Management and Structural Aspects of Creation of Sustainable Smart Cities

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ABSTRACT

In light of the exponential rate at which urbanization is accelerating, the smart city concept has gained more attraction worldwide. Smart cities use the latest technologies, sensors, and various monitoring tools in their infrastructure and smart buildings and adopt green sustainable practices in all of their sectors to improve their operational efficiency, sustainability, safety, and disaster resilience while providing the best access to different services and enhancing the quality of life of their citizens. To some extent, the smart city movement has been limited to developed countries, primarily due to several obstacles that may prevent developing countries from implementing smart city initiatives successfully.

The research in smart cities initiative, especially in the field of civil engineering is relatively new and is developing rapidly and continuously and is expanding to include more areas in construction and building techniques.

The aim of this study is to identify the key factors affecting smart cities from sustainability and disaster management aspects and propose some strategies for improving the more effective factors. For the identification of more important factors a Strengths-Weaknesses-Opportunities-Threats (SWOT) analysis is used. First, a questionnaire survey technique is used to determine the relative importance of these factors. Then, a TOWS matrix is conducted to find the relationship between the SWOT's external and internal factors and draw strategies accordingly.

Specifically, this thesis aims to draw strategies for developing countries to take advantage of smart cities' strengths and opportunities while minimizing their weaknesses and threats in two areas of sustainability and disaster management.

Keywords: Smart City, Civil Engineering, Sustainability, Disaster Resilience, SWOT Analysis, TOWS, Information and Communication Technologies, Internet of Things.

ÖZ

Kentsel dönüşümün hızla artan üstel oranında, akıllı şehir kavramı küresel düzeyde daha fazla ilgi çekmeye başlamıştır. Akıllı şehirler, altyapılarında ve akıllı binalarında en son teknolojileri, sensörleri ve çeşitli izleme araçlarını kullanırken, tüm sektörlerinde yeşil sürdürülebilir uygulamaları benimsemekte ve işletme verimliliği, sürdürülebilirlik, güvenlik ve felaket direncini artırmayı amaçlamaktadır. Aynı zamanda vatandaşlarına farklı hizmetlere en iyi erişimi sağlayarak yaşam kalitesini artırmaktadır. Akıllı şehir hareketi, belirli engeller nedeniyle gelişmekte olan ülkelerde uygulama zorlukları yaşandığı için belirli ölçüde gelişmiş ülkelerle sınırlı kalmıştır.

Özellikle inşaat mühendisliği alanındaki akıllı şehir girişimi araştırmaları oldukça yeni ve hızlı bir şekilde gelişmektedir ve sürekli olarak genişlemektedir; inşaat ve yapı teknikleri gibi daha fazla alanı içermektedir.

Bu çalışmanın amacı, akıllı şehirleri sürdürülebilirlik ve felaket yönetimi açılarından etkileyen temel faktörleri belirlemek ve daha etkili faktörleri geliştirmek için bazı stratejiler önermektir. Daha önemli faktörlerin belirlenmesi için Güçlü Yönler-Zayıf Yönler-Fırsatlar-Tehditler (SWOT) analizi kullanılmıştır. İlk olarak, bu faktörlerin göreceli önemini belirlemek için anket tekniği kullanılmıştır. Ardından, SWOT'un dışsal ve içsel faktörleri arasındaki ilişkiyi bulmak ve buna göre stratejiler çizmek için bir TOWS matrisi uygulanmıştır.

Sonuç olarak, bu tez gelişmekte olan ülkelerin sürdürülebilirlik ve felaket yönetimi alanlarındaki zayıf yönlerini ve tehditlerini en aza indirirken akıllı şehirlerin güçlü yönlerinden ve fırsatlarından faydalanmalarını sağlayacak stratejiler çizmeyi amaçlamaktadır.

Anahtar Kelimeler: Akıllı Şehir, İnşaat Mühendisliği, Sürdürülebilirlik, Afete Dayanıklılık, SWOT Analizi, TOWS, Bilgi ve İletişim Teknolojileri, Nesnelerin İnternet.

To my father, my dearest person in the world

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AI	Artificial Intelligence
ICT	Information and Communications Technology
IoT	The Internet of Things

Chapter 1

INTRODUCTION

1.1 Background

Nowadays, the majority of people on Earth live in cities, and this trend of urbanization is expected to continue on all continents, with estimates predicting that 70% of people on some continents will live in cities by 2050, according to the United Nations (2017).

Consequently, a new development strategy is needed to meet the rising demands on services and resources in cities and to provide citizens with quick access to services and resources and a better quality of life. As a relatively new trend in civil engineering and city planning and development, smart cities present a promising vision to encounter the challenges posed by increased urbanization. In smart cities, technology can be used to solve issues related to infrastructure, increasing demands, public safety, and resilience to disasters (Berglund et al., 2020).

Tompson (2017) stated that the concept of a "smart city" has been considered as a solution to address issues that cities face, including rapid urbanization, significant demographic shifts, climatic and environmental changes, economic restructuring and reforms, and disruptions brought on by digital technology.

Civil engineers are extremely important for smart city development because they design, build, and maintain the infrastructure necessary for effective and sustainable urban growth. They assist in creating a more advanced and sustainable urban environment for the future by utilizing advanced information and communication technologies and advanced management aid software, smart analysis systems, and adopting smart infrastructure and buildings, in addition to integrating sources of clean energy and smart energy grids, and green building practices. By doing so, they assist in improving connectivity, optimizing resource usage, and promoting environmental responsibility.

In the case of developing countries more people are moving to cities and urbanization is on the rise. Smart city initiatives can be effective in addressing a variety of urbanization-related issues while striving for sustainability and a better life for city citizens. Smart city technologies offer the chance for developing countries to cope with urbanization's impacts (Vu & Hartley, 2022). But there are several obstacles in the way of smart city development in developing countries.

Datta (2015), highlighted how the creation of smart cities might be restricted in many developing countries by unconducive conditions. In comparison to those in developed countries, smart cities in developing countries were established relatively late and have inadequate infrastructure, resulting in policy instability, Chen (2022). In research conducted by (Nkwunonwo et al., 2023), they reviewed some of the challenges that many developing countries may face while looking into smart city development. They highlighted some of these challenges, such as: Firstly, development knowledge, critical issues, and implementation strategies regarding smart cities lacking a chronological record. Secondly, in discussing smart cities, the literature mostly relies on standard examples and similar narratives. Thirdly, there is a lack of comprehensive research on smart city development, and a lack of comparative studies showing how different countries around the world are developing smart cities, which is also similar to the finding of a study conducted by (Reis et al., 2022), which suggested that smart cities research has been narrow and excessively concentrated on megacities in developed nations. Hence, future studies should be more comprehensive and focus on developing countries' smaller cities. and finally, the engagement of different stakeholders in the creation of smart cities is limited to nonexistent.

1.2 Aim of the Study

This study aims to examine two key aspects of smart cities in developing countries: sustainability and disaster management. Study objectives include analyzing each of these aspects from a SWOT perspective, which helps identify the strengths, weaknesses, opportunities, and threats, followed by a TOWS perspective to link the internal and external factors. Bringing these insights together, this study proposes strategies for developing and implementing smart cities in developing countries in a way that addresses challenges and capitalizes on potential advantages to create sustainable and resilient urban environments.

1.3 Scope and Limitations

The scope of this study includes management and structural aspects regarding two aspects of smart cities, namely: sustainability and disaster resilience, with specific attention to developing countries. A questionnaire survey is distributed among civil engineering academics from different institutes in developing countries to gain comprehensive results for the study.

The study limitations can be summarized as follows:

1) In the questionnaire survey, only civil engineering academics were surveyed; therefore, stakeholders' and ordinary citizens' perspectives were not included.

2) The data collection limitation is highlighted by the absence of data points in some regions due to the challenges of reaching expertise in some developing countries as well as the lack of response from them. Therefore, the research is based on insights from academics from a sub-collection of developing countries.

1.4 Research Methodology

An intensive review of the literature is used to draw a SWOT matrix showing strengths, weaknesses, opportunities, and threats related to smart city implementation for the two aspects of the study separately. Then a TOWS matrix is conducted to connect internal factors (strengths, weaknesses) with external factors (opportunities, threats) to develop strategies. A questionnaire survey technique is used to determine the level of importance of the SWOT factors from the point of view of academics and Ph.D. students in civil engineering. After collecting the data from the questionnaire survey, the data were analyzed with the use of software such as SPSS 26.0 and Microsoft Excel.

Cronbach's alpha is used to measure the reliability of the variables, and the mean of the factors is calculated to determine the relative importance and rank of the factors. Relative priority and the total prioritization of the factors are calculated and then used to calculate the total weight and the rank of the TOWS strategies.

1.5 Overview of the Thesis

This thesis consists of five chapters. Chapter 1 presents an introduction about the study including a background of smart cities in developing countries, the aim of the study, the scope and limitations, the research methodology, and an overview of the Thesis.

Chapter 2 presents a comprehensive literature review containing a state of the art about the historical evolution of Smart Cities, the role of civil engineering in smart cities, and a review of the core technologies used in smart cities.

