alternative and the FNIS is calculated using the same formula with inverted values. The Euclidean distance is the square root of the sum of the squared differences between each criterion's value for the alternative and the corresponding value for the FPIS or FNIS.

After calculating the distances for each alternative, the relative closeness to the FPIS and FNIS is determined by computing the ratio of the distance to the FPIS to the sum of the distance to the FPIS and the distance to the FNIS. The alternative with the highest relative closeness to the FPIS is chosen as the optimal solution.

A^+			
p_1^+	5.000	5.000	5.000
p_2^+	0.333	0.333	0.333
p_3^+	4.000	4.000	4.000
p_4^+	0.500	0.500	0.500

Table 6.27 Fuzzy Positive Ideal Solution (FPIS)

A^-			
p_1^-	0.016	0.016	0.016
p_2^-	0.004	0.004	0.004
p_3^-	0.006	0.006	0.006
p_4^-	0.014	0.014	0.014

Table 6.28 Fuzzy Negative Ideal Solution (FNIS)**Step 7: Distance of criteria of each alternative from FPIS and FNIS**

Step 7 is an important step in the Fuzzy TOPSIS methodology because it is applied to determine the alternatives' proximity to the ideal solutions. We calculated the distance of each criterion of both alternatives from the Fuzzy Positive Ideal Solution (FPIS) and Fuzzy Negative Ideal Solution (FNIS) by using the following equation:

$$(\bar{a}, \bar{b}) = \sqrt{1/3[(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2]}$$

equation (3)

The results showed the relative performance of each alternative concerning each criterion. By calculating the distances from both FPIS and FNIS for each criterion, we determined the overall closeness of each alternative to the ideal solution. Alternatives closer to the FPIS and farther from the FNIS reflect the best values. On the other hand, alternatives that are closer to the FNIS and farther from the FPIS reflect the worse values. Table 6.28 shows the distance of the Criteria of Each Alternative From FPIS.

Criteria	FPIS(A1)	FPIS(A2)	FPIS(A3)	FPIS(A4)
C1	4.684	3.801	3.868	3.709
C2	0.277	0.212	2.842	0.307
C3	3.343	3.115	4.156	3.049
C4	0.380	0.382	2.869	0.339

Table 6.29 Distance of Criteria of Each Alternative from FPIS

Strength, Distance of Criteria of Each Alternative from FPIS & FNIS

Using equation 9 as

$$d(\bar{a}, \bar{b}) = \sqrt{1/3[(a1 - b1)^2 + (a2 - b2)^2 + (a3 - b3)^2]}$$

Putting values from Table respective column of S1 and A+ from Table as

$$d(\bar{a}, \bar{b}) = \sqrt{1/3[(0.111 - 5)^2 + (0.292 - 5)^2 + (0.556 - 5)^2]}$$

$$d(\bar{a}, \bar{b}) = \sqrt{\frac{1}{3}[(23.90) + (22.165) + (29.74)]}$$

$$d(\bar{a}, \bar{b}) = \sqrt{25.36}$$

$$d(\bar{a}, \bar{b}) = 4.684$$

All values of Table are calculated by using the same equation 9.

FNIS

Strength								
A+					A-			
Criteria	FPIS (S1)	FPIS (S2)	FPIS (S3)	FPIS (S4)	FNIS (S1)	FNIS (S2)	FNIS (S3)	FNIS (S4)
C1	4.684	4.717	4.586	3.801	0.354	0.350	0.502	2.904
C2	2.405	2.393	2.387	2.841	1.731	1.731	1.731	0.202
C3	4.308	4.305	4.246	3.973	1.284	1.284	1.296	2.315
C4	0.786	0.786	0.784	0.784	0.570	0.570	0.570	0.570

Table 6.30 Strength, Distance of Criteria of Each Alternative from FPIS &FNIS

Weaknesses, Distance of Criteria of Each Alternative from FPIS & FNIS

All values of Table 6.3 are calculated using the same equation 9 and the values can be taken for the equation from the respective column of W of and column A+

Weaknesses								
A+					A-			
Criteria	FPIS (W1)	FPIS (W2)	FPIS (W3)	FPIS (W4)	FNIS (W1)	FNIS (W2)	FNIS (W3)	FNIS (W4)
C1	3.801	3.868	3.868	3.867	2.904	2.893	2.893	2.893
C2	2.851	2.858	2.408	2.409	0.201	0.197	1.730	1.730
C3	3.098	3.186	3.790	3.806	2.315	2.307	0.266	0.265
C4	0.784	0.784	0.784	0.767	0.570	0.570	0.570	0.571

Table 6.31 Weaknesses, Distance of Criteria of Each Alternative from FPIS & FNIS

Opportunities, Distance of Criteria of Each Alternative from FPIS & FNIS
All values of Table 6.3 are calculated using Equation 9.

Opportunities								
A+					A-			
Criteria	FPIS(O1)	FPIS (O2)	FPIS (O3)	FPIS O4)	FNIS (O1)	FNIS (O2)	FNIS (O3)	FNIS (O4)
C1	3.7088	3.7088	3.6675	3.9187	2.9294	2.9294	2.9300	2.8847
C2	2.4316	2.4619	2.4619	2.4581	1.7298	1.3449	1.3449	1.3450
C3	3.6754	3.0487	3.0500	3.1302	0.3983	2.3254	2.3254	2.3125
C4	0.7692	0.9247	0.9412	0.9519	0.5753	0.0739	0.0681	0.0619

Table 6.32: Opportunities, Distance of Criteria of Each Alternative from FPIS & FNIS

Threats, Distance of Criteria of Each Alternative from FPIS & FNIS. All values of Table 6.27 were calculated by using Equation 9, and the values were extracted from column T in Table 6.15 and Table 6.19.

Threats								
A+					A-			
Criteria	FPIS (T1)	FPIS (T2)	FPIS (T3)	FPIS (T4)	FNIS (T1)	FNIS (T2)	FNIS (T3)	FNIS (T4)
C1	4.6841	4.7187	4.5355	3.7398	3.7927	3.7980	3.7980	3.7953
C2	2.4278	2.4143	2.3871	2.8405	2.8520	2.8747	2.4580	2.4580
C3	3.1302	3.1269	3.0930	3.0930	3.1462	3.1860	3.7900	3.8062
C4	0.8017	0.8025	0.8042	0.8042	0.7966	0.7848	0.7952	0.7782

Table 6.33 Threats, Distance of Criteria of Each Alternative from FPIS & FNIS

Step 9: Closeness coefficient of each alternative

The closeness coefficient is a crucial parameter in Fuzzy TOPSIS analysis as it represents the overall ranking or priority of the alternatives. It measures the relative distance between each alternative and the ideal solution (FPIS) and non-ideal solution (FNIS) based on the criteria weights and the performance evaluations. The closer an alternative is to the ideal solution, the higher the closeness coefficient and vice versa.

Step 9 of Fuzzy TOPSIS analysis involves calculating the closeness coefficient for each alternative by dividing the negative distance by the summation of negative and positive distances determined for each SWOT component. The negative distance is between the alternative and the FNIS, while the positive distance is between the alternative and the FPIS. The formula for the closeness coefficient is:

$$1. C_i = d_i^- / (d_i^- + d_i^+), i = 1, 2, \dots, m$$

C_i = the closeness coefficient of alternative i

d_i^- = the negative distance of alternative i from FNIS

d_i^+ = the positive distance of alternative i from FPIS

The closeness coefficient ranges from 0 to 1, where 1 indicates the best alternative and 0 indicates the worst alternative. The alternative with the highest closeness coefficient is chosen as the best solution.

In summary, Step 9 of Fuzzy TOPSIS analysis is essential in determining the final ranking of the alternatives based on their relative distances from the ideal and non-ideal solutions. The closeness coefficient provides a measure of the overall performance of each alternative and is used to select the best alternative for the given SWOT analysis. The closeness coefficient for SWOT's strength component was obtained using equation 10.

$$C_1 = d^-_i / (d^-_i + d^+_i),$$

$$C_1 = 12.1825 / (12.1825 + 3.93931)$$

$$C_1 = 0.24435$$

Similarly, C_i is calculated S2 as

$$C_2 = 12.2006 / (12.2006 + 3.93513)$$

$$C_2 = 0.24388$$

For S3

$$C_3 = 12.003 / (12.003 + 4.09938)$$

$$C_3 = 0.25458$$

For S4

$$C_4 = 11.399 / (11.399 + 5.99132)$$

$$C_4 = 0.34452$$

		d1+	d1-	CC
S1	S1+	12.1825	3.93931	0.24435
S2	S2	12.2006	3.93513	0.24388
S3	S2	12.003	4.09938	0.25458
S4	S4	11.399	5.99132	0.34452

Table 6.34 Closeness Coefficient for Strength Component of SWOT

The closeness coefficient for weakness component of SWOT. Obtained by using equation 10.

$$C_1 = \frac{10.5341}{(10.5341 + 5.9906)}$$

$$C_1 = 0.36253$$

Similarly, CC calculated for the rest of the weaknesses components using equation 10. The result can be seen in Table 6.35.

		d1+	d1-	CC
W1	W1+	10.5341	5.9906	0.36253
W2	W2+	10.6961	5.96733	0.35811
W3	W3+	10.8501	5.45935	0.33474
W4	W4+	10.8486	5.45833	0.33472

Table 6.35 Closeness Coefficient for Weakness Component of SWOT

The closeness coefficient for the opportunities component of SWOT obtained by using equation 10.

$$C_i = d^-_i / (d^-_i + d^+_i)$$

$$C_1 = \frac{10.585}{(10.585 + 5.63286)}$$

$$C_i = 0.34732$$

Moreover, CC calculated the rest of the opportunity components using Equation 10. The result can be seen in Table 6.36

		d1+	d1-	CC
O1	O1+	10.585	5.63286	0.34732
O2	O2+	10.1441	6.6736	0.39682
O3	O3+	9.17939	6.66844	0.42078
O4	O4+	10.4589	6.60413	0.38704

Table 6.36 Closeness Coefficient for Opportunities Component of SWOT

The closeness coefficient for threats component of SWOT. Using equation 10.

$$C_1 = d^-_i / (d^-_i + d^+_i)$$

$$C_1 = \frac{11.044}{(11.044 + 10.643)}$$

$$C_1 = 0.4894$$

The CC calculated for the rest of threat components by using equation 10. The result can be seen in Table 2.37

		d1+	d1-	CC
T1	T1+	11.044	10.587	0.4894529
T2	T2+	11.062	10.643	0.4903513
T3	T3+	10.820	10.841	0.500494
T4	T4+	10.478	10.838	0.508445

Table 2.37 Closeness Coefficient for Threats Component of SWOT

Step 10: Obtaining alternatives ranking

In step 10 of the Fuzzy TOPSIS analysis, we compare the calculated closeness coefficient (CC) for both alternatives, A1 and A2. The alternative with the higher value of CC is considered better and, therefore, ranked first. The CC value measures the closeness of the ideal positive solution (FPIS) and the farthest from the negative ideal solution (FNIS). Once the CC values are obtained for both alternatives, we can compare them to determine which is more convenient. The alternative with a higher CC value is considered better because it is closer to the ideal solution and farther from the negative ideal solution.

Ranking the alternatives based on their CC values allows decision-makers to make the best decision. Using the Fuzzy TOPSIS method, the decision makers can select the alternative that capitalizes on the strengths and opportunities while minimizing the weaknesses and threat factors in ESCO project implementation on governmental premises.

	CC1	CC2
	A1	A2
Closeness coefficient	0.24434692	0.243877
Rank	1	2

Table 6.38 Alternative Rankings

6.4 Results and Discussions of SWOT and Fuzzy TOPSIS Methodology

The analysis indicates that of the two alternatives, A1 is the best option to be selected. The results showed that A1 was the more affordable option in terms of cost. On the efficiency level, A1 is categorized as high. The simulation results showed that A1 had a higher effect on the decision-makers than A2. Therefore, we recommended selecting alternative A1 for ESCO implementation.