Chapter 3 presents the research methodology of the study including information about the questionnaire and the methods used to analyze the results.

Chapter 4 presents the results of the study and its analysis and discussion.

Chapter 5 presents the summary of the study and conclusions and recommendations for future studies.

Chapter 2

LITERATURE REVIEW

2.1 State of the Art: Historical Evolution of Smart Cities

In recent decades, cities have faced increasing pressure from investors, tourism, skilled labor, and international events due to significant economic and technical changes Begg (1999). Therefore, finding new effective strategies for building and managing cities has become a priority for governments in the majority of countries.

The creation of cities with urban environments that give people the best and quickest access to all services has been crucial to economic and societal success due to the significant increase in urbanization over the past decade. From this, the necessity to research and develop long-term sustainable cities arose, giving rise to the concept of sustainable smart cities.

Although research into "smart cities" has been going on since the 1990s, the past decade has seen a rapid increase in the number of disciplines involved in this field. This growth is due to the increasing interest in cities creation, urban life, and the increasing technology use in both the private and public sectors. The creation of Smart cities is one of the most recent development trends in civil engineering and construction techniques.

NCP (1992) published a significant document outlining its strategic vision for Singapore's IT development moving forward. Singapore was described as an intelligent island that was aiming to integrate IT into various aspects like infrastructure to improve the quality of life for its residents and make it one of the most developed and leading countries in the region.

Andrew & Jonathan (1994) described a “smart city” as a concept that outlines the applications and infrastructure needed to create an electronic platform for the delivery of digital urban services.

Mahizhnan (1999) studied the case of Singapore, one of the first nations to start researching and attempting to implement the smart city concept.

After the year 2000, several studies on smart cities were published. Buchmann (2007) discussed the future of the applications for Event-based Computing in Smart Cities, including the use of basic sensor readings, a large number of sensors, and mobile devices, as well as their integration with the infrastructure. (Washburn et al., 2009) discussed smart computing technologies and how they can be planned, implemented, and delivered to make cities smart, as well as the operational benefits that smart cities can provide by implying these technologies, such as enabled sensors, Internet Protocol (IP), supervisory control and data acquisition (SCADA), and the role of smart utility infrastructure in increasing sustainability by reducing waste and improving energy efficiency. Additionally, they discussed the potential for incorporating smart technology into existing cities' vital infrastructure to make it smart.

(Al-Hader et al., 2009) described a digital or smart city as one that uses communication and telecom IP/internet networks and other smart applications to improve its infrastructure. A smart city has features such as smart interfaces, building management systems, and database resources, which can help make it more efficient and easier to manage. They then proposed the stages that must be implemented to create a smart city, beginning with planning and infrastructure and progressing to implementing databases and information management to achieve the goal of providing the essential instructions to optimize operations and maintenance, lower operating costs, provide improved energy management capabilities, and allow scalability and freedom for the future.

Until 2010, the number of smart city studies reported in the literature was low. Since the beginning of 2010 and the start of evolving trends and adaptations of the smart city concept in many parts of the world, the number of academic papers and publications on the issue has nearly doubled. Barcelona was one of the first smart city references mentioned. In 2011 in order to improve the operation and management of the city as a whole, boost economic growth, and improve citizen well-being, the city concentrated on experimenting with new technologies transformation through the adoption of new, innovative technologies Ferrer (2017).

Giffinger & Gudrun (2010) discussed different strategies to approach the "smart city" concept, with a focus on the smart characteristics that are already being used in some cities, some advantages and disadvantages of this approach were also covered. Chen (2010) Stated that in order to enhance the electrical, transportation, and other logistical operations that support daily life and raise everyone's quality of life, so-called "smart cities" will make better use of the communications and sensor capabilities found in the city's infrastructure. He also pointed out that while the engineering aspects of smart cities might be more challenging, on the other hand, it will lead to new fields in networking and communication.

Harrison & Donnelly (2011) mentioned that information technology's role in smart cities has received a lot of attention in its early years. Several studies began to link the creation and sustainability of smart cities with the use of information and communication technologies (ICT) and the Internet of Things (IoT). Information and communication technologies are a longstanding research topic that has been used by academics since the 1980s. According to Ashton (2009) the term "Internet of Things (IoT)" was introduced in 1999, following the appearance of internet-related technologies in the 1990s. (Kortuem et al., 2009) stated that the term "Internet of Things" has become more well-known to describe the concept of a worldwide infrastructure of networked physical objects, which means that the Internet can be integrated into the physical object “things” by implying various sensors and information and communication tools that can be very beneficial in the case of smart cities. (Su et al., 2011) stated that a smart city uses ICT to sense, analyze, and integrate critical data from critical functions in the operational cities, as well as the impact of employing sensing systems for monitoring, alerting, and improving the sustainability of cities.

To be considered "smart" a city must also have elements that make it resilient to natural disasters and even man-made ones. Therefore, disaster resilience is critical to the development of smart cities' sustainability and citizen safety. Data and information processing and analysis are significantly critical in disaster prediction by accessing information and data before the occurrence of the disaster and providing alerts or signals to take the required preventative actions to minimize the impact and consequences as much as possible. The goal of the smart city is to reduce the severity of the repercussions of a disaster by making it easier for authorities to spot victims and reach them quickly. Assuring maximum structural flexibility in the event of a disaster, providing maximum safety for the structures and the inhabitants, and aiding rescue operations after a disaster can all help achieve this goal. (Attwood et al., 2011); (Asimakopoulou & Bessis, 2011) emphasized the development of ICT and IoT in smart cities to create a more advanced and effective integrated disaster management strategy and emergency response. They explained that by incorporating sensors and ICT into buildings and critical infrastructure, it is possible to make them "smart" and give them the ability to detect seismic events and other natural disasters, as well as the role that these technologies play in protecting critical infrastructure and ensuring their continued operation.

(Hancke et al., 2012) discussed the potential of advanced sensing in smart cities and the various ways in which it can be implemented to improve the effectiveness of smart cities. The benefits of using advanced sensors for smart buildings, environmental monitoring, and structural health monitoring were then explained, in addition to how they may reduce costs and promote the sustainability of buildings and structures. (Mitton et al., 2012) discussed the need for more research into sensing, actuation, and IoT to create advanced services that can be used in a specific smart city application. They suggest using the cloud as a way to provide these services, which would allow sensors and actuators to be developed and managed dynamically furthermore they stated that while there are still several open challenges and questions, this research is critical for future development. During the mid-1990s, the concept of sustainability was introduced in the building and civil engineering sectors, and it continued to grow.

In the wake of the significant increase in interest in smart cities after 2010, some studies have begun to link smart city initiatives with the concept of sustainability and the importance of emerging sustainability in smart city construction. (Falconer & Mitchell, 2012) addressed the lack of progress in implementing smart city initiatives and proposed strategies to improve the situation. They concentrate on understanding how smart cities function, the role of ICT in physical city assets, and how smart cities can promote sustainability.

(GhaffarianHoseini et al. 2013) presented several case models of intelligent buildings and smart houses equipped with ICT technologies and containing smart elements within the structure of the building that can aid in providing more security, easier access and control, better energy consumption, and enhancing the living environment, such as indoor sensors, monitoring systems, fire detection systems, smart energy management systems, and integrated building management systems (IBMS), then argued that promoting and implementing these kinds of technologies into buildings will have a positive impact on the sustainable living environment and can also enhance life quality and cost efficiency.

Dubai was one of the first cities in the Middle East to adopt a sustainable smart city approach. According to (Virtudes et al., 2017) Dubai adopted the sustainable smart city approach earlier than any other city in the Middle East. The study examined the strategies that Dubai has implemented to achieve sustainability for the environment by integrating ICT and communication systems, creating green buildings, using green energy, and planning green urban areas. A key part of Dubai's sustainable vision was smart infrastructure and smart buildings, which aim to reduce CO_2 emissions, increase the security of its residents, and make their lives more comfortable while using less energy and water. (Olawumi & Chan, 2018) stated in their scientometric review of global sustainability research that, as part of a sustainable smart city initiative, industries or sectors such as the construction sector are identifying and enhancing their sustainability implementation.

A qualitative shift has occurred in the literature on smart cities over the last five years, with thousands of articles published covering a wide range of topics related to smart cities. It is also becoming increasingly common to see the term "smart city" used in every aspect and area of urban life. Civil engineering was also one of the fields that witnessed a significant increase in smart city initiatives as interest in computing, digitalization, and smart applications in civil engineering has grown to unprecedented levels.

Toli & Murtagh (2020) reviewed 43 definitions of smart cities from different literature and evaluated them according to sustainability dimensions. Based on their findings, sustainability-oriented definitions often emphasize merging soft assets like humans with hard assets like physical city infrastructure. On the other hand, non-sustainability-oriented definitions often concentrate on the importance of ICT utilization so that cities become more connected, smart, and livable. Then they noted that it is important to conduct further study on the role smart cities play in attaining sustainable development and urban management.

As part of the smart cities initiative in recent years, building and information modeling (BIM), digital twins, and blockchain were among the main topics discussed in the literature. (Lokshina et al., 2019) Stated that by incorporating these technologies, an innovative framework can be created for digital transformation within the construction industry. Although the implementation of BIM and blockchain in the construction sector has not yet reached widespread adoption, they have proven their potential to contribute to sustainable development (Liu et al., 2021).

Several studies were conducted that showed the benefits of utilizing such technologies in making significant improvements in smart cities' disaster management (Ford & Wolf, 2020). As well as smart cities' construction sustainability (Waqar et al., 2023).

(Baduge et al., 2022) presented a state-of-the-art review of the applications of AI in the building and construction industry 4.0, demonstrating how utilizing AI in various aspects of civil engineering under the smart city concept can be extremely beneficial and can lead to a huge advancement in the field. Some of the applications that were discussed in depth were construction material design and optimization, structural design and analysis, smart building operation and health, construction management, and sustainability life cycle analysis.

Smart city research continues to grow, and the number of studies is increasing significantly and expanding into new areas and aspects of city development as time goes on.

To get a brief understanding of the increase in research on smart cities initiative, a Web of Science topic, and title search was conducted with the following keywords:

Note:

Title Search: This will show publications containing the search terms specifically in the title of the document.

Topic Search: This will show publications with search terms appearing throughout the document, not just in the title. This could include abstracts, keywords, and other sections.

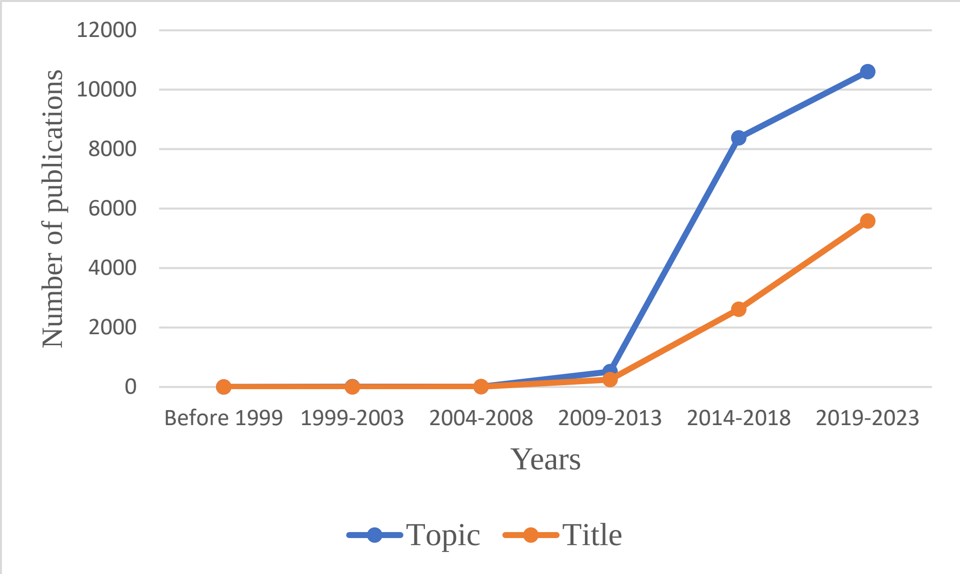

Figure 2.1: WoS Search with the Keywords ("Smart Cities" OR "Smart City")

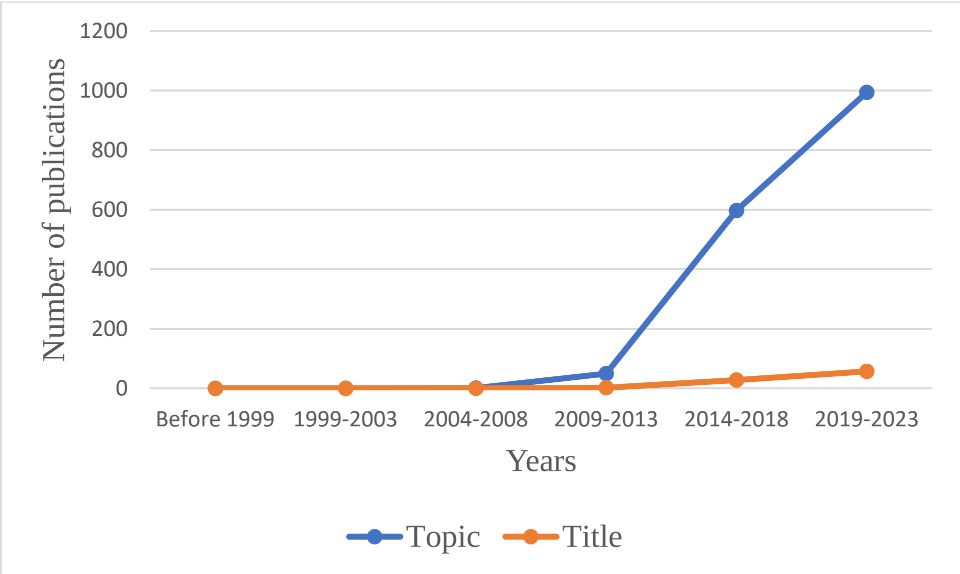

Figure 2.2: WoS Search with the Keywords ("Smart Cities" OR "Smart City") AND "Sustainability"

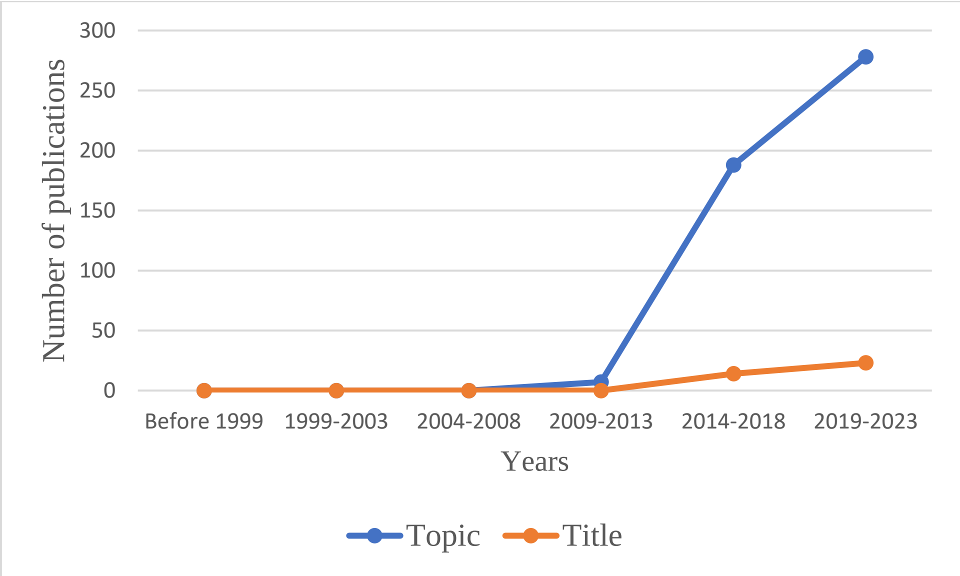

Figure 2.3: WoS Search with the Keywords ("Smart Cities" OR "Smart City") AND (Disaster OR Hazard)

2.2 Role of Civil Engineering in Smart Cities

For smart cities to be created with the necessary smart infrastructure and buildings, different fields of engineering must collaborate. However, civil engineering must be recognized as a key player in this process, as it works closely with the other departments to create the foundations for smart cities.

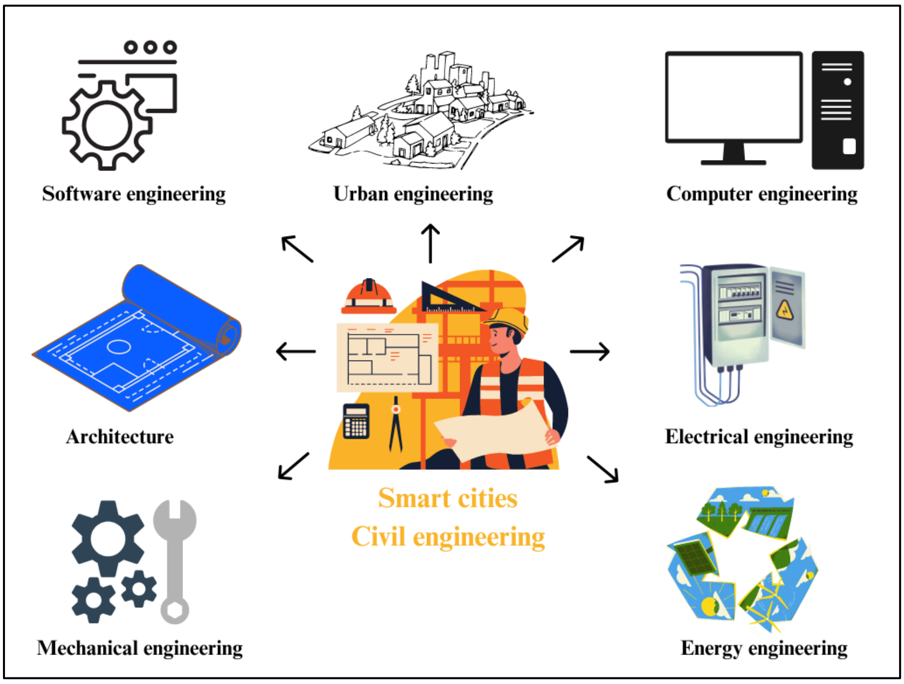

Figure 2.4: Connection Between Civil Engineering and other Engineering Departments in Smart Cities

Smart city applications are progressively replacing traditional civil engineering applications as advancements in technologies such as smart structures and artificial intelligence (AI) continue to improve according to (Peralta & Smartly, 2021). Smart cities are one of the latest trends in civil engineering. One of the most important goals that smart cities aspire to, is achieving sustainability in resources and environment and ensuring an effective and safe lifestyle for citizens using information technology, communication, and the most modern monitoring and sensing technology.