6.5 AHP Results & SWOT Factors Ranking

To obtain the priorities of SWOT factors and sub-factors for the decision goal, the pairwise comparison matrices constructed using expert judgments as per the AHP methodology shown in Figure 6.2 Comparison of SWOT Factors

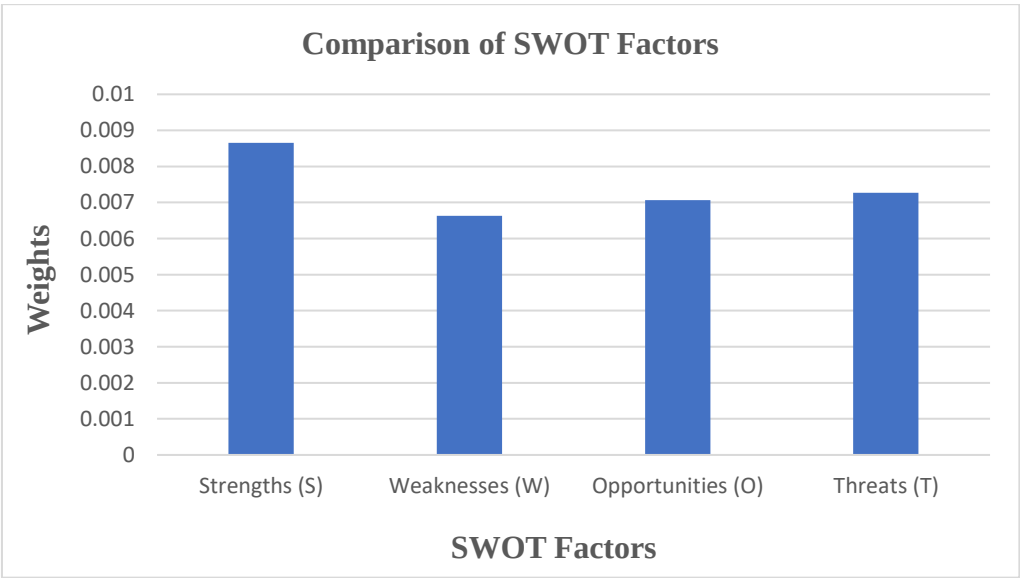


Figure 6.2 Comparison of SWOT Factors

The result obtained from the analysis shows that the four SWOT factors, namely Strengths (S), Weaknesses (W), Opportunities (O), and Threats (T), have been assigned weights based on their relative importance in the

decision-making process. The weights obtained are 0.0086 for Strengths, 0.0066 for Weaknesses, 0.0070 for Opportunities, and 0.0072 for Threats. The weightage values indicated that Strengths have the highest importance and are considered the most significant factor among SWOT in the strategy proposing to promote ESCO projects. On the other hand, weaknesses have the lowest weight, suggesting that they are considered the least significant factor in the decision-making process and strategy proposal. Overall, the analysis provides valuable insights into the relative importance of the SWOT factors in the experts' judgments to prioritize the strengths factors in setting the strategy for ESCO implementation projects. The conclusion in TOPSIS matches the conclusion obtained from Chapter 5, which confirmed that the Strength factors are the most influential and dominant factors for ESCO implementation.

6.5.1 Strengths Sub-Factors Ranking

The subfactors of Strength for ESCO implementation in premises can be ranked in order of dominance as $S1 > S4 > S3 > S2$. This means that S1 (reduction in the electricity consumption and cost in buildings has the highest weightage or importance among the subfactors, followed by S4 (Technical knowledge sharing between ESCO and employees), S3 (Reduce CO2 emission and contribution to environmental improvement), and S2 (Contribution to national target in energy efficiency) have the lowest importance as shown in Figure 6.3.

It is important to note that these rankings are based on the AHP methodology, which involves the judgment of experts and pairwise comparisons of the subfactors concerning the decisive goal of the study. The results indicate that the reduction in electricity consumption in buildings (S1) is considered the most significant subfactor contributing to the overall

strength of implementing the project, which is inconsistent with the conclusion obtained by (Hannon et al., 2015), (Hou et al., 2017), (Suhonen & Okkonen, 2013), (Augustins et al., 2018).

On the other hand, the contribution of the ESCO project to the national energy target (S2) is recognized as the least significant subfactor, suggesting that it has a lower impact on the overall Strength.

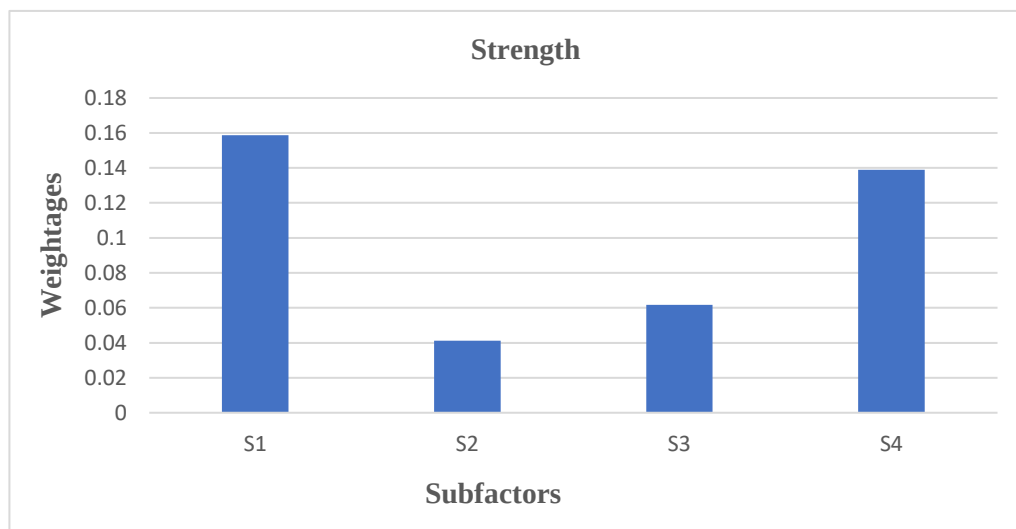


Figure 6.3 Subfactors of Strength

Our justification for the results is that experts viewed S2 (Contribute to achieving the national target in energy efficiency (6% reduction by 2023) as one of many factors that buildings in Bahrain need to be considered to achieve the national energy efficiency and 6% reduction in electricity by 2023. Including building efficiency codes, standards, regulations framework, building envelope and regulations for designing energy efficiency (Crawford et al., 2016) (Chandel et al., 2016). Our second justification is that the experts believed that to achieve national energy efficiency in buildings, several other direct factors and energy efficiency in governmental buildings need to be considered. Moreover, residential buildings consume more electricity than government buildings, as

mentioned in Chapter 4; therefore, we assumed the expert viewed governmental buildings as less dominant than residential buildings.

These rankings can be helpful in decision-making and strategic planning to implement ESCO projects. By understanding the relative importance of each subfactor within the Strengths category, decision-makers can develop strategies that leverage the dominant subfactors while addressing the less significant ones to achieve optimal results.

6.5.2 Weaknesses Sub-Factors Ranking

The most significant weakness factor for the given scenario is W1. It can be concluded that W1(high upfront capital cost/limited access to funds) is the most dominant weakness factor with a weightage of 0.1234, followed by W3 (lack of knowledge in technical and legal formalities for ESCO) and W4 (operational interruption in the buildings) with weights of 0.0617 each, and W2 (Business-as-usual mentality) being the least dominant with a weightage of 0.0411. The weights of W3 and W4 are also considerable, which indicates that these factors also significantly impact the ESCO project's implementation and overall decision-making process. On the other hand, the weightage of W2 is comparatively lower, which means that it has a relatively lesser impact on the decision-making process. Therefore, it is recommended that the decision-makers focus more on addressing W1 to promote the ESCO projects on governmental premises. The outcomes are inconsistent with (Madurai et al., 2020), (Garbuzova et al., 2016) and (Retallack et al., 2018).

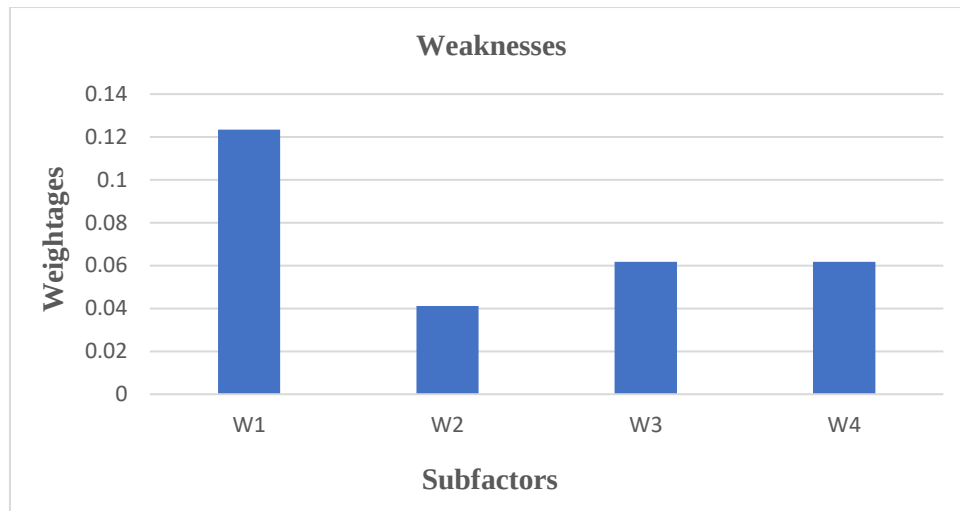


Figure 6.4 Weaknesses Subfactors

6.5.3 Opportunities Sub-Factors Ranking

The figure shows the ranking of opportunities subfactors for SWOT analysis as follows:

1. O1 with a weightage of 0.1234
2. O3 with a weightage of 0.0793
3. O4 with a weightage of 0.0617
4. O2 with a weightage of 0.0411

According to the obtained weights, it can be inferred that O1(downturn in the Economy encourages governmental institutions to invest more in energy efficiency) is the most dominant subfactor among the opportunities with a weightage of 0.1234, followed by O3 (huge building energy conservation potential) with a weightage of 0.0793. In addition, O4 (benefiting from lessons from other countries' experience) and O2 (banks' capability to provide financial solutions for energy efficiency and green finance projects) are less significant subfactors with weights of 0.0617 and 0.0411, respectively. The ranking of opportunity sub-factors leads the decision-makers to emphasise O1 and O3 in formulating strategies for ESCO projects. Both are interrelated since investing in the energy efficiency

project led to colossal energy conservation in buildings. Energy conservation can be reallocated for different purposes, such as operation expansion in buildings. O1 is considered the biggest influential sub-factor in our analysis in Chapter 5 and is consistent with the report published in the Kingdom's national energy efficiency action plan.

In the report, the country encouraged investment in energy efficiency initiatives to reduce exposure to energy price volatility, optimize the use of indigenous gas resources, and decrease peak electricity demand in Bahrain (SEU, 2017).

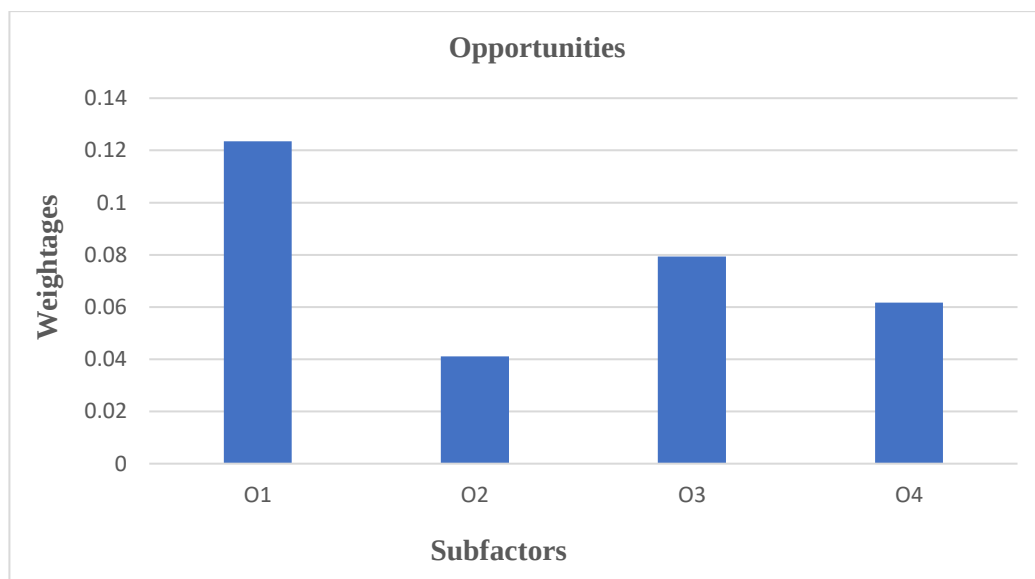


Figure 6.5 Opportunities Subfactors

6.5.4 Threats Sub-Factors Ranking

The ranking of the sub-factors for the Threats category in the SWOT analysis would be T1 (lack of incentive from the government to reduce the energy efficiency cost in buildings) as the most dominant factor with a weightage of 0.1234, followed by T3 (absent of regulations to support ESCO based projects in governmental buildings) with a weightage of 0.0793. T4 (bureaucracy constraints - bureaucracy required at different levels of government authority) ranked third with a weightage of 0.0617. Finally, T2

(energy cost allocated and paid by the government budget) ranked as the least dominant factor with a weightage of 0.0462. The ranking indicates that lack of incentive to implement such projects (T1) has the highest impact on the overall Threats category. Since ESCO is a new concept in the governmental sector, incentives are needed to encourage decision-makers and people at different levels to support the projects and limit the barriers. The results agreed with other types of energy efficiency project models in buildings (Alasseri et al., 2017) and the incentive mechanism for utility energy efficiency programs (Cook, 2013), (Shen al., 2016) and (Liang et al., 2019). While T2 has the lowest negative impact on ESCO projects, as shown in Figure 6.