Civil engineering plays a critical role in accelerating the performance of smart cities which rely heavily on civil engineering in several respects, the most important of which is developing and effectively managing smart cities' infrastructure, ensuring the best distribution and efficiency of energy consumption, applying sustainable and green building methods, and minimizing the negative environmental impact as much as possible. The role of civil engineering does not end there but rather includes a very essential component, which is to ensure the safety of the citizen in all aspects, as civil engineering works to secure the maximum resistance to disasters in the infrastructure and residential buildings and to secure the early warning signs of the occurrence of disasters to limit any possible form of harm to the infrastructure and the safety of citizens. Civil engineering also focuses on effective environmental monitoring to ensure citizens' better quality of life. As part of the smart city management process, civil engineering involves citizens in decision-making and gathering feedback, according to Cosgrave (2018) Civil engineers must engage in critical debates that incorporate and value human experience in order to build smart infrastructure and construction that meets both social and technical needs. Smart cities strive to create a smart and sustainable civil infrastructure through a variety of approaches. These include smart structures, resilient structures, green buildings, and implementing material science using smart and green building materials.

Farag (2019) demonstrated how ICT and smart materials, which included sensing, actuating, and self-repairing materials, can be integrated into smart structural systems to enhance the monitoring of safety, performance, and maintenance of crucial civil engineering structures in smart sustainable cities. Furthermore, a study by (Varshney et al., 2021) reviewed some models that can aid in time and cost savings, which employ AI machine learning (ML) to predict some concrete mix design properties, also demonstrated the significant contribution of AI to the advancement of civil engineering field in smart cities. Sensors play critical roles in smart cities systems, (Salehi et al., 2021) Reviewed several IoT-based self-powered sensors for civil engineering applications in smart cities, which are being utilized for monitoring structural health, controlling structural vibrations, predicting corrosion, and several more demands, then explained how applying these kinds of sensors can improve the safety, efficiency, and sustainability of smart city civil infrastructure.

In a state of the art conducted by (Berglund et al., 2020), a general vision for the role of the civil engineering profession in smart cities was presented, along with a wide range of smart technologies that can be utilized for civil engineering applications. Among these technologies were ICT, IoT, big data systems, sensors, actuators, and crowdsourcing. As stated in the study, civil engineering plays a critical role in smart cities by successfully implementing these modern technologies efficiently so that smart cities can meet their main objectives, which include providing optimal urban services, infrastructure, and resource sustainability, minimizing environmental impact, improving air quality, ensuring citizen safety, managing construction projects well, and engaging citizens in smart city infrastructure operations. The authors also emphasized that more research is needed to fill the gaps and provide a better understanding of the role of civil engineering in smart cities.

2.3 Smart Cities Technologies

2.3.1 Information and Communication Technologies (ICT)

Information and communication technologies (ICT) are one of the key components that may transform a city into a smart city. It is also said to be the cornerstone for the development of smart cities. When ICT is properly implemented in the infrastructure and various sectors of the city, smart cities can achieve an optimized system for transmitting information from all of their vital sectors and enabling effective communication. This, in turn, can significantly enhance the efficiency of many critical city operations. For example, its construction performance, disaster response capability, resource and energy sustainability, and ability to effectively engage citizens in the smart city development process. Based on the findings of a study conducted by (Kim et al., 2016) smart cities share characteristics with both the ICT and construction industries, indicating that acquiring the competitive edge of both sectors is the key to the success of smart cities. (Oluwafemi et al., 2021) noted that the application of information and communication technologies might be critical in civil engineering practice in reducing costs, operating time, increasing safety, etc. Therefore, ICT remains relevant in the civil engineering field. Civil engineering capitalizes on ICT by utilizing several ICT applications such as IoT, Remote Sensing, Building Information Modeling (BIM), Cloud Computing, and various project management software.

2.3.2 Internet of Thigs (IoT)

The IoT (Internet of Things) is a rapidly developing concept as a wide variety of devices are connected to the Internet to support ubiquitous monitoring and analysis. It is clear that smart cities will be driven by advances in pervasive sensing and computing and home automation Sterbenz (2017).

IoT is integrated into smart cities by connecting physical objects (things) to the internet to establish a communication link IoT solutions, such as sensors, are used by smart cities to connect infrastructure and buildings and collect data ranging from environmental quality to structure health to disaster prediction for analysis. IoT technology can help civil engineers manage building sites more effectively by boosting efficiency and safety. Additionally, the IoT can considerably support several applications for environmental monitoring, energy management, and structural health monitoring. Smart cities have also used IoT technologies to develop solutions for specific urban infrastructures, including transportation, water, and energy management. They have also developed urban-scale IoT platforms that enable citizen engagement and integrate social networks with IoT (Lea & Blackstock, 2014).

According to (Mehmood et al., 2017), providing connectivity to every IoT device with sensing capabilities that create significant data is the only way to succeed with smart cities. Hence, in order for IoT to fulfill its full potential, the network infrastructure must be reliable, secure, and efficient, in addition to integrating data analytics that can handle the enormous volumes of data gathered.

2.3.3 Artificial Intelligence (AI)

According to (Navaratnam et al., 2018) artificial intelligence (AI) is the science of training machines to mimic intelligent human behavior by teaching them human skills including learning, judgment, and decision-making.

Artificial intelligence and intelligent grid systems can be implied in different parts of smart cities by implementing deep learning and machine learning techniques. The use of AI in cities will improve the delivery of individualized services. It can be useful for forecasting and identifying potential trends. Additionally, it can simulate the adoption of various policies before their implementation, which will benefit the city's construction financial management by allowing for more precise estimations and cost control.

By using AI in smart cities, we can improve their sustainability; it can be applied in different areas like security, resource and energy management, waste management, reducing traffic, and pollution control, (Yigitcanlar et al., 2021) stated that the capabilities of artificial intelligence (AI) go beyond processing and storing data (storage, communication, and processing) to improve the efficiency of whole infrastructure ecosystems through analysis and optimization.

Smart cities can also utilize AI in disaster management systems. It is possible to predict potential disasters like floods and earthquakes using advanced methods and modern technology. Additionally, it is possible to improve the infrastructure's ability for coping with such events. According to a review by (Munawar et al., 2022), using innovative technologies, such as artificial intelligence, can help smart cities respond to disasters more effectively while reducing the loss of lives and resources that comes with them. For this reason, innovative technologies should be leveraged, and a global solution reached to increase disaster resilience.

2.3.4 Big Data

(Uddin et al. 2014) defined big data set as an extremely large amount of data that is more complex and difficult to handle by the capabilities of traditional databases or engines. One of the key elements in smart city operations is data gathering by various sensors and monitoring systems that collect data from various parts of the city infrastructure, smart buildings, and energy systems to analyze and aid decision-making and ensure the optimal flow of the process. As a result, a significantly large amount of data will be generated. Regarding that, (Al Nuaimi et al., 2015) found that there is a requirement for substantial computing and storage platforms. And suggested that in order to facilitate big-data management and applications for smart cities, we can rely on cloud computing and its multiple benefits of utilizing cloud services. Big data is most commonly handled through cloud computing. Providing on-demand services at a cost-effective price makes cloud computing a leading solution for Big Data applications according to (Nachiappan et al., 2017). When dealing with big data, it is essential to keep in mind that the security and privacy of the collected data should be one of the top priorities, especially when it relates to city infrastructure and its citizens.

While research in the field of smart cities has significantly expanded and encompassed broader areas, a notable gap still exists, particularly in the realm of smart city disaster management and sustainability. The majority of studies are theoretical and may ignore some important aspects and overlook several critical factors. Moreover, a comprehensive framework for translating smart city concepts into practical implementation is conspicuously lacking, particularly in the context of developing countries and their financial and social factors considering that this study aims to address these existing limitations to some extent by identifying often-overlooked issues in prior research. It aims to bring these issues together and propose practical strategies that developing countries can adopt. By incorporating both sustainability and disaster management aspects, these strategies will aid in enhancing the effectiveness of smart city initiatives implementation in developing countries.

Chapter 3

RESEARCH METHODOLOGY

3.1 Introduction

This chapter aims to present the research methodology, including constructing the SWOT matrix, questionnaire design, data gathering techniques, and analysis methodologies.

3.2 SWOT & TOWS Matrix

3.2.1 SWOT

SWOT is typically credited to Albert Humphrey, who defined (not created) the modern version of SWOT analysis in the 1960s, Jain (2015). SWOT analysis is considered an important technique for developing strategies and making decisions.

The term SWOT is an acronym that stands for strengths, weaknesses, opportunities, and threats. SWOT helps in identifying internal factors, which are strengths and weaknesses, and external factors, which are opportunities and threats. By determining these factors, strategies may be built by leveraging and maximizing the strengths, overcoming and minimizing the weaknesses, capitalizing on the opportunities, and mitigating the threats.

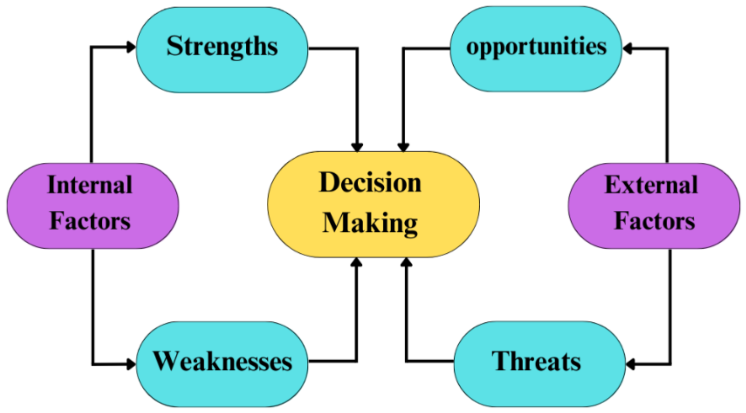

Figure 3.1: SWOT analysis Decision-making Matrix

SWOT analysis is frequently cited as a framework for both its simplicity and efficiency in concentrating on the main issues that impact industry development and growth. Therefore, it has the potential to be a useful tool for determining which factors are most likely to influence the strategy and success (Pickton & Wright, 1998).

SWOT analysis can provide a general overview of a phenomenon's internal and external environments and help in determining the subject's strategic space but does not recommend strategies to improve the subject which some consider as a disadvantage of the SWOT matrix. That's why, as an extension of SWOT analysis, TOWS was developed to make it more practical and realistic (Al Salmi & Hasnan, 2015). After drawing the SWOT matrix, TOWS is typically used to suggest strategies for improving current and future situations (Şeker & Özgürler, 2012). By cross matching the internal and external factors of the SWOT.

3.2.2 TOWS

In 1982, Heinz Weihrich, a professor in management introduced the TOWS matrix as a strategic planning technique, which can be used to develop alternative strategies, tactics, and other action plans, and can also aid in evaluating and choosing strategies.

He proposed a framework for identifying internal factors (Strengths and weaknesses) and external factors (threats and opportunities) as shown in the table below Weihrich (1982).

Table 3.1: TOWS Framework Weihrich (1982).

Internal Factors / **External Factors**	**STRENGTHS (S)**	**WEAKNESSES (W)**
OPPORTUNITIES (O)	**S-O** (Maxi-Maxi) Strategies	**W-O** (Mini-Maxi) Strategies
THREATS (T)	**S-T** (Maxi-Mini) Strategies	**W-T** (Mini-Mini) Strategies

S-O strategy (Maxi-Maxi): This strategy aims to utilize internal strengths to take advantage and capitalize on opportunities.

S-T strategy (Maxi-Mini): This strategy aims to use internal strengths to handle and overcome threats.

W-O strategy (Mini-Maxi): This strategy aims to mitigate internal weaknesses to capitalize and take advantage of opportunities.

W-T strategy (Mini-Mini): This strategy aims to reduce internal weaknesses to avoid threats.

It was noted that while this analysis focuses on strategies, it could also apply to developing the tactics necessary for implementing the strategies, and to more specific actions supporting them, which is done in this thesis.

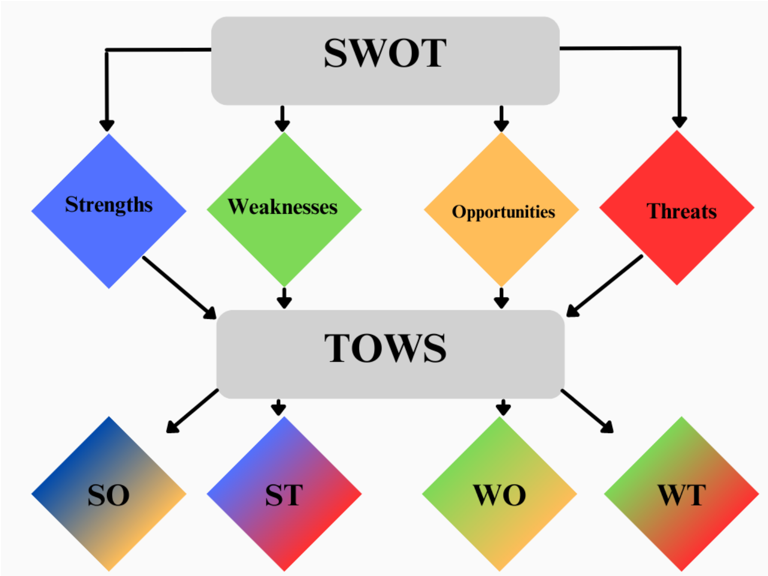

Figure 3.2: Link Between SWOT and TOWS Matrix

3.3 Constructing the SWOT

Studying smart cities from two different perspectives, sustainability and disaster management, was the focus of this study. SWOT analysis factors were gathered through an extensive review of the literature. A comprehensive search was conducted across multiple academic databases; the primary databases were the Web of Science and Google Scholar. The selection process for the majority of the articles involved Finding relevant articles from reliable scientific journal publishers like Elsevier, Springer, Taylor & Francis, MDPI, and IEEE. The selection of publishers was based on their strong reputations and rigorous peer-review processes, which ensure the reliability and quality of the publications. A wide range of scholarly sources were analyzed for a comprehensive understanding of the SWOT analysis factors. A systematic strategy was employed during the literature research process to identify significant aspects of the SWOT analysis factors. A broad range of keywords, search terms, and combinations were implied to ensure finding relevant work, including peer-reviewed articles, conference proceedings, and books. The point of following these guidelines in the literature review is to gain a thorough and reliable understanding of the factors that contribute to a SWOT analysis.

3.4 Assessing the Significance of SWOT Factors

In this section, the motivation behind the questionnaire survey's creation and how it helped shed light on the priorities and preferences of the various questionnaire survey participants in the development of smart cities is discussed.

This study used the essential and empirical tool, the questionnaire survey, in its attempt to comprehend the dynamics of sustainability and disaster management within the context of smart cities in developing countries. This study had two objectives: first, it used SWOT analysis to identify the significant factors influencing the sustainability and resilience of smart cities in developing countries, and second, it developed strategies to address these factors. The research methodology is based on a comprehensive survey conducted to achieve these goals. This survey was essential in identifying the most critical SWOT (Strengths, Weaknesses, Opportunities, and Threats) factors but also served as a key element for determining the importance of TOWS strategies.

3.5 Questionnaire Survey

The primary data was collected through a questionnaire developed by the researcher. The questionnaire was administered both on paper and online for this study to collect the necessary data. The study targeted civil engineering academics from different universities and research centers in various developing countries, such as Jordan, North Cyprus, Iran, Turkey, Oman, Saudi Arabia, Egypt, and Nigeria.

3.5.1 Data Collection

Paper forms were handed out personally to the participants, and it was explained to them what the study was about. Any necessary clarifications were addressed, clear instructions were provided, and sufficient time was given to complete the surveys. After the respondents had completed the surveys, all the data was collected from the papers for further analysis. Google Forms was used to create an online survey, which had the same content and was identical to the paper form. Emails were sent to the targeted academics containing an explanation of the study purpose and clear instructions with a link to the online form giving them the option to complete the survey whenever it is convenient for them. The academic experts' email addresses were gathered from official university websites in a range of developing countries. The completed questionnaires were automatically sent to the Google form account and the data were later collected for further analysis.

3.5.2 Study Contributors

Table 3.2: Distribution of the study sample according to academic degree:

Variable	**Frequency**	**Percentage %**
Professor	13	24%
Associate professor	15	28%
Assistant Professor	11	20%
Doctor	7	13%
Ph.D. student	8	15%
SUM	54	100%

Table 3.3: Weight assign to the study Contributors

Contributor	Weight
Professor, Associate professor	1.0
Assistant Professor, Doctor	0.9
Ph.D. student	0.8

3.5.3 Questionnaire Validity

To measure the reliability of the questionnaire Cronbach's alpha coefficient was used. The reliability index (α) ranges from zero to one. A high alpha value indicates a higher level of reliability. The values of Cronbach's alpha reliability index were as shown in Table 3.4 and Table 3.5. The reliability index for Cronbach's alpha for the SWOT factor was between (0.62 - 0.88), This indicates a good degree of reliability. Cronbach coefficient is acceptable when ($\propto > 0.6$).