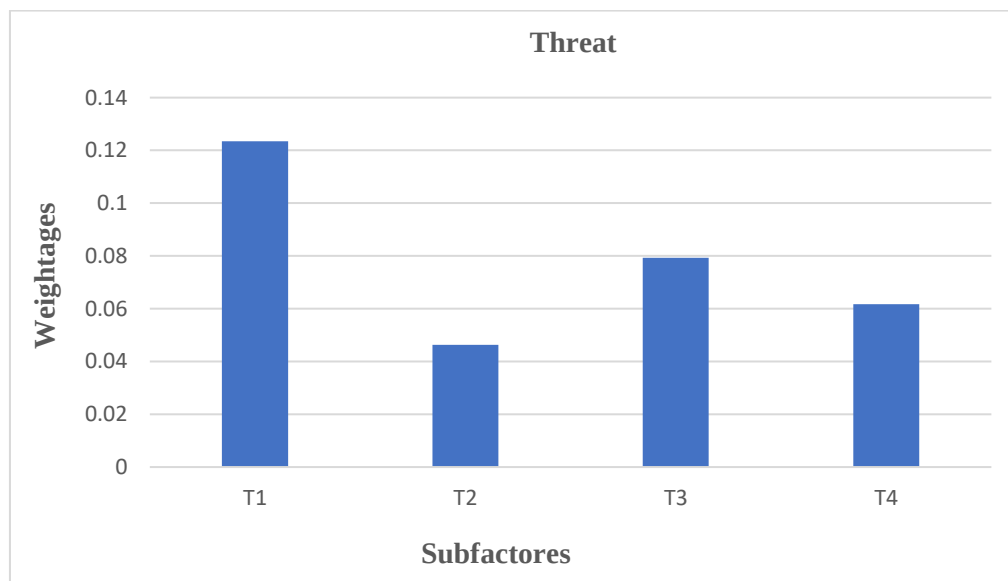


Figure 6.6 Threats sub-factors

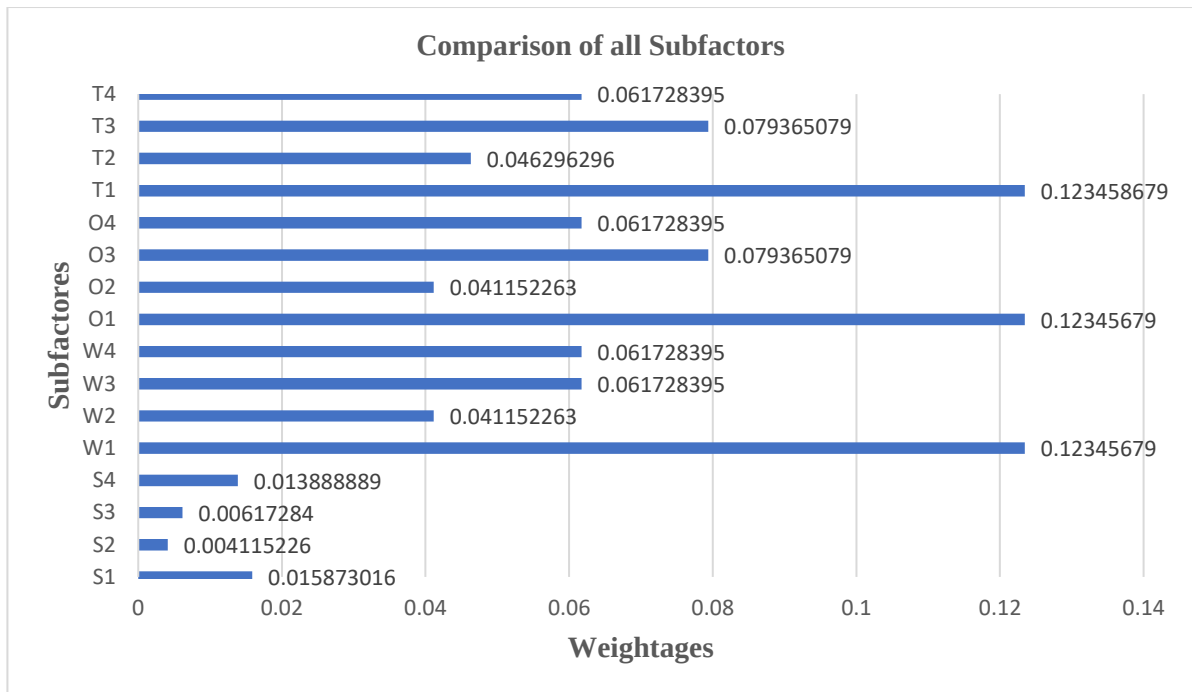


Figure 6.7 Comparison of all Sub-factors

Figure 6.7 shows the comparison of 16 subfactors in one view. The T1, O1 and W1 play a significant role in implementing ESCO projects in buildings. The same is true for T3 and O3. It is recommended to be addressed in the strategy setting and to promote ESCO projects.

6.6 Results Fuzzy TOPSIS and Coefficient Closeness (CC)

The result of Fuzzy TOPSIS showed a comprehensive evaluation of the SWOT factors and sub-factors based on their closeness coefficient (CC), distance from the positive ideal solutions (d^+), and distance from the negative ideal solutions (d^-). The SWOT factors and sub-factors are ranked based on the CC values. The higher the CC value, the better the factor's or sub-factor's performance.

The d^+ and d^- values measure the distance between each factor or sub-factor and the positive and negative ideal solutions, respectively. The factor or sub-

factor with the smallest d^+ value is considered the best, while the factor or sub-factor with the smallest d^- value is considered the worst.

	d1+	d2+	CC	Rank
S1	12.1824863	3.939312	0.244347	15
S2	12.20058294	3.935129	0.243877	16
S3	12.00298588	4.099377	0.254582	14
S4	11.39900526	5.991324	0.34452	11
W1	10.53405474	5.990601	0.362525	8
W2	10.6961396	5.967334	0.358109	9
W3	10.8500729	5.45935	0.334736	12
W4	10.84863013	5.458333	0.334724	13
O1	10.58502783	5.632861	0.347324	10
O2	10.14407353	6.673604	0.396821	6
O3	9.179394995	6.66844	0.420779	5
O4	10.45891688	6.604131	0.387043	7
T1	11.04378513	10.58749	0.489453	4
T2	11.06230856	10.64344	0.490351	3
T3	10.81980762	10.84121	0.500494	2
T4	10.47757374	10.83759	0.508445	1

Table 6.39 Fuzzy TOPSIS result Showing ranks of each Subfactor.

Based on the results, the highest-ranking factor is T4 (bureaucracy constraints) with a CC value of 0.5084, which is the most influential factor among all the other factors and T3 (absent of regulations to support ESCO-based projects in governmental buildings) is ranked second with a CC value of 0.5005, followed by T2 (energy cost allocated and paid by the government budget) with a CC value of 0.4904, and T1 (lack of incentive) with a CC value of 0.4895.

The final ranking indicated that the experts are more concerned with the threat factors in implementing the strategy for implementing ESCO projects on governmental premises. Both T3 and T4 are related to the usual challenges and factors in most government departments, which face bureaucracy in approving and drafting all administrative formalities and documents, which delays the implementations and delays gaining the related benefits of ESCO energy efficiency projects. The challenge makes the

government sector less attractive for ESCOs and financial creditors. In Bahrain, several national authorities and ministries must be involved in studying and evaluating different projects (Ministry of Finance, 2023). To facilitate the process and minimize the effect of bureaucratic constraints, such projects have to be initiated from a top-down policy. (Maistry et al., 2016) agreed that delays in adopting an energy policy were partly due to the institutions' cumbersome, procedural, and bureaucratic nature. Therefore, most experts viewed bureaucracy constraints as a factor that adversely affects the increase in energy efficiency projects.

The absence of regulations to support ESCO-based projects in governmental buildings (T3) affects ESCO projects as the existing regulations do not support such projects. An energy efficiency policy framework is needed at numerous political levels to support energy efficiency projects. In the Kingdom of Bahrain, there is a need to adopt regulation and a solid regulatory framework to promote energy efficiency policies. Building ESCO markets emerged in countries, including GCC, due to supportive energy policies and regulatory actions.

On the other hand, the lowest-ranking factor is S2 (Contribute to achieving the national target in energy efficiency) with a CC value of 0.2439, indicating that it is the least influential factor among all the sub-factors. S1 (Reduce the electricity consumption and cost in buildings) is ranked second lowest with a CC value of 0.2443, followed by S3 (Reduce CO₂ emission and contribute to environmental improvement) with a CC value of 0.2546, and S4 (Technical knowledge sharing between ESCO and employees) with a CC value of 0.3445. Therefore more

6.7 Conclusions

Based on the SWOT analysis and fuzzy TOPSIS approach for implementing ESCO projects on governmental premises, the results indicate that strengths have the highest weights, followed by opportunities, threats, and weaknesses with the lowest weights.

In the subfactors category, it was found that S1, which was related to the reduction in the electricity consumption in buildings, was the most dominant subfactor among all the strengths, while S2, which was related to the contribution of the ESCO to the national energy efficiency target, was the least dominant. On the other hand, in the weaknesses category, W1 was related to the high upfront capital cost. O3, related to government incentives, had the highest weight among the opportunities. In the case of threats, T1, which was related to the lack of incentive from the government to reduce the cost of energy efficiency, had the highest weightage.

Furthermore, the fuzzy TOPSIS approach was used to rank the SWOT factors and subfactors according to their closeness coefficients (CC). The results indicated that threat factors have the most significant impact on ESCO implementation. Hence, T4, related to the bureaucracy constraint in government authority, had the highest CC, followed by T3, T2, and T1. Based on the CC values, T4 (bureaucracy constraints - bureaucracy required at different levels of government authority) was the most critical threat factor for ESCO implementation and energy efficiency planning.

Among all the strengths, S4, related to the technical knowledge sharing between ESCO and employees, had the highest CC, followed by S3, S1, and S2. Similarly, O3, related to the considerable building energy conservation potential, had the highest CC among all the opportunities, followed by O4, O1, and O2. In the weakness factors, W1, related to the high upfront capital

cost to fund the energy efficiency project, had the highest CC, followed by W2, W3, and W4.

The Fuzzy TOPSIS analysis results comprehensively evaluate the SWOT factors and sub-factors based on their efficiency, distance from the ideal solutions, and CC values. The ranking of the factors and sub-factors can be used to identify the areas needing improvement while mitigating weaknesses as part of a strategy to promote ESCO projects in governmental buildings. The fuzzy TOPSIS approach can provide valuable insights for decision-makers by ranking the SWOT factors and subfactors.

CHAPTER SEVEN

FINDINGS OF RESEARCH

Both models confirm similar results based on the analysis in Chapters 5 and 6. The results ensure joint agreement among the experts' insights and judgment about the ESCO project, with no conflicts in opinion. The results proved the hypothesis explained in Chapter 4. The results mostly confirm the importance of the ESCO project in energy efficiency planning in governmental buildings and the proposed strategies.

The results addressed the following research questions highlighted in Chapter 1:

7.1. Addressing the Research Questions

The coming section states the research questions raised in Chapter 1 and the results obtained from the analysis to answer the questions.

1. What are the most significant SWOT factors that influence the implementation of ESCO projects based on governmental premises in the Kingdom of Bahrain?

We found from the results obtained from Fuzzy AHP and Fuzzy AHP TOPSIS that strength was the most influential factor in SWOT analyses. The analysis confirmed the findings of (Nurcahyanto et al., 2020) and (Liu et al., 2018), who argued that the strengths factors of ESCO in buildings are more important and significant compared to other factors in SWOT analysis—encouraging the decision-making to capitalise more on strengths, factors, and drivers.

2. What internal strengths sub-factors positively affect the implementation of ESCO projects based on governmental premises in the Kingdom of Bahrain?

We found that both models highlighted the reduction in the electricity consumption and cost in buildings factor (S1) as the most influential sub-factors across all factors in strength factors. It ranked the highest among other strengths sub-factors. Most experts agree that implementing ESCO in the building reduces electricity consumption and operational costs. Therefore, the finding was consistent with other research which proved ESCO in buildings contributed to cost reduction in electricity (Hannon et al., 2015), (Hou et al., 2017), (Suhonen & Okkonen, 2013), (Augustins et al., 2018).

3. What are the weakness sub-factors that negatively affect the implementation of ESCO projects based on governmental premises in the Kingdom of Bahrain?

High upfront capital cost and limited access to funds (W1) were the most influential factors in the weakness area; the findings were consistent with other studies (Madurai et al., 2020) (Retallack et al., 2018). Experts agreed that investing upfront capital in energy projects is one of the most significant barriers to implementing ESCO projects. Developing creative financing mechanisms for attracting public and private investment is essential to fill the immense financial gap and reach national energy efficiency and greenhouse gas reduction targets. Their opinion agreed with Zhany et al. on green financing for building energy retrofit in China (Zhang et al., 2020).

4. What external opportunity sub-factors positively affect the implementation of ESCO projects based on governmental premises in the Kingdom of Bahrain?

In the opportunities area, we found the highest priority sub-factors related to the government plan and several initiatives to reduce the operational

expenditure in government sectors and invest in energy efficiency (O1). The investment in energy efficiency is a critical reason to face the fluctuations in oil price, the cost of energy intensity, and environmental pressure (Wang et al., 2020). The experts realized the importance of reducing the operational cost of building by investing in energy efficiency. They agreed that ESCO projects could cut operational costs without compromising the energy demand in buildings or premises.

5. What external threats sub-factors negatively affect the implementation of ESCO projects based on governmental premises in the Kingdom of Bahrain?

The need for an incentive from the government to reduce the energy cost in buildings ranked as the highest priority among threat factors. The lack of incentive to reduce the energy cost in buildings is considered one of the most important factors and threats. Table 7.1 Shows the most influential sub-factor in the SWOT analysis framework obtained from Fuzzy AHP and Fuzzy TOPSIS analysis.

	Strengths Factors	Weaknesses Factors
Internal	S1: Reduce the electricity consumption and cost in buildings	W1: High upfront capital cost/limited access to funds
External	Opportunities factors	Threats factors
	O1: The economic downturn encourages governmental institutions to cut operational costs and invest more in energy efficiency.	T1: Lack of incentive from the government to reduce the energy cost in buildings

Table 7.1 The Highest Ranked Sub-Factors in SWOT Analysis in both Models

6. Which strategies can be suggested to the decision-makers to promote the implementation of ESCO projects based on governmental premises in the Kingdom of Bahrain?

To answer the final question, we used the TOWS matrix to identify the best feasible strategies.

7.2 TOWS Matrix and Strategies Identification

We manifest four strategies based on SO, ST, WO and WT (Haque et al., 2020), (Gottfried et al., 2018). Table 7.2 shows the TOWS matrix and findings strategies. In the strategies identified, SO strategy depends on the optimal use of internal strengths and external opportunities sub-factors. WO strategies depend on capitalizing on external opportunities to limit internal weaknesses. ST strategy uses internal strengths to limit or reduce external threats. Finally, use the WT strategy to decrease external threats by limiting or reducing internal weaknesses.

Based on the TOWS, we identify the following strategies related to economic and financial.

S1O1: Investing Strategy

The strategy focused on reducing electricity consumption in buildings (S1) by encouraging the investment in energy efficiency solutions offered by ESCO in buildings for potential savings (O1). The strategy suits the country's economic plans for growth without compromising the energy supply. The payback from the investment in energy efficiency helps the government sector face any potential increase in operational cost and energy intensity.

The identified strategy matches the IEA (IEA, 2020) strategic recommendation for decision-makers to invest in energy-efficiency renovation and ESCO project buildings to recover from the unexpected costs encountered during the COVID-19 pandemic.

There must be an appropriate investment strategy for planning energy efficiency programs and strategies to overcome the cost of energy in specific buildings and the energy cost saving (Lee et al., 2013).

S1T1: Incentive Strategy

The strategy depends on reducing energy consumption and electronic costs in buildings (S1) by offering an incentive program (T1) to encourage government entities to invest in energy efficiency solutions offered by ESCO. The incentive offered by the government set the stage for a considerable increase in energy efficiency investment environments. The lack of incentives is a significant barrier to implementing energy-saving projects. It can only be overcome by appropriate government action.

The incentives may include tax reductions, high energy prices, utility incentives and low interest rates. The incentive program strategy will also encourage the government sector to study the finances. The energy performance contracting (EPC) implemented by energy service providers has been recognized as a mechanism to overcome some barriers. Strategy formulation based on the cost saving in the buildings is proven to be effective in several cases (Sun et al., 2023), (Cho et al., 2015) and (Fontecha et al., 2022). A study exploring several works of literature on incentive mechanisms concluded that incentive plans and the program could be considered meaningful solutions to control electricity consumption, one of the most suitable solutions to address this problem (Allasseri, 2017). A case study conducted on ESCOs in the UK recommended economic incentives in the policy to support the ESCOs' activity.

The incentives included capital grants, long-term financial support for low-carbon energy projects, tax breaks, and energy subsidies (Hannon et al., 2015). Another study discussed the critical role of financial incentives in developing ESCOs (Goldman et al., 2005).

W1O1: Promoting ESCOs Market Strategy

Minimizing the high upfront capital cost (W1) and benefiting from the potential in energy efficiency investment (O1) can be achieved by creating a business market for ESCOs in local Bahrain. Creating a competitive market where ESCO can grow and provide a competitive advantage for the clients and building owners to implement ESCO projects where the needed up-front capital is limited and increase energy efficiency opportunities in the local market. The ESCO market offers an oriented mechanism to improve energy efficiency and has had successful experiences in developed countries (Painuly et al. 2004).

Vine (2003) estimates world ESCO markets to have been approximately one-half to one-third of US market activity in 2000, though growth is anticipated. Local availability of financing at reasonable terms is essential for a mature, well-functioning ESCO market (World Bank, 1999). By setting the right market strategy and increasing active government involvement (through the findings strategies), policymakers should expect significant growth over time in the number of energy contracts, including shared savings and guaranteed and energy performance-based contracts.

W1T1: Partnership Strategy

The partnership between public and private sectors, such as banks and ESCOs, can provide upfront capital for the governmental sector and benefit from the financial market opportunities offered by ESCOs.

ESCOs are driven by partnerships (public-private) that are dedicated to policy measures, regulations, and financial solutions (Bertoldi, 2017). Long-term and low-interest loans and tax credits have allowed ESCO's investment projects to develop since 1993. They promoted private investment in China and introduced an incentive program to support public-private partnerships to engage private players in creative investment programs and finance mechanisms (Gottfried, 2018). Building cooperation and partnership between Bahrain's government and the financial sector will facilitate paying for energy efficiency capital and unlocking the country's green financing market (Zhang, 2020). This alliance and partnership ensure public sector involvement while leveraging private investment costs (Tsai & Mezher, 2020).

A United Nations published in 2019 a report (titled Economic and Social Commission for Western Asia) revealed that Bahrain could benefit from the partnership between the public and Super ESCO. Super ESCO" can support ESCO projects and direct the government support to energy efficiency.

At the regional level, UAE's Etihad ESCO successes in implementing the Super ESCO model and Saudi Arabia retained the model of the Super ESCO to support its energy efficiency program (UN, 2019)

External Sub-Factors	Internal Sub-Factors		
	TOWS Strategies	Strengths (S1)	Weakness (W1)
	Opportunity (O1)	S1O1: Investment Strategy	W1O1: Risk management strategy
	Threat (T1)	S1T1: Incentive Strategy	W1T1: Alliance strategy

Table 7.2 TOWS Matrix (Haque et al.,2020) and The Finding Strategies

All findings' strategies can be applied and initiated by a centralized government entity named Super ESCO structure.

The role of Super ESCO has been recognized in several counties. The government provide Super ESCO with sufficient capital with a clear target to undertake public sector performance contracting projects, retrofit and leverage commercial financing. The Super ESCO may also act as a financing or leasing entity for energy efficiency projects (Limaye, 2011). New policies and regulations at a systemic level within super ESCO will overcome barriers at the operational. Moreover, benefiting from the Kingdom's experience in the pilot project and experts' knowledge will add value to the Super ESCO initiatives.

Active involvement of Super ESCO will assure the public sector commitment to capital budgeting and can reduce the rejection of profitable energy efficiency projects. Established Super ESCO in Bahrain, facilitate studies budgets to be allocated for government buildings linked with defined energy efficiency objectives in terms of saving percentage and cost savings over a specific project period.

Although the results in the TOPSIS model rated threat factors the highest among the SWOT sub-factors, the initiation of Super ESCO can still set energy policy to overcome the threats sourced from external forces such as

incentives, budgeting, regulations and Bureaucracy in decision-making. Moreover, the integrated framework of SWOT-Fuzzy AHP and Fuzzy SWOT outlines a feasible approach for the decision-makers to rank the priorities of factors for energy efficiency planning.

CHAPTER EIGHT

Conclusion

Decision-making and setting a successful strategy to implement energy efficiency projects such as ESCO in governmental buildings must be built on several factors. Therefore, the process is very complex, involving various positive and negative factors. Considering that ESCO is an emerging concept in Bahrain, it needs a proper strategy to overcome all challenges that could be faced in implementing the project. Therefore, this study evaluates various factors for energy efficiency strategies in governmental buildings and employs an integrated methodological approach comprised of SWOT analysis, AHP, and F-TOPSIS to determine the best factors and sub-factors for energy strategy.

This research is based on fuzzy theory, which shows decision makers have different judgments and insights that may affect the implementation of energy efficiency projects such as ESCO. The fuzziness in decisions can be solved by implementing MCDA models to prioritise and rank decision-makers preferences to obtain the most influential factors.

We conclude from the results obtained from Fuzzy AHP and Fuzzy AHP TOPSIS that the strength factor was the most influential in SWOT analyses. The analysis confirmed the findings of (Nurcahyanto et al., 2020b) and (Liu et al., 2018), who argued that the strengths factors of ESCO in buildings are more important and significant compared to other factors in SWOT analysis—encouraging the decision-making to capitalize on strengths.

The results for both models confirm similar results, which provide an assurance to the common agreement among the experts' insights and

judgment about the ESCO project and confirm the importance of such a project. The results can contribute to energy sustainability, economic growth and environmental protection.

Finally, we conclude that most experts realized the effect of economic factors in SWOT. Reducing energy costs, the up-front payment challenge, and cutting operational costs were the dominant factors in their judgments and responses.

Overall, the results answered the study's research questions. However, they provide a useful framework for systematising and understanding the challenges faced by energy efficiency projects in buildings. They reveal substantial opportunities for future research, helping different sectors overcome challenges.

CHAPTER NINE

Recommendations, Limitations of the Research, Research Implementation and Future Research

9.1 Recommendation

This study has several recommendations to enhance building energy efficiency and contribute to the country's sustainable energy planning and goals.

First, the strategy to implement the ESCO project on governmental premises is recommended to be integrated with national authorities' efforts toward energy efficiency objectives in buildings. We recommend that such a project be embedded within the country's development plan and as one of its energy sustainability strategies. All national authorities (EWA, SEA, Ministry of Finance, Tatweer, Ministry of Oil and Environment) collaborate and integrate resources, including institutional and administrative, finance, capacity, and technology, toward tangible outcomes to achieve the energy efficiency target of the country.

Secondly, a collaboration between government authorities and the ESCO industry can stimulate the development and deploy a broad portfolio of renewable and cleaner energy technologies to reduce energy use on governmental premises—the public-private partnership business model to hustle public facilities to lower transaction costs and to facilitate project finance.

We recommend establishing a Super ESCO, a model that functions as an ESCO for the government sector to evolve to overcome challenges and weaknesses in handling the large-scale implementation of energy efficiency projects. We strongly recommend benefiting from the experiences the ESCO pilot project offers for four premises in government buildings. At the same time, it is recommended to involve the Electricity and Water Authority (EWA) to support the development of ESCO activities.

Thirdly, banks in Bahrain need to finance energy efficiency projects such as ESCO. Banks must pay more attention to the significant potential in efficiency demands in the local market. Banks are recommended to study the energy efficiency in buildings as financial opportunities to fulfil their mandate toward sustainability in the country. Banks in Bahrain continue to focus on traditional investments, which needs to be more consistent with its mandate to be a lender for green funds. We recommend that financial sectors study the market need for energy efficiency projects and utilize the available resources to benefit from the ESCO financial mechanism, which applies to insurance companies.