Table 3.4: Cronbach's alpha for Sustainability SWOT matrix

SWOT Category	Cronbach alpha
Strengths	0.67
Weaknesses	0.81
Opportunities	0.62
Threats	0.76
Sustainability SWOT matrix	0.82

Table 3.5: Cronbach's alpha for disaster management SWOT matrix

SWOT Category	Cronbach alpha
Strengths	0.88
Weaknesses	0.69
Opportunities	*0.75*
Threats	0.74
Disaster SWOT matrix	0.86

3.6 Analyzing the Questionnaire Survey Output

After collecting the data from the questionnaire survey, the weighted mean of each factor in the SWOT was calculated as follows:

$$WM_i = \sum_{j=1}^{n} \frac{(w_{ij} \times S_{ij})}{n} \qquad \text{(Equation 1)}$$

WM_i : The weighted mean for factor i

w_{ij} : The weight of responder j for factor i

S_{ij}: The score of responder j for factor i

n: The total number of responders

Development strategies were identified in four TOWS modes: SO, ST, WO, and WT by employing strength, weakness, opportunity, and threat together (Table 4.16 and Table 4.29).

In this phase, each of the strategies was derived from a combination of several Factors. For example, sustainability strategy SO1 was derived from a combination of S1, S3, O2, and O3 factors.

Then, the total weight of each strategy was calculated (Table 4.30) as follows:

$$TW_{SO1} = f\,(TP_{S1,\,S2,\ldots Sn,\,/\,O1,\,O2,\,\ldots,\,O}) \qquad \text{(Equation 2)}$$

$TW_{SO} = (TP_{S1} \times TP_{O1}) + (TP_{S1} \times TP_{O2}) + \cdots + (TP_{S1} \times TP_{On}) + (TP_{S2} \times TP_{O1}) + (TP_{S2} \times TP_{O2}) + \cdots + (TP_{S2} \times TP_{On})$

Chapter 4

RESULTS AND DISCUSSIONS

4.1 Sustainability SWOT

Table 4.1: Sustainability SWOT matrix

Strengths	**Weaknesses**
Sustainable Infrastructure and smart building.	Higher costs for green building practices and materials
Disasters resiliency	Sustainability Implementation Complexity
Green construction	Overreliance on technology
Opportunities	**Threats**
Lower pollution levels	Lack of specialists in smart and green building
Protection of natural resources	Increasing energy needs and demand
Citizen engagement	Low demand for green/smart buildings

Strengths

1) Sustainable Infrastructure and smart buildings

One of the most essential characteristics of a smart city is its ability to develop sustainable infrastructure and buildings that consider both the environment and resource efficiency. Furthermore, smart city infrastructure should be managed strategically to be more efficient, sustainable, reliable, and resilient. (Shahidehpour et al., 2018).

Smart cities are those that are long-term sustainable. Nowadays, it is extremely difficult to perform maintenance and inspection of structures and infrastructure due to high in-service costs. Earthquakes and vibrations, temperature-induced stress, reinforcement corrosion, and structural distress all have a negative impact on structural health. Smart structural systems that have the ability to self-sufficiently adapt structural characteristics in response to changes in environmental and external conditions are known as smart structural systems (Apurva et al., 2017). It is possible to avoid structural failures by monitoring the infrastructure and estimating its lifespan, which will help provide early solutions and extend the structure's lifespan, making the structure more sustainable.

2) Disasters resiliency

It is crucial for sustainability that structures are disaster resilient. Das (2021) ties disaster risk management and sustainable development together under one general concept, demonstrating how successful disaster resilience strategies and procedures result in the accomplishment of more general goals for sustainable development. A city's disaster resilience can be improved through a variety of measures. Smart cities are those that are designed to be as prepared as possible for such events to reduce the impact on infrastructure and residents. Smart cities can play a critical role in increasing the safety and well-being of their citizens by allowing them to predict and respond to potential disasters. Predictive analytics can assist them in predicting and preparing for future disasters. Identifying and responding to problems as soon as possible is critical to reducing the impact of disruptions on cities.

Technologies commonly employed in smart cities today include information and communication technology (ICT), the Internet of Things (IoT), and artificial intelligence (AI). These technologies use smart urbanization approaches such as continuous monitoring, data fusion, disaster warning, and so on to protect critical infrastructure, increase the efficacy of the urban system, and manage disasters (Shahrabani et al., 2022).

3) Green construction

Over the past few years, various methods for green construction have been developed around the world to address environmental issues and reduce energy consumption and pollution. Smart cities around the world started to adopt green construction methods and green buildings to achieve sustainability. According to (Shi et al., 2013), green engineering construction is defined as using scientific management and technological advancement to reduce negative environmental impact while optimizing resource conservation, as long as quality, safety, and other basic requirements are preserved. The main goals are environmental protection and conservation of energy, land, water, and materials.

Capeluto & Ben-Avraham (2016) and Kubba (2010) define green buildings as those that are designed and constructed with an emphasis on maximizing energy efficiency as well as utilizing materials that are natural and recycled. The green construction concept encompasses designing, constructing, operating, maintaining, and managing structures utilizing methods that are considerate of the environment and resources throughout the building's lifecycle. In a study conducted by (Guo et al., 2022) has demonstrated how smart city construction can significantly reduce carbon emissions and energy usage.

Weaknesses

1) Higher costs for green building practices

According to (Hwang & Tan, 2012) green building practices which smart cities aim to adopt to achieve sustainability could face several obstacles, such as the high-cost premium of green building projects. Green building practices are also costly to implement compared to traditional construction projects. (Williams & Dair, 2007) stated that the sustainability measures and materials in construction cost too much, and that can be one of the main reasons for not pursuing sustainable development in many countries.

2) Sustainability Implementation Complexity

Many studies pointed out the complexity of implementing smart city initiatives. In order to plan and implement smart city concepts, multiple aspects need to be considered (Al Sharif & Pokharel, 2022). Taking a holistic approach to smart environmental planning including urban planning, sustainability, resilience, and smart cities is one of the great challenges of the 21st century (Ramirez et al., 2020).

In a study conducted by (De Santis et al., 2014), they stated that it is complex and multidimensional to transform a city into a Smart City, as is measuring progress towards that goal, As The smart city transformation affects many aspects of city operations including infrastructure, buildings, energy, mobility, services, and environment. Furthermore, the potential of the initial goals of the smart city changing over time in order to reach a better and more effective result should be considered.

In smart cities, sustainability is achieved by utilizing the most recent techniques and technology. Smart cities integrate many different systems and devices using sensors, cameras, and software and process enormous amounts of data. Bringing together these various components into one system can be quite a challenge and can result in instabilities, data breaches, and other technical issues along the way. To achieve the highest level of sustainability, it is also necessary to stay up to date on the latest technologies and trends, which can be a difficult undertaking. The development of sustainable solutions in smart cities can also be complex due to the interaction of various stakeholders and the need for careful planning.

3) Overreliance on technology

Technologies utilization is the core of smart cities, (Al Nuaimi et al., 2015) Stated that the main aim of smart cities is to enhance their citizens' quality of life while creating infrastructure that is sustainable and environmentally friendly. A variety of techniques are used to achieve this, such as heavily utilizing ICT and next-generation information technology, integrating the physical aspects of the city with ICT, and implementing advanced monitoring and control technologies into operation to improve the efficiency and sustainability of the city infrastructure. While Smart cities greatly benefit from technology utilization, however, the overreliance of smart cities on technology to achieve their goals could lead to a variety of obstacles and drawbacks.

Opportunities

1) Lower pollution levels

Smart cities always strive to provide the best environment and life quality for their citizens. By implementing sustainable practices in general, as well as environmental monitoring, pollution levels can be reduced. The pollution level of an urban area should be monitored efficiently and effectively in a smart city (Siregar et al., 2016). Air pollution monitoring and maintenance are critical aspects of smart city management (Spandana & Shanmughasundram, 2018).

Air pollution is one of the main elements that must be taken into consideration when considering sustainability, Numerous issues with air quality are brought on by the rise of urbanization and industrialization. Smart cities are dealing with air pollution from several angles, by using different air monitoring systems and different approaches and solutions to make the city operations environmentally friendly. Several studies discussed how using sensors, the Internet of Things, and deep learning models could improve air quality severely (Bekkar et al., 2021), (Toma et al., 2019). (Nitoslawski et al., 2019) offered scientific methods that can guide the layout of green areas in smart cities, improving sustainability and air quality.

2) Protection of natural resources

(Silva et al., 2018) stated that utilizing natural resources is a key component of modern cities' development. According to (Khan et al., 2013) a "smart city" is one that makes investments in ICT-enhanced governance, participatory methods, improved quality of life, and smart natural resource management. One of the main elements of sustainability is the protection of resources, which smart cities aim to achieve through utilizing technologies, using greener building solutions, and building solid sustainable resource management plans.

3) Citizen engagement

ICT technologies are undoubtedly the fundamental force behind any smart city initiative, but without taking into account human resources, technology, and strategic goals, will not produce public value for citizens (Dameri et al., 2019).

Citizens should be actively involved in the creation of smart cities since they are users, decision-makers, consumers, and providers of data and information (Tadili & Fasly, 2019). Social media and digital platforms may be used by smart cities to engage their residents and encourage sustainable behavior. (Bastos et al., 2022) highlighted the applications that promote citizen engagement in smart city management, including an engagement to promote sustainability. Smart city opportunities for citizen-technology collaboration will significantly assist in achieving smart cities' sustainability goals.