We recommend that the concerned government authority study the four strategies in Chapter 7 and promote policies on developing ESCO projects. Capitalizing on the strength factors can add value to energy efficiency planning and reduce the impact of threats, weaknesses, and risks on implementation. Meanwhile, it gives ESCO projects a considerable chance to succeed in governmental buildings. Bahrain's government should introduce an incentive mechanism to raise the default opportunity in implementing ESCO Project-based, thus creating a healthy environment for spreading ESCO projects and overcoming the weak factors highlighted in the research.

Effective policies and legislative action should be initiated from a higher level of public authority in Bahrain and at a strategic level to expedite the policy actions and achieve the energy efficiency target setup for 2025. The results can assist with strategic planning for governmental agencies to implement the most effective policies and legislative actions in buildings. In addition, the framework relationship can enhance the ESCO project's impact on the building sector in Bahrain.

The energy planning strategies in buildings could be implemented to improve the overall coherence of Bahrain's energy and climate policies. The first is to create incentives for energy planning and energy firms to collaborate with public actors to benefit from the resources and technology in ESCOs. Such collaboration would also tackle challenges like energy intensity and energy efficiency plans. Reinforcing public–private cooperation would be appropriate for Bahrain since its energy sector will be characterized by diverse private actors cooperating with public agents to establish a Super-ESCO entity. Studying suitable business models that incorporate the opportunities and risks between public and private enforcement for the ESCO project could be an opportunity to conduct research in the future.

Finally, residential and commercial buildings consume significant energy in Bahrain, eventually contributing to environmental pollution. Therefore, we recommend that owners of commercial and residential buildings and premises benefit from the study results to lower the energy consumption and carbon footprints sourced from the operation of those buildings.

9.2 Limitation

Some research limitations need to be improved in future research.

9.2.1 Samples

In this study, the data input was discussed by the expert group involved in ESCO pilot projects or who had practical experience in such projects. The concept of ESCO in buildings is an emerging country. More experts should be involved to improve the accuracy of the results in further research.

9.2.2 Availability of Information

The second limitation was information availability. Information related to governmental buildings, such as energy consumption, equipment type, ages of specific buildings, number of governmental premises and buildings, types of energy efficiency programs, and investment amounts, is limited.

9.2.3 Channel of Communications:

The second limitation is that the study was conducted during the global COVID-19 pandemic. Due to the pandemic, most experts worked from home, and the interviews were conducted online through their communication platforms. Face-to-face recorded interviews were not accomplished.

9.2.4 Lack of Time

Due to the pandemic, most experts could not conduct the interviews at the scheduled time and date, delaying the thesis submission as planned.

9.2.5 Equation Performance

The mathematical equations in the study were only used in the context of the research objectives to provide a focused result without elaborating on the mathematical perspectives of each equation. We followed other studies on this.

2.6 Technology Resources

More technology resources are needed to solve multi-criteria decision problems automatically based on factors and sub-factors. Therefore, we used the common function in Microsoft Excel to obtain the values in the analysis sections.

9.3 Research Implementation

We recommend deploying a similar study and analysis for energy planning strategy to ESCO project implementation for private buildings since the residential and commercial buildings consume significant energy in Bahrain and eventually contribute to environmental pollution.

There are many common sub-factors between governmental and private buildings. The decision-makers of commercial and residential buildings promise to benefit from the study results by lowering the energy consumption and carbon footprints sourced from the operation of those buildings.

Decision makers in energy authority can benefit from the study to implement an incentive program linked to the attainable energy target to the incentive program and reform electricity tariff subsidies to encourage more energy efficiency projects by ESCOs.

9.4 Future Research

The study will help other academia, practitioners and environmental activists in the government and private sector in providing direction for possible research areas and questions for future research.

In the study, SWOT factors and sub-factors were treated solely and independently. The independence among the sub-factors still needs to be addressed. The AHP method provides an analytical means to determine the relative importance of the factors and ignores the interdependence between factors and sub-factors. Future research can apply the Analytical Network Process (ANP) to analyse the dependence between the factors and sub-factors.

ESCOs offer several financial models with high ROI and limited credit risk, including energy services contracts, energy performance, guaranteed saving, and shared saving models. The local and international banks in Bahrain can study the direction of the study and find out the opportunities ESCO projects offer in the governmental sector. The results can assist with fulfilling the banks' credit commitment to green investment. Such investment will meet banks' objectives toward SDG goals and the three dimensions of sustainability: environment, economic and social.

CHAPTER TEN

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Appendices

Appendix 1

Table 1 shows a SWOT analysis of the ESCO EE project for Building in Bahrain before selecting each SWOT's four most important sub-factors.

Internal factors	
Strength (S)	Items
	• Providing professional building energy services • Taking the risks of clients Weaknesses: • ESCO is willing to work in Bahrain and assume the financial and technical risk while fulfilling the energy needs • There is an urgent need to reduce the energy intensity in Bahrain • Government support for energy efficiency projects on governmental premises. • Improvement in environmental and climate change • contribute to achieving the national target in energy efficiency (6% reduction by 2023) • Match the government initiative strategy in reducing the operational cost in the governmental buildings • performance position of local banks allows facilitating new financial vehicles for ESCO project
Weakness (W)	• Lack of energy efficiency technologies in Bahrain • lack of knowledge in legal documentation, i.e., EPC • Financial difficulty between ESCO and local banks • Limited cultural awareness of ESCO benefits
External factors Strengths:	
Opportunity (O)	• Huge building energy conservation potential • increase the knowledge in ESCO energy efficiency projects • Possibility to expand on the EE market in Bahrain and increase the knowledge of ESCO building projects

	• possible support from the government sector (including EWA, Tatweer, ESU, and NOGA) for ESCO building projects in governmental institutions • Fulfill the international target of energy efficiency • The downturn in the Economy may encourage governmental institutions to invest in EE • Open new financial opportunities/products for green finance in local banks • Lessons from developed countries' experience
Threat (T)	• Low energy price • Continue increase in energy intensity • The slow process of implementing EE projects • The slow process of new product development - competition does it faster and better in the same amount of time • Business as usual mentality slows the recognition and process of EE projects • inefficiency in types of equipment for energy consume more energy than needed • Absent of regulation to support the ESCO project • lack of incentive to undertake EE ESCO project and business-as-usual mentality

Appendix 2

Dear participant

My name is Fatema Janahi, and I am a PhD candidate in the Environment and Sustainable Development Program at the University of Bahrain and a faculty member in the College of Applied Studies at the same university. I am a certified risk management member and have more than 15 years of experience in the banking sector. I am conducting this survey to investigate the **Strengths, Weaknesses, Opportunities, and Threats (SWOT) factors for Energy Efficiency Projects in Governmental buildings in Bahrain.**

To make the study more focused, we are conducting this survey on Energy Services Companies (ESCOs) that audit, design, develop and implement energy efficiency projects while considering the technical and financial risks and the resulting guaranteed savings.

This research aims to improve the strengths and opportunities factors and overcome the weaknesses and threats for ESCO –based Energy Efficiency Projects to formulate proper strategies suitable for implementation in the Kingdom of Bahrain.

Please note that this survey targets energy efficiency experts in different sectors and will take only 15 minutes. Please let me know if you want to survey the Microsoft Teams meeting.

All the responses will be kept private, confidential, and anonymous. The responses will be used for the purpose mentioned above only. You will have the option to be emailed if you would like to receive the study results.

If you have any questions regarding this research, please contact me at 00973-39444046.

Sincerely yours

Fatima Mohamed Janahi

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The Interviews Questionnaires

Part 1: General Questions

1) Gender

- Male
- Female

2) Educational level

- Secondary
- Diploma
- Bachelors
- Master
- PhD

3) What sector do you work in?

- Government
- Industrial
- Academia
- Others

4) What is your position in your organization?

- Owner
- Decision-maker
- Manager
- Consultant
- Engineer
- Researcher
- Others

5) How many years of experience do you have in the energy efficiency field?

- 1-5
- 6-10
- 11-15
- 16-20
- 21-25
- More than 25 years

6) How many projects have you been involved in related to energy efficiency?

- None
- 1-5 projects
- 5-10 projects
- 15-20 projects
- 20-25 projects
- More than 25 projects

7) What experience do you have with Energy Services Companies (ESCOs)? ESCO audits, designs, develops and implements energy efficiency projects while guaranteeing energy-saving and assuming technical and financial risks.

- Not familiar with ESCO-based projects
- Limited knowledge of ESCO-based projects
- Aware of ESCO-based projects but have no implementation experience
- Aware of ESCO-based projects but with limited ESCO implementation experience

- With good ESCO implementation experience

Part Two: Compare the SWOT factors (pair-wise comparison)

The rating scale for the experts

	Scale
Extremely less important	1/9
	1/8
Very strongly less important	1/7
	1/6
Strongly less important	1/5
	1/4
Moderately less important	1/3
	1/2
Equally importance	1
	2
Moderately more important	3
	4
Strongly more important	5
	6
Very strongly more important	7
	8
Extremely more important	9

Strength Factors

S1: Reduction of the electricity consumption and cost in buildings

S2: Contribution to achieving the national target in energy efficiency (6% reduction by 2023)

S3: Reduction of CO₂ emission and contribution to environmental improvement

S4: Technical knowledge sharing between ESCO and employees

**Compare the Strengths factors with each other (pair-wise comparison).
Choose the rating scale.**

1. **S1** (Reduction of the electricity consumption and cost in buildings) is ----- **than S2** (Contribution to achieving the national target in energy efficiency (6% reduction by 2023)).
2. **S1 (Reduction** of the electricity consumption and cost in buildings) is ----- **than S3 (Reduction** of CO₂ emission and contribution to environment improvement).
3. **S1 (Reduction** of the electricity consumption and cost in buildings) is ----- **than S4** (Technical knowledge sharing between ESCO and employees).
4. **S2 (Contribution** to achieving the national target in energy efficiency (6% reduction by 2023)) is **than S3** (Reduction of CO₂ emission and contribution to environment improvement).
5. **S2** (Contribution to achieving the national target in energy efficiency (6% reduction by 2023)) is -----**than S4 (Technical** knowledge sharing between ESCO and employees).

6. **S3** (Reduce CO2 emission and contribute to environment improvement) is than
S4 (Technical knowledge sharing between ESCO and employees).

Weaknesses Factors

W1: High upfront capital cost/limited access to fund

W2: Business-as-usual mentality slows the acknowledgement of the benefits related to ESCO based Energy Efficiency projects

W3: lack of knowledge in technical and legal formalities for ESCO-based Energy Efficiency projects, i.e. EPC

W4: Operational interruption in the buildings

Compare the Weaknesses factors with each other (pair-wise comparison). Choose the rating scale.

1. **W1 (High upfront capital cost/limited access to funds) is -----
 ---- than W2 (Business-as-usual mentality slow the acknowledgement of the benefits related to ESCO-based Energy Efficiency projects).**
2. **W1 (High upfront capital cost/limited access to funds) is -----
 ---- than W3 (lack of knowledge in technical and legal formalities for ESCO-based Energy Efficiency projects, i.e., EPC).**
3. **W1 (High upfront capital cost/limited access to funds) is -----
 ---- than W4 (Operational interruption in the buildings).**

4. **W2** (Contribute to achieving the national target in energy efficiency - 6% reduction by 2023) is than **W3** (lack of knowledge in technical and legal formalities for ESCO-based Energy Efficiency projects, i.e., EPC).
5. **W2** (Business-as-usual mentality slow the acknowledgement of the benefits related to ESCO based Energy Efficiency projects) is -----
-----than **W4** (Operational interruption in the buildings).
6. **W3** (lack of knowledge in technical and legal formalities for ESCO-based Energy Efficiency projects, i.e., EPC) is than **W4** (Operational interruption in the buildings).

Opportunities Factors

O1: The downturn in the Economy encourages governmental institutions to invest more in EE

O2: Banks' capability to provide financial solutions for energy efficiency and green finance projects

O3: Huge building energy conservation potential

O4: Benefiting from lessons from other countries experience

Compare the opportunity factors with each other (pair-wise comparison). Choose the rating scale.