Threats

1) Lack of specialists in smart and green buildings

Smart cities, as is evident, are far more complex to implement, maintain and operate due to the huge amount of technology involved. Furthermore, Smart cities are a modern civil engineering and construction trend, and they have remained immature until this time, particularly in developing countries. Also, the trend towards green and environmentally friendly construction to preserve the environment and resources as much as possible is one of the most recent trends when it comes to the world of construction and city establishment. So, it is evident that the field of smart and sustainable cities lacks sufficient and knowledgeable engineering expertise to develop clear strategies, plans, and visions.

Circo & Carl (2007) described green building as the process of developing buildings and utilizing methods that are sustainable and resource-efficient throughout a building's life cycle, from site selection to design construction, operation, maintenance, and restoration.

2) Increasing energy needs and demand

It is important to note that smart cities rely heavily on modern technology and devices in all parts of their operations. There is an urgent need for more energy, electricity, and resources in order for the city to function efficiently and effectively. In a study conducted by (Colding et al. 2020), they tied the complexity of smart cities due to their high number of technologies and devices being utilized with the increase in energy consumption. Smart cities aim to bring economic growth, sustainability, and a higher quality of life while also developing a diverse range of dependable, economical, and sustainable energy sources, which are fundamental to the sustainable smart city concept (Motyka et al., 2019). (Chenic et al., 2022) stated that the use of renewable energy sources such as solar power and wind power has become increasingly important in order for many smart cities to meet their goals.

3) Low demand for green/smart buildings

The possibility of Low demand for green and smart buildings in smart cities must be addressed. Smart cities are ones that actively use technology to improve the quality of life for their residents. However, one of these cities' primary challenges is a lack of demand for green and smart buildings. "Green" or "smart" structures are those that are designed to be energy-efficient and environmentally beneficial by using technologies and green sustainable materials.

According to (Liu et al., 2022) the development of green buildings might be confronted with potential economic repercussions, such as a lack of demand on the market for such buildings. One of the main reasons for this is a lack of awareness among people about the benefits of these structures for the environment and sustainability, as well as their economic advantages. Another reason for the limited demand for such buildings is the lack of government regulations and restrictions on green buildings and their implementation in the city.

4.2 Disaster Management SWOT

Table 4.2: Disaster management SWOT Matrix

Strengths	**Weaknesses**
Developed disaster management system	The high cost of disaster management technologies
Resilient Smart structure	Reliance on energy for operating
Real-time disaster Control System	Lack of experience and training in smart disaster management
Opportunities	**Threats**
Post-disaster rescue systems	Communication systems breakdowns and fails
Faster emergency response	Cyber security threats
Early warning systems	Sensors and monitoring devices get damaged during hazards

Strengths

1) Developed disaster management system

When establishing smart cities, one of the most critical characteristics the city needs to possess is resilience to disasters, hazards, and emergencies, as well as the ability to deal with them on time. Several studies have shown that smart cities can utilize a smart disaster management system that is far superior to traditional systems. Smart cities are equipped with technologies, devices, and sensors that can track and send signals in cases of disasters and emergencies to the concerned authorities in real-time. This is so that the situation can be dealt with as quickly as possible to ensure the safety of citizens and facilities. (Shah et al., 2019) discussed the importance of the Internet of Things and big data analytics in making smart cities more resilient against disaster and how they can be game changers for a city's disaster management. Further technologies and devices that can be used in smart cities can also enhance disaster management, such as UAVs, drones, and mobile data gathering.

2) Resilient Smart structure

(Khatibi et al., 2021) stated that, in a Smart city, which is based on intelligent devices, sensors, real-time data, and ICT integration, these technologies should be integrated so that resiliency can be maximized for all human aspects. Furthermore, the smart city urban structure should be resilient and avoid degeneration to meet sustainable urbanization challenges.

The study area known as "smart structures" encompasses terminology like "intelligent structures," "adaptive structures," and "active structures" (Gabbert et al., 2001). Smart structures in general integrate actuators, sensors, and enhanced signal processing with materials or structural components and generally utilize some kind of control unit or signal processing (Hurlebaus & Gaul, 2006). In the case of smart cities, utilizing smart infrastructure and building with ICT and IoT can improve the structure's resilience and make it far more resilient against structural failures and hazards. Also, smart materials could be utilized in smart city infrastructure to achieve greater disaster resilience, such as seismically resistant steel structures (Fang et al., 2022). Fire-resistant materials can be used on concrete and will aid fire hazard resilience (Liang et al., 2018). Smart cities aim to achieve the optimum framework for hazard resilience, leading to the safety of citizens and the city's assets.

3) Real-time disaster Control Systems

Fast response to a disaster is the most critical element when looking at disaster management, which is why receiving feedback at the moment of the disaster occurring can change a lot. According to (Ford & Wolf, 2020), real-time data made available by smart city technology can aid disaster management authorities to improve their decisions and to respond quickly to hazards caused by conditions that often change quickly and require quick responses, by providing additional information and reducing the time to obtain data about the hazards.

Smart cities aim to use real-time monitoring for their big databases and analysis tools. (Rathore et al., 2018) Overviewed real-time monitoring applications in smart cities such as smart homes, weather and water systems, surveillance, and security systems, and environmental pollution systems. (DesRoches et al., 2018) mentioned that big data applications that operate in a rapid or real-time manner, especially as they relate to smart cities, can mitigate the negative impact and enhance the city's capacity to recover from extreme events as quickly as possible.

Weaknesses

1) The high cost of technology

Advanced technological solutions used in smart cities result in high disaster management costs. These systems include sensors, specialized software, and other devices that can detect and respond quickly to potential hazards. Installing and maintaining these systems is often expensive and operating them requires specialized training and skilled staff. (Munawar et al., 2022) noted that the development of smart cities is also challenged by high costs and maintenance requirements. Disaster management systems which IoT-base cabling costs for an enormous number of sensors can be extremely expensive (Hancke et al., 2012). Furthermore, time, energy, and resources are required to collect and analyze data in smart cities, according to (Jin et al., 2014) data collection exercises are often costly and difficult to replicate.

Additionally, managing disasters in smart cities can also be costly due to the need for coordination between multiple agencies and organizations to ensure that all operations and information sharing run smoothly.

2) Reliance on energy for operating

Smart cities may be vulnerable to power outages, especially during hazards. It is important to keep in mind that smart cities rely on technology in many aspects of their operations and have an infrastructure that depends on electricity, so power outages can have serious consequences during disasters. Sensors, analytic systems, and emergency response systems may all stop functioning and shut down entirely during a power loss.

3) Lack of experience and training in smart disaster management

Smart technologies must be installed, operated, managed, and maintained by trained and qualified engineers and technicians. Smart city disaster management plans cannot be successful without these technologies, which are critical for understanding and responding to the data collected by the sensing devices as well as the outcome of the analysis. This includes identifying potential risks and responding to disasters quickly and effectively. That is to say that in addition to cutting-edge technology, humans play a significant role in disaster management. From here arises the challenge that, because of the field's novelty, and with the rapid pace of technological advancement, there is a lack of previous experience and knowledge regarding using smart technologies in hazards management, leading to a lack of qualified, trained engineers and experts that can handle such complex technologies in the field of hazards management in smart cities.

Opportunities

1) Post-disaster smart rescue systems

In the event of a disaster, an early and quick response is critical, and every second matters to save a human life. Therefore, city planners must plan and assign rescue teams efficiently and quickly to disaster zones. In the case of smart cities, technologies, and communication tools can massively improve victims' detection and reach. (Fajardo et al., 2010) explained how Android technology in mobile phones can provide the geographic locations of their users in the event of a disaster. (Alsamhi et al., 2019) studied the network performance of collaboration between the Internet of Public Safety Things (IoPST) and how drones can be implied in smart cities for remote sensing and how they have the ability to reach disaster areas, give real-time feedback, and aid in victim detection in some hard-to-reach areas. (Boukerche et al., 2018) mentioned how using body-warmth and heartbeat detectors can help find victims and rescue them in the event of a hazard such as an earthquake in smart cities.

2) Faster emergency response

Urbanization is being driven by smart cities. Thus, in order to prevent and control various disaster-related risks, emergency response and resilience are the most critical dimensions of smart city design (Sahil & Sood, 2020).

By adopting emergency response protocols, smart cities can become more resilient to emergencies. These protocols use the latest technology to monitor the environment and coordinate emergency service responses when necessary. Smart cities use a variety of sensors and cameras to detect potential threats and respond very quickly. An emergency response is triggered once all of this data is fed into a central control system which can happen very quickly. Additionally, smart cities use artificial intelligence and machine learning to detect patterns and anticipate threats. By anticipating and responding to situations before they turn dangerous or out of control, emergency responders are able to prevent situations from becoming dangerous. Furthermore, smart cities try to implement IoT Based buildings in the city infrastructure to achieve this goal (Park et al., 2018).

Several studies discussed the role of big data and IoT in enhancing the emergency management systems and emergency response in smart cities such as (Wellington & Ramesh, 2017) and (Shah et al., 2019).