1. **O1 (Downturn in the Economy encourages governmental institutions to invest more in EE) is ----- than O2 (Bank's capability to provide financial solutions for energy efficiency and green finance projects).**
2. **O1 (Downturn in the Economy encourages governmental institutions to invest more in EE) is ----- than O3 (Huge building energy conservation potential).**
3. **O1 (Downturn in the Economy encourages governmental institutions to invest more in EE) is ----- than O4 (Benefiting from lessons from other countries' experience).**
4. **O2 (Bank's capability to provide financial solutions for energy efficiency and green finance projects) is than O3 (Huge building energy conservation potential).**
5. **O2 (Bank's capability to provide financial solutions for energy efficiency and green finance projects) is -----than O4 (Benefiting from lessons from other countries' experience).**

6. **O3** (Huge building energy conservation potential) is than
O4 (Benefiting from lessons from other countries' experience).

Threats Factors

T1: Lack of incentive from the government to reduce the EE cost in buildings

T2: Energy expenses allocated and paid from the government budget

T3: Absent of regulations to support ESCO based-projects in governmental buildings

T4: Bureaucracy constraints - bureaucracy required at different levels of government authority

Compare the opportunity factors with each other (pair-wise comparison). Choose the rating scale.

1. **T1 (Lack of incentive from the government to reduce the EE cost in buildings) is ----- than T2 (Energy expenses allocated and paid from the government budget).**
2. **T1 (Lack of incentive from the government to reduce the EE cost in buildings) is ----- than T3 (absence of regulations to support ESCO projects).**
3. **T1 (Lack of incentive from the government to reduce the EE cost in buildings) is ----- than T4 (Bureaucracy constraints - bureaucracy required at different levels of government authority).**
4. **T2 (Energy expenses allocated and paid from the government budget) is than T3 (Absent of regulations to support ESCO based-projects).**

5. **T2** (Energy expenses allocated and paid from the government budget) is -----than **T4** (Bureaucracy constraints - bureaucracy required at different levels of government authority).
6. **T3** (absence of regulations to support ESCO-based projects) is than **T4** (Bureaucracy constraints - bureaucracy required at different levels of government authority).

Sample of Semi-Constructive Interview Questions

1. Participant Name (Optional)

1. Gender

Mark only one oval.

☐

Male

☐

Female

2. Educational level*

Mark only one oval.

☐

Secondary

☐

Diploma

☐

Bachelor's

☐

Master's

☐

PhD

☐

Others: _____

3. What sector do you work in?

Mark only one oval

☐

Government

☐

Industrial

☐

Academia

☐

Other

4. What is your position in your organization?

Mark only one oval.

- ☐ Owner
- ☐ Decision-
- ☐ Maker Manager
- ☐ Consultant
- ☐ Engineer
- ☐ Researcher
- ☐ Other

5. How many years of experience do you have in the energy efficiency field?

Mark only one oval.

- ☐ 1-5
- ☐ 6-10
- ☐ 11-15
- ☐ 16-20
- ☐ 21-25
- ☐ More than 25

6. What is your experience level with Energy Services Companies(ESCOs)?
ESCO audits, designs, develops and implements energy efficiency
projects while guaranteeing energy-saving and assuming technical and
financial risks.

Mark only one oval.

- ☐ Not familiar with ESCO-based
- ☐ projects. Limited knowledge of
- ☐ ESCO-based projects
- ☐ Aware of ESCO-based projects but have no implementation
- ☐ experience
- ☐ Aware of ESCO-based projects but with limited ESCO
- ☐ implementation experience with good ESCO implementation
- ☐ experience

Strengths Factors

Compare the Strengths factors with each other by choosing the
rating scale

(From 1/9 to 9)

S1: Reduction of the electricity consumption and cost in buildings

S2: Contribution to achieving the national target in energy
efficiency (6% energy saving by 2025)

S3: Reduction of CO₂ emission and contribution to environmental
improvement

S4: Technical knowledge sharing between ESCO and employees in the
governmental building

1. S1 (Reduction of the electricity consumption and cost in buildings) is ----

----- than S2 (Contribution to achieving the national target in energy efficiency(6% energy saving by 2025)).

Mark only one oval.

- | | |
|-----------------------|------------------------------------|
| ☐ | 1/9 (Extremely less important) |
| ☐ | 1/7 (Very strongly less important) |
| ☐ | 1/5 (Strongly less important) |
| ☐ | 1/3 (Moderately less important) |
| ☐ | 1 (Equally important) |
| ☐ | 3 (Moderately more important) |
| ☐ | 5 (Strongly more important) |
| ☐ | 7 (Very strongly more important) |
| ☐ | 9 (Extremely more important) |

5. **S1 (Reduction of the electricity consumption and cost in buildings)** is ----- than S3 (Reduction of CO2 emission and contribution to environment improvement).

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

6. **S1 (Reduction of the electricity consumption and cost in buildings) is -----
- than S4 (Technical knowledge sharing between ESCO and employees in
the governmental building).**

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

7. **S2 (Contribution to achieving the national target in energy efficiency (6% energy saving by 2025) is than S3 (Reduction of CO2 emission and contribution to environment improvement)).**

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

8. **S2 (Contribution to achieving the national target in energy efficiency (6% energy saving by 2025) is ----- than S4 (Technical knowledge sharing between ESCO and employees in the governmental building)**

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

9. S3 (Reduction of CO2 emission and contribution to environment improvement) is..... than S4 (Technical knowledge sharing between ESCO and employees in the governmental building)

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

**Weakness
esFactors**

Compare the Weaknesses factors with each other by choosing the rate scale (from 1/9 to 9)

W1: High upfront capital costs and limit access to funds

W2: Business -as-usual mentality slowing the acknowledgment of the benefits related to ESCO based energy efficiency projects

W3: Lack of knowledge in technical and legal formalities for ESCO based energy efficiency projects e.g., EPC

1. W1 (High upfront capital costs and limited access to funds) is -----
than W2 (Business-as-usual mentality slowing the acknowledgement of the
benefits related to ESCO-based energy efficiency projects).

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

10. W1 (High upfront capital costs and limited access to funds) is ----- than W3 (Lack of knowledge in technical and legal formalities for ESCO-based energy efficiency projects, e.g., EPC).

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

11. W1 (High upfront capital costs and limited access to funds) is -----
than W4 (Operational interruption in the buildings).

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)4
- ☐ 5 (Strongly more important)6
- ☐ 7 (Very strongly more important)8
- ☐ 9 (Extremely more important)

12. W2 (Business-as-usual mentality slowing the acknowledgement of the benefits related to ESCO-based energy efficiency projects) is.....less than **W3 (Lack of knowledge in technical and legal formalities for ESCO-based energy efficiency projects, e.g., EPC).**

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)4
- ☐ 5 (Strongly more important)6
- ☐ 7 (Very strongly more important)8
- ☐ 9 (Extremely more important)

13. W2 (Business-as-usual mentality slowing the acknowledgement of the **benefits related to ESCO-based energy efficiency projects**) is -----
--- than W4 (Operational interruption in the buildings).

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

14. W3 (Lack of technical and legal formalities knowledge for ESCO-based energy efficiency projects, e.g., EPC) is than W4 (Operational interruption in the buildings).

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

Opportunities
Factors

Compare the Opportunities factors with each other by choosing the rate scale (from 1/9 to 9)

O1: Downturn in the economy encourages governmental institution to invest more in EE

O2: Banks capability to provide financial solutions for energy efficiency and green finance projects

O3: Huge building energy conservation potential

O4: Benefiting from lessons from other countries experience

1. O1 (Downturn in the economy encourages governmental institutions to invest more in EE) is ----- than O2 (Bank capability to provide financial solutions for energy efficiency and green finance projects).

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

4.4 **O1 (Downturn in the economy encourages governmental intuition to invest more in EE) is ----- than O3 (Huge building energy conservation to potential).**

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

4.5 **O1 (Downturn in the economy encourages governmental institutions to invest more in EE) is ----- than O4 (Benefiting from lessons from other countries' experience).**

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

- 1. O2 (Bank's capability to provide financial solutions for energy efficiency and green finance projects) is more than O3 (Huge building energy conservation potential).**

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

5. **O2 (the Bank's capability to provide financial solutions for energy efficiency and green finance projects) is more than O4 (Benefiting from lessons from other countries' experience).**

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

6. **O3 (Huge building energy conservation potential) is..... than O4**
(Benefiting from lessons from other countries' experience).

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

Threats
Factors

Compare the Threats factors with each other by choosing the rate scale (from 1/9 to 9)

T1: Lack of incentive from the government to reduce the Energy cost in buildings

T2: Energy expenses allocated and paid from the government budget

T3: Absence of regulations to support ESCO based-projects in governmental buildings

T4: Bureaucratic constraints - bureaucracy required at different levelsof government authority

2. T1 (Lack of incentive from the government to reduce the energy cost in buildings) is ----- than T2 (Energy expenses allocated and paid from the government budget).

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

4.6 T1 (Lack of incentive from the government to reduce the energy cost in buildings) is ----- than T3 (Absence of regulations to support ESCO to projects).

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

3. T1 (Lack of incentive from the government to reduce the energy cost in buildings) is ----- than T4 (Bureaucratic constraints – bureaucracy required at different levels of government authority).

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

4. T2 (Energy expenses allocated and paid from the government budget) is than T3 (Absence of regulations to support ESCO-based projects).

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

5. **T2 (Energy expenses allocated and paid from the government budget) is**
-----than T4 (Bureaucratic constraints - bureaucracy required at
different levels of government authority).

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

6. **T3 (Absence of regulations to support ESCO-based projects)** is than T4 (Bureaucratic constraints - bureaucracy required at different levels of government authority).

Mark only one oval.

- ☐ 1/9 (Extremely less important) 1/8
- ☐ 1/7 (Very strongly less important) 1/6
- ☐ 1/5 (Strongly less important) 1/4
- ☐ 1/3 (Moderately less important) 1/2
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important) 4
- ☐ 5 (Strongly more important) 6
- ☐ 7 (Very strongly more important) 8
- ☐ 9 (Extremely more important)

SWOT
Factors

Compare the SWOT factors with each other by choosing the rating scale(from 1/9 to 9)

Strength Factors

S1: Reduction of the electricity consumption and cost in buildings

S2: Contribution to achieving the national target in energy efficiency (6% energy saving by 2025)

S3: Reduction of CO2 emission and contribution to environmental improvement

S4: Technical knowledge sharing between ESCO and employees in the governmental buildings

Weakness Factors

W1: High upfront capital costs and limited access to funds

W2: Business-as-usual mentality slowing the acknowledgment of the benefits related to ESCO-based energy efficiency projects

W3: Lack of knowledge in technical and legal formalities for ESCO-based energy efficiency projects, e.g. EPC

W4: Operational interruption in the buildings

Opportunity Factors

O1: The downturn in the economy encourages governmental institutions to invest more in EE

O2: Banks' capability to provide financial solutions for energy efficiency and green finance projects

O3: Huge building energy conservation potential

O4: Benefiting from lessons from other countries experiences.

Threat Factors

T1: Lack of incentive from the government to reduce the energy cost in buildings

T2: Energy expenses allocated and paid from the government budget

T3: Absence of regulations to support ESCO based-projects in governmental buildings

T4: Bureaucratic constraints - bureaucracy required at different levels of government authority

1. Strength factors are than weakness factors

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more import

2. Strength factors are than opportunity factors

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

3. Strength factors are than threat factors

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)
- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

5. Weakness factors are then threat factors

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

6. Opportunity factors are then threat factors

Mark only one oval.

- ☐ 1/9 (Extremely less important)
- ☐ 1/7 (Very strongly less important)
- ☐ 1/5 (Strongly less important)
- ☐ 1/3 (Moderately less important)
- ☐ 1 (Equally important)
- ☐ 3 (Moderately more important)
- ☐ 5 (Strongly more important)
- ☐ 7 (Very strongly more important)
- ☐ 9 (Extremely more important)

Appendix 3

1. Which of the SWOT sub-factors is more important when comparing the four strength (S) sub-factors?

Sub-factor	Weight								Same	Weight								Sub-factor
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
S1																		S2
S1																		S3
S1																		S4
S2																		S3
S2																		S4
S3																		S4

Table 4.3 Pair-Comparison Questionnaires in Strengths (S)

2. Which of the SWOT sub-factors do you think is more important when comparing the four sub-factors of the Weaknesses (W) with each other?

Sub-factor	Weight								Same	Weight								Sub-factor
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
W1																		W2
W1																		W3
W1																		W4
W2																		W3
W2																		W4
W3																		W4

Table 4.4 Pair-Comparison Questionnaires in Weaknesses (W)

3. Which of the SWOT sub-factors is more important when comparing the four sub-factors of the Opportunities (O) with each other?																		
Sub-factor	Weight								Same	Weight								Sub-factor
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
O1																		O2
O1																		O3
O1																		O4
O2																		O3
O2																		O4
O3																		O4

Table 4.5 Pair-Comparison Questionnaires in Opportunities (O)

3. Which of the SWOT sub-factors is more important when comparing the four sub-factors of the Threats (T) with each other?																		
Sub-factor	Weight								Same	Weight								Sub-factor
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
T1																		T2
T1																		T3
T1																		T4
T2																		T3
T2																		T4
T3																		T4

Table 4.6 Pair-Comparison Questionnaires in Threats (T)

3. Which of the SWOT factors is more important when comparing the other ones in SWOT?

Sub-factor	Weight								Same	Weight								Sub-factor
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
S																		W
S																		O
S																		T
W																		O
W																		T
O																		T

Table 4.7 Pair-Comparison Questionnaires for SWOT Factors

Appendix 4

The scale of 1/9: 9 (Saaty,1999) was converted into three values (Reference) to be processed in both models. In Excel Microsoft Format

Expert 1	S			W			O			T		
S	1	1	1	1	1	1	1	1	1	1/7	1/6	1/5
W	1	1	1	1	1	1	1	1	1	1/6	1/5	1/4
O	1	1	1	1	1	1	1	1	1	1	1	1
T	7	6	5	6	5	1	1	1	1	1	1	1

Expert 2	S			W			O			T		
S	1	1	1	1	1	1	1/4	1/3	1/2	1/4	1/3	1/2
W	1	1	1	1	1	1	1/4	1/3	1/2	1	1	1
O	4	3	2	4	3	2	1	1	1	2	3	4
T	4	3	2	1	1	1/4	1/2	1/3	1/4	1	1	1

Expert 3	S			W			O			T		
S	1	1	1	2	3	4	1	1	1	9	9	9
W	1/2	1/3	1/4	1	1	1	1/9	1/9	1/9	9	9	9
O	1	1	1	9	9	9	1	1	1	1	1	1
T	1/9	1/9	1/9	1/9	1/9	1	1	1	1	1	1	1

Expert 4	S			W			O			T		
S	1	1	1	1	2	3	1	2	3	1	2	3
W	1	1/2	1/3	1	1	1	1	2	3	1	2	3
O	1	1/2	1/3	1	1/2	1/3	1	1	1	1	2	3
T	1	1/2	1/3	1	1/2	1/3	1	1/2	1/3	1	1	1

Expert 5	S			W			O			T		
S	1	1	1	1	2	3	2	3	4	2	3	4
W	1	1/2	1/3	1	1	1	1/5	1/4	1/3	2	3	4
O	1/2	1/3	1/4	5	4	3	1	1	1	1	1	1
T	1/2	1/3	1/4	1/2	1/3	1	1	1	1	1	1	1

Expert 6	S			W			O			T		
S	1	1	1	1	1	1	1	1	1	1	2	3
W	1	1	1	1	1	1	1/3	1/2	1	1/3	1/2	1
O	1	1	1	3	2	1	1	1	1	1	1	1
T	1	1/2	1/3	3	2	1	1	1	1	1	1	1

Expert 7	S			W			O			T		
S	1	1	1	6	7	8	1	1	1	1/6	1/5	1/4
W	1/6	1/7	1/8	1	1	1	1/6	1/5	1/4	1/7	1/6	1/5
O	1	1	1	6	5	4	1	1	1	3	4	5
T	6	5	4	7	6	1/5	1/3	1/4	1/5	1	1	1

Expert 8	S			W			O			T		
S	1	1	1	1	1	1	1	1	1	1	2	3
W	1	1	1	1	1	1	1	1	1	1/3	1/2	1
O	1	1	1	1	1	1	1	1	1	1	2	3
T	1	1/2	1/3	3	2	1/3	1	1/2	1/3	1	1	1

Expert 9	S			W			O			T		
S	1	1	1	9	9	9	1	1	1	1/4	1/3	1/2
W	1/9	1/9	1/9	1	1	1	1/5	1/4	1/3	1	1	1
O	1	1	1	5	4	3	1	1	1	1	2	3
T	4	3	2	1	1	1/3	1	1/2	1/3	1	1	1

Expert 10	S			W			O			T		
S	1	1	1	1	1	1	1	1	1	1	1	1
W	1	1	1	1	1	1	1	1	1	1	1	1
O	1	1	1	1	1	1	1	1	1	1	1	1
T	1	1	1	1	1	1	1	1	1	1	1	1

Expert 11	S			W			O			T		
S	1	1	1	9	9	9	1	1	1	9	9	9
W	1/9	1/9	1/9	1	1	1	1/8	1/7	1/6	1/4	1/3	1/2
O	1	1	1	8	7	6	1	1	1	9	9	9
T	1/9	1/9	1/9	4	3	1/9	1/9	1/9	1/9	1	1	1

Expert 12	S			W			O			T		
S	1	1	1	1	1	1	3	4	5	3	4	5
W	1	1	1	1	1	1	1	1	1	2	3	4
O	1/3	1/4	1/5	1	1	1	1	1	1	1/4	1/3	1/2
T	1/3	1/4	1/5	1/2	1/3	2	4	3	2	1	1	1

Expert 13	S			W			O			T		
S	1	1	1	1	1	1	1	1	1	1	1	1
W	1	1	1	1	1	1	1	1	1	1	1	1
O	1	1	1	1	1	1	1	1	1	1	1	1
T	1	1	1	1	1	1	1	1	1	1	1	1

Expert 14	S			W			O			T		
S	1	1	1	6	7	8	9	9	9	2	3	4
W	1/6	1/7	1/8	1	1	1	1	1	1	1	1	1
O	1/9	1/9	1/9	1	1	1	1	1	1	2	3	4
T	1/2	1/3	1/4	1	1	1/4	1/2	1/3	1/4	1	1	1

Expert 15	S			W			O			T		
S	1	1	1	1	1	1	1	1	1	2	3	4
W	1	1	1	1	1	1	1/6	1/5	1/4	1/4	1/3	1/2
O	1	1	1	6	5	4	1	1	1	2	3	4
T	1/2	1/3	1/4	4	3	1/4	1/2	1/3	1/4	1	1	1

Expert 16	S			W			O			T		
S	1	1	1	4	5	6	1/6	1/5	1/4	1/8	1/7	1/6
W	1/4	1/5	1/6	1	1	1	1/4	1/3	1/2	1	1	1
O	6	5	4	4	3	2	1	1	1	6	7	8
T	8	7	6	1	1	1/8	1/6	1/7	1/8	1	1	1

Expert 17	S			W			O			T		
S	1	1	1	4	5	6	4	5	6	4	5	6
W	1/4	1/5	1/6	1	1	1	4	5	6	4	5	6
O	1/4	1/5	1/6	1/4	1/5	1/6	1	1	1	4	5	6
T	1/4	1/5	1/6	1/4	1/5	1/6	1/4	1/5	1/6	1	1	1

Expert 18	S			W			O			T		
S	1	1	1	1/4	1/3	1/2	1/3	1/2	1	1	1	1
W	4	3	2	1	1	1	2	3	4	2	3	4
O	3	2	1	1/2	1/3	1/4	1	1	1	1	1	1
T	1	1	1	1/2	1/3	1	1	1	1	1	1	1

Expert 19	S			W			O			T		
S	1	1	1	6	7	8	1	1	1	1/4	1/3	1/2
W	1/6	1/7	1/8	1	1	1	1/6	1/5	1/4	1/6	1/5	1/4
O	1	1	1	6	5	4	1	1	1	3	4	5
T	4	3	2	6	5	1/5	1/3	1/4	1/5	1	1	1

Expert 20	S			W			O			T		
S	1	1	1	1	1	1	1	1	1	1	1	1
W	1	1	1	1	1	1	1	1	1	1	1	1
O	1	1	1	1	1	1	1	1	1	1	1	1
T	1	1	1	1	1	1	1	1	1	1	1	1

Expert 21	S			W			O			T		
S	1	1	1	1	1	1	1	1	1	1/9	1/8	1/7
W	1	1	1	1	1	1	6	7	8	1	1	1
O	1	1	1	1/6	1/7	1/8	1	1	1	1/9	1/8	1/7
T	9	8	7	1	1	7	9	8	7	1	1	1

Expert 22	S			W			O			T		
S	1	1	1	4	5	6	4	5	6	3	4	5
W	1/4	1/5	1/6	1	1	1	1/6	1/5	1/4	1	1	1
O	1/4	1/5	1/6	6	5	4	1	1	1	4	5	6
T	1/3	1/4	1/5	1	1	1/6	1/4	1/5	1/6	1	1	1

Expert 23	S			W			O			T		
S	1	1	1	1/5	1/4	1/3	1/3	1/2	1	1/4	1/3	1/2
W	5	4	3	1	1	1	2	3	4	2	3	4
O	3	2	1	1/2	1/3	1/4	1	1	1	1	1	1
T	4	3	2	1/2	1/3	1/4	1	1	1	1	1	1

Expert24	S			W			O			T		
S	1	1	1	6	7	8	2	3	4	2	3	4
W	1/6	1/7	1/8	1	1	1	1/4	1/3	1/2	2	3	4
O	1/2	1/3	1/4	4	3	2	1	1	1	2	3	4
T	1/2	1/3	1/4	1/2	1/3	1/4	1/2	1/3	1/4	1	1	1

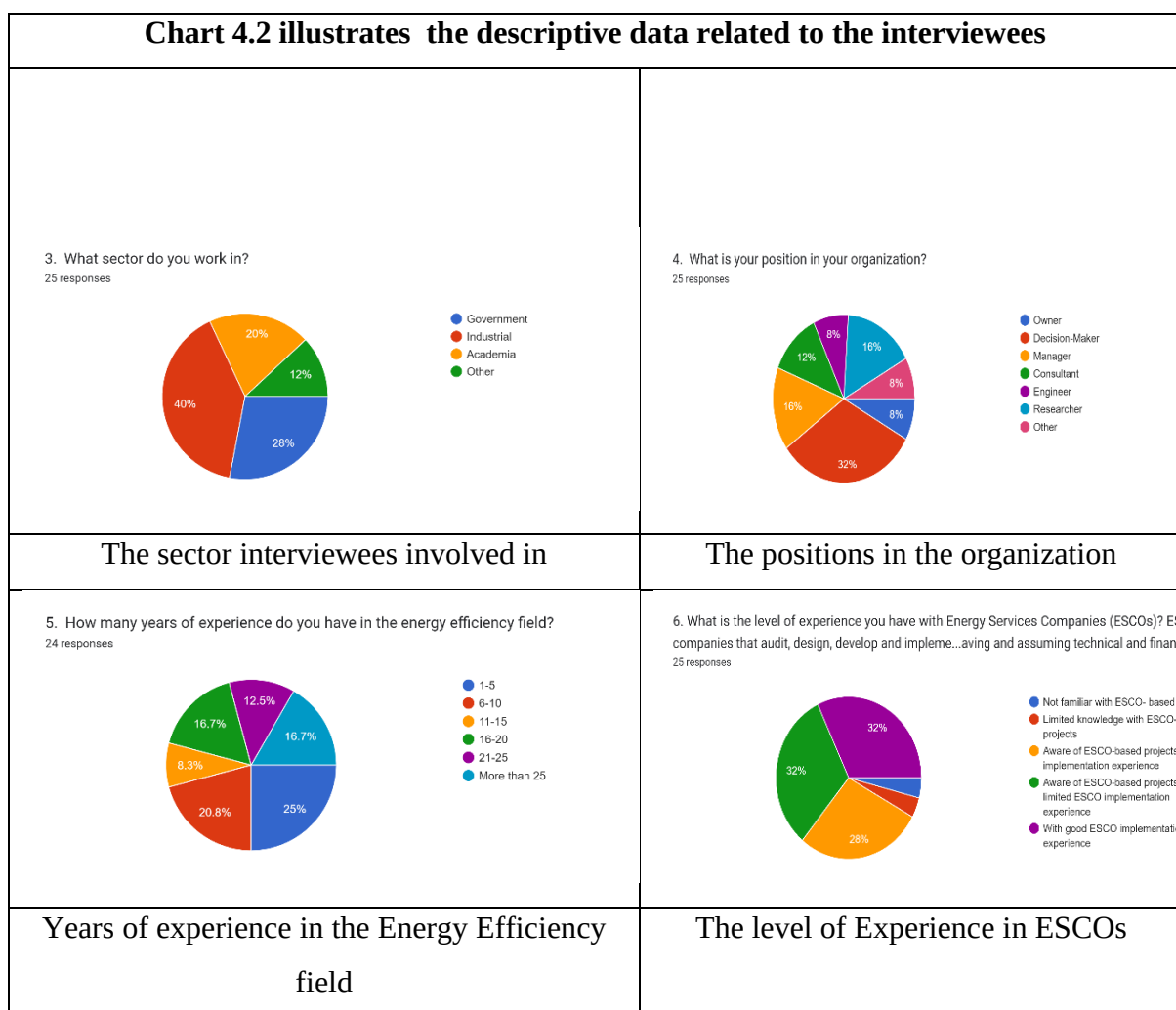
Expert25	S			W			O			T		
S	1	1	1	9	9	9	1	1	1	4	5	6
W	1/9	1/9	1/9	1	1	1	1/6	1/5	1/4	1	1	1
O	1	1	1	6	5	4	1	1	1	6	7	8
T	1/4	1/5	1/6	1	1	1/8	1/6	1/7	1/8	1	1	1

Appendix 5: Outcomes from the Descriptive Data

The tables below show a pair-wise comparison among the SWOT factors' Strengths (S), weaknesses (W), Opportunities (O), and Threats (T) factors.

Gender		Education Level		Sector			
M	F	Low	High	Government	Industrial	Academia	Other
88%	12%	1%	99%	40%	28%	20%	12%
Total:100%		Total:100%		Total: 100%			

Table 4.5 Analysis Outcomes from Descriptive Data in Percentage



	Gender	Educational level	Sector	Position in Organization	Years of experience in the EE field	Level of Experience in ESCO
1	Male	PhD	Academia	Researcher	1-5	Aware of ESCO-based projects but have no implementation experience
2	Male	PhD	Academia	Researcher	More than 25	Aware of ESCO-based projects but with limited ESCO implementation experience
3	Male	PhD	Academia	Other	6-10	Limited knowledge of ESCO-based projects
4	Male	PhD	Academia	Researcher	16-20	Aware of ESCO-based projects but have no implementation experience
5	Female	PhD	Academia	Researcher	16-20	With good ESCO implementation experience
6	Male	Bachelor's	Government	Consultant	More than 25	With good ESCO implementation experience
7	Male	PhD	Government	Consultant	More than 25	Aware of ESCO-based projects but with limited ESCO implementation experience
8	Female	Bachelor's	Government	Other	1-5	Not familiar with ESCO- based projects*
9	Male	Master's	Government	Decision-Maker	6-10	With good ESCO implementation experience
10	Male	Master's	Government	Manager	21-25	With good ESCO implementation experience
11	Male	Master's	Government	Engineer	16-20	Aware of ESCO-based projects but have no implementation experience
12	Male	Master's	Government	Decision-Maker	21-25	Aware of ESCO-based projects but with limited ESCO implementation experience
13	Male	Bachelor's	Industrial	Engineer	11-15	Aware of ESCO-based projects but with limited ESCO implementation experience
14	Male	Master's	Industrial	Owner	11-15	With good ESCO implementation experience
15	Male	Bachelor's	Industrial	Consultant	More than 25	Aware of ESCO-based projects but have no implementation experience

16	Male	Bachelor's	Industrial	Decision-Maker	6-10	Aware of ESCO-based projects but with limited ESCO implementation experience
17	Male	Bachelor's	Industrial	Manager	6-10	With good ESCO implementation experience
18	Male	Advanced Professional Certificates	Industrial	Decision-Maker	16-20	With good ESCO implementation experience
19	Male	Master's	Industrial	Manager	1-5	With good ESCO implementation experience
20	Male	Bachelor's	Industrial	Decision-Maker	1-5	Aware of ESCO-based projects but with limited ESCO implementation experience
21	Male	Bachelor's	Industrial	Decision-Maker	1-5	Aware of ESCO-based projects but have no implementation experience
22	Male	Bachelor's	Industrial	Manager	6-10	Aware of ESCO-based projects but with limited ESCO implementation experience
23	Male	PhD	Other	Owner	11-15	Aware of ESCO-based projects but have no implementation experience
24	Female	Master's	Other	Decision-Maker	1-5	Aware of ESCO-based projects but have no implementation experience
25	Male	Diploma	Other	Decision-Maker	21-25	Aware of ESCO-based projects but with limited ESCO implementation experience

Table 4.6 Descriptive Data Collected from the Semi-Structured Interviews

* One interviewee was unfamiliar with the ESCO but was heavily involved in the polite projects conducted in the four governmental facilities.

	S1 is---- than S2	S1 is ----- than S3	S1 is-----than S4	S2 is-----than S3	S2 is-----than S4	S3 is----than S4
1	7	1	8	1/8	1	8
2	1/6	1/5	1/5	1/5	1/6	1/5
3	1	1/3	1/2	1	1/2	1/3
4	1	1	1	1	1	1
5	1	1	1	1/3	9	2
6	1	1	5	1/5	5	7
7	1	1	1	1/7	1/5	1/3

8	7	4	5	3	1/3	1
9	1	1	3	1	9	9
10	1	1	1	1	3	4
11	1	1	1	1	1	1
12	1	1	9	1	9	9
13	1	1	1	1/9	1	1
14	3	5	1	4	1	1
15	9	9	9	3	1	1/3
16	9	7	9	1/5	3	9
17	1	1	5	1/5	5	5
18	4	1	5	1	2	7
19	5	1	7	1/3	5	7
20	1	3	1)	3	3	3
21	1/3	1/6	2	1/3	3	6
22	1/3	1/5	1/3	1	3	5
23	1	1	3	5	3	5
24	1	1	1	1	3	3
25	1	1	1	1	1	1

Table 4.6 pair-wise comparison of the Strengths (S) Factors

	W1 is ---than W2	W1 is ---than W3	W1 is---than W4	W2 is--- than W3	W2 is--- than W4	W3 is---than W4
1	1/9	1/8	1	1	1	1
2	1/2	1/2	1/2	1/2	1/3	1/3
3	1/2	1	3	1/2	5	3
4	2	3	1	1/2	4	1
5	9	7	1	1	3	1
6	5	5	7	1/5	1/5	7
7	1/7	1/9	7	1/9	9	9
8	1	1/5	2	4	1/5	1/4
9	1/3	1/3	1	5	1	5
10	5	1	1	1/3	1/3	1

11	5	5	1/3	1/5	1/9	1/5
12	1**	1/5	1/7	1	1/3	3
13	1/3	1/3	1/5	1/3	5	3
14	3	3	5	1	6	5
15	3	1	1/5	3	3	1/3
16	9	9	9)	1/7	5	1/7
17	1/5	5	7	1/7	1/7	1/7
18	5	3	5	1/3	1/3	1
19	5	1/5	1/7	1/8	9	6
20	5	1	7	1/3	3	5
21	1/5	1/5	1/4	5	7	6
22	5	3	1/4	1/7	1/7	1/3
23	5	1	5	3	4	6
24	1	1	1	1/3	1/4	1
25	1	1/6	1/8	3	1/9	1

Table 4.7 Pair-wise Comparison of the Weakness (W) Factors

* One of the interviewees missed rating the W1:W2, and we added 1 to equalize the weight among both Was without affecting the overall comparison.

	O1 is---than O2	O1 is ---than O3	O1 is---- than O4	O2 is---- than O3	O2 is----than O4	O3 is----- than O4
1	1	1/9	8	1/8	8	8
2	1/4	1/4	1/4	1/4	1/4	1/4
3	1	3	1	1	1/3	1/2
4	1	1	5	4	5	5
5	5	1	5	1	7	7
6	3	5	5	5	7	7
7	1/5	1/8	1/4	1/3	1/4	7
8	3	7	1	1/3	1/4	1
9	5	5	3	1	3	1
10	4	5	4	1/5	1/3	5
11	1	1	1	1	1	1

12	5	1	1	5	3	5
13	1	1	5	1	3	3
14	1/3	1/2	1	1	1	2
15	5	5	5	3	5	3
16	8	8	7	1	7	7
17	1/7	1/3	1/5	7	5	5
18	1/2	5	1/4	5	3	5
19	1/7	1/4	1/5	1	6	7
20	1/5	1/3	1	3	5	3
21	4	3	3	1/4	1/4	1/2
22	5	3	1	7	1/9	1/5
23	1/3	3	4	9	9	1/2
24	1	1	1	1	1	1
25	7	1	1	1/5	1/5	1

Table 4.8 Pair-wise Comparison of the Opportunities (O) Factors

	T1 is---- than T2	T1 is ---- than T3	T1 is----- than T4	T2 is---- than T3	T2 is----than T4	T3 is--- than T4
1	8	1	1/8	1	1	1
2	1	1	1	1	1	1
3	3	3	1	2	1	1/2
4	4	1	1	3	1	1
5	9	1/3	1/9	1/5	1/9	1
6	1/7	1	1/3	3	1	7
7	1/4	1/9	1/9	1/5	1/4	1/2
8	1	5	1/2	4	4	1/2
9	1	1	1	1	1	1/5
10	3	1/4	1/4	1/3	1/3	4
11	5	1/5	5	1/9	1/5	5
12	1	3	1/7	5	3	9
13	9	1/5	9	1/3	1/3	1/5
14	5	5	1	1/5	1/5	3

15	5	1/3	1/3	5	5	1/5
16	1/5	7	7	7	7	1
17	7	1	5	1/7	1/7	5
18	1/3	1/3	1/3	1	1/3	7
19	5	1/5	1/8	1/6	1/4	7
20	6	2	4	1/4	4	1/4
21	1	1/3	1/5	1/3	1/5	1/5
22	9	1/5	1/4	1/5	1/3	4
23	8	7	6	1/3	1/4	1
24	5	1	1	1/3	1/3	1
25	7	1	1	1/7	1/8	1

Table 4.8 Pair-wise Comparison of the Threats (T) Factors

الملخص

الغرض من الدراسة: قطاع البناء هو قطاع حيوي في الاقتصاد، يستهلك قدرًا كبيرًا من الطاقة ويساهم في التلوث البيئي. في عام 2018، أنفق العالم 138 مليار دولار أمريكي على كفاءة استخدام الطاقة في المباني، لكي يقلل من كثافة استخدام الطاقة بأكثر من 3٪ سنويًا (Forrester & Reames 2020). لذلك تقدم شركات خدمات الطاقة (ESCO) حلولاً لتحقيق الكفاءة في المباني بمقاييس عالية. ونظرًا لأن مملكة البحرين وضعت أهداف مهمة لإدارة المباني ورفع كفاءة استهلاك الطاقة في المباني والمنشآت كجزء مهم من استدامتها، فإن البحث يهدف إلى خدمة هذا الهدف الوطني. وتكشف هذه الدراسة العوامل التي تؤثر على تنفيذ مشاريع ESCO والمساهمة في تحقيق أهداف الحكومة. كما أكدت الدراسة على دور متخذي القرار في التفكير في إستراتيجيات مناسبة تعتمد على العوامل المهمة لتنفيذ مشاريع رفع كفاءة الطاقة و الطاقة المستدامة بما يناسب الأهداف التي تطمح الحكومة في تحقيقها والتي صدق عليها صاحب الجلالة الملك حمد بن عيسى بن سلمان آل خليفة ملك البلاد على الرؤية الاقتصادية 2030 لمملكة البحرين.

المنهج والتصميم: تم استخدام أسلوب البحث الكمي والنوعي للإجابة على الأسئلة المطروحة في الدراسة. تأتي البيانات المستخدمة في الدراسة من استبيانات محددة مسبقًا تتناول فوائد وتحديات تنفيذ مشروع ESCO بناءً على الأهداف الحكومية. تم جمع البيانات الأولية البحثية من خلال الاستبيانات شبه المنظمة والاستطلاعات عبر الإنترنت بناءً على مقياس (تقييم من 1/9 - 9 نقاط) من خلال تصميم الاستبيان. و كان حجم العينة 25 خبيراً في مشروع كفاءة الطاقة من القطاعات الحكومية والصناعية والقطاع الخاص والأوساط الأكاديمية. تم اختيار العينة بناءً على مشاركتهم في مشاريع ESCO وكفاءة الطاقة في المباني.. وتم استخدام العديد من الأساليب الرياضية والتحليلية لتوفير تقييم شامل للبيانات، مثل Fuzzy AHP و Fuzzy TOPSIS و Sensitive Analysis و Fuzzy TOPSIS والفرضيات ودمجها مع تقنيات تحليل SWOT لإيجاد أفضل العوامل التي تقوم عليها الاستراتيجيات لتنفيذ مشاريع ESCO في المرافق الحكومية.

النتيجة: كشفت الدراسة أن نقاط القوة في هذه المشاريع هي أهم العوامل التي يجب مراعاتها عند اختيار استراتيجيات مناسبة. وكشفت الدراسة أيضاً عن أربع استراتيجيات مهمة تساعد على نجاح تلك المشاريع في المرافق و المباني الحكومية لمملكة البحرين.