Overall, smart cities are making use of technology to develop an effective, quick, and efficient emergency response system. Furthermore, smart cities implement smart mobility systems to aid authorities to reach the emergency zone more quickly.

3) Early warning systems

Disaster prevention requires a pre-hazard early warning system, which can play a crucial role in the planning of smart cities (Liu et al., 2021). By utilizing sensors, analytics, and AI predictive modeling, smart cities can implement early warning systems that detect potential disasters and give early warnings using artificial intelligence and machine learning. (Yekeen et al., 2020) describe an early warning system (EWS) as a tool used to acquire and communicate timely and useful information about a predicted disaster or severe event. It is possible to organize and monitor at a local level and patrol and monitor high-risk areas with model-based early warning systems, preventing floods or fires, and reducing damages by significantly reducing the elapsed time following the detection of a wildfire (Elvas et al., 2021).

Threats

1) Communication systems breakdowns and fails

Smart cities use the Internet of Things (IoT) to connect the physical infrastructure with the software and monitoring systems (Mehmood et al., 2017), and they also heavily rely on communication and information technologies (ICT) in the majority of their operations. (El Khaled et al., 2019) studied communications system failures during harsh environments, natural extremes, and hazards. During hazards, people may be unable to connect with one another in a timely and convenient manner as a result of communication system failure, which can have catastrophic consequences for their personal lives and economic activities. Thus, in smart cities, it is essential to find the best ways and take the necessary precautions to prevent information and communication systems failure during hazards.

2) Cyber security threats

Smart cities are investing a lot of resources in safety measures, while technology companies are developing new mechanisms to protect them from cybercrime and hacking (Neffati et al., 2021). (Dong et al., 2018) noted that, given the broad adoption of the next generation of information technology in urban management in Smart cities, including IoT, cloud computing, big data, and other associated technologies, the threat of information security is now present in every spot across the city.

A "citizen's right to privacy" is a legal and social concept that is connected with the issues of cybersecurity and the advantages of a smart city (Elmaghraby & Losavio, 2014). For smart cities to achieve optimum disaster management, a huge amount of data needs to be collected from all the city's critical structures and infrastructure for analysis and to detect any indications or signs of a possible hazard. Smart cities heavily rely on ICT, gathering information and data from all city sectors and storing it in big databases before processing it to carry out the necessary operations for the city's activity. That's why cyber-criminals may be able to access and exploit a significant amount of targeted personal information collected by smart city infrastructure, providing them with the information needed to commit fraudulent transactions and identity theft. There is always the possibility of hackers interrupting or even disabling the city's operations completely, which may lead to high financial losses.

3) Sensors and monitoring devices get damaged during hazards

During the first stage of a disaster, sensors that are responsible for monitoring and detecting any unusual distribution in the environment in real-time should send signals to the databases for processing and then take the necessary procedures if necessary. If sensors reach the hazard threshold, they might get damaged and stop functioning, leading to a breakdown in communication between the area where the disaster occurred and the processing and databases, which can negatively affect the disaster management process. Hong (2019) proposed that during hazards, when sensors get damaged, they can be used as an indicator for the accuracy of the hazard and that the sensors reach the hazard threshold, so processing and decision-making need to be done to send an alert that needs to be sent to the concerned authorities to take action.

4.3 Quaternaries Output

4.3.1 Sustainability

Table 4.3: Range of the Importance Level

Descriptive Label of the importance level	Range Scale Value
Low	0 – 3
Moderate	3.1 – 6
High	6.1 – 9

Table 4.4: Sustainable Infrastructure and Smart Building - Assessment Summary

	Range Scale Value	Frequency	Percentage %	Mean	Standard deviation	Local Rank	Global Rank
Strength Factor (1): **Sustainable infrastructure and smart building**	Low	4	7.41	6.55	1.79	1	2
	Moderate	15	27.78				
	High	35	64.81				

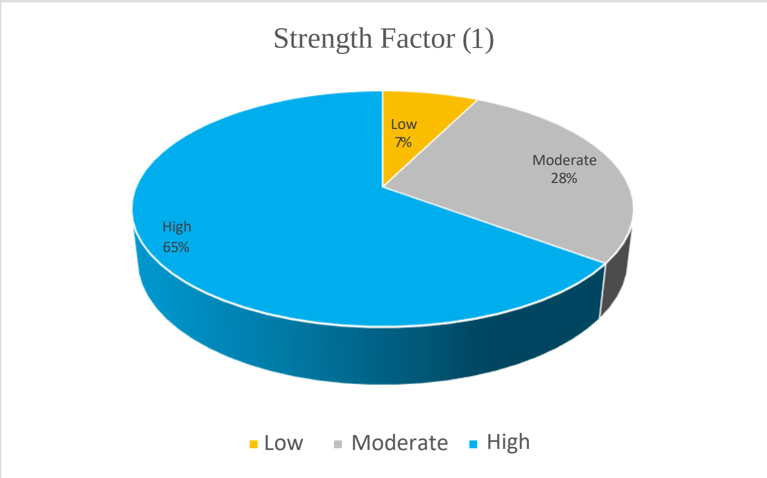

Figure 4.1: Importance Distribution by Respondent Frequency Sustainability S (1)

Table 4.5: Disasters resiliency - Assessment Summary

	Range Scale Value	Frequency	Percentage %	Mean	Standard deviation	Local Rank	Global Rank
Strength Factor (2): **Disasters resiliency**	Low	2	3.70	6.25	1.66	3	7
	Moderate	23	42.59				
	High	29	53.71				

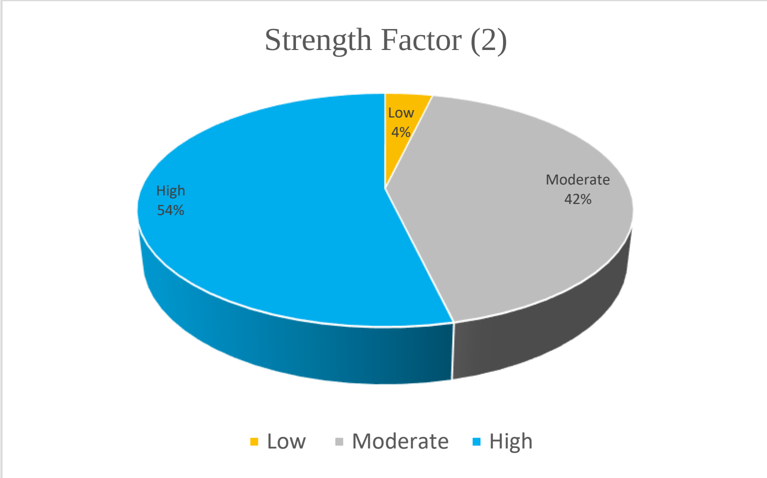

Figure 4.2: Importance Distribution by Respondent Frequency - Sustainability S (2)

Table 4.6: Green Construction - Assessment Summary

Strength Factor (3): **Green construction**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	6	11.11	6.52	1.92	2	3
	Moderate	13	24.07				
	High	35	64.82				

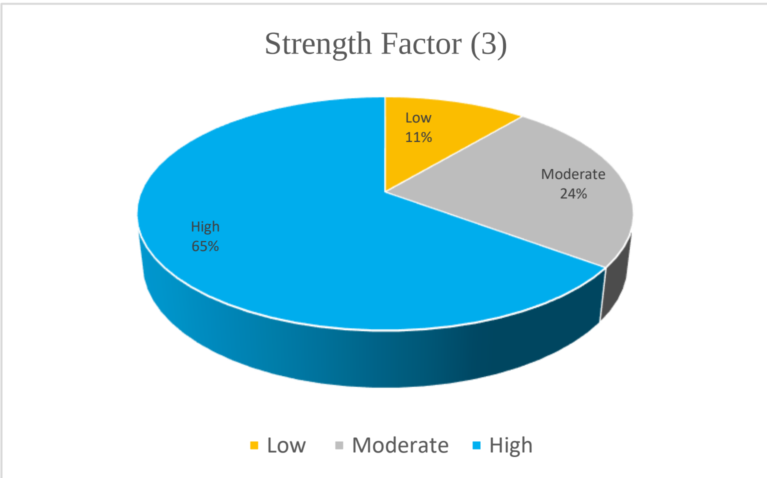

Figure 4.3: Importance Distribution by Respondent Frequency - Sustainability S (3)

The results presented in Tables 4.4 to 4.6 indicate that the most critical strength factor is "**Sustainable infrastructure and smart building**" with a mean value of (6.55), with a global rank (2) meaning it's the second most critical factor in the overall SWOT, while the second most critical strength factor is "**Green construction**" with a mean value of (6.52), and a global rank (3), and in third place is "**Disasters resiliency**" with a mean value of (6.25) and a global rank (7) mean it's the third most critical factor in the overall SWOT.

It can be noticed that the strengths category holds two of the top three factors in the overall SWOT, which can explain that the strengths category is the most important category in the sustainability SWOT matrix as it will be shown later in the study in Table 4.16.

Table 4.7: Higher Costs for Green Building - Assessment Summary

Weakness Factor (1): **Higher costs for green building**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	10	18.52	5.42	1.98	3	12
	Moderate	22	40.74				
	High	22	40.74				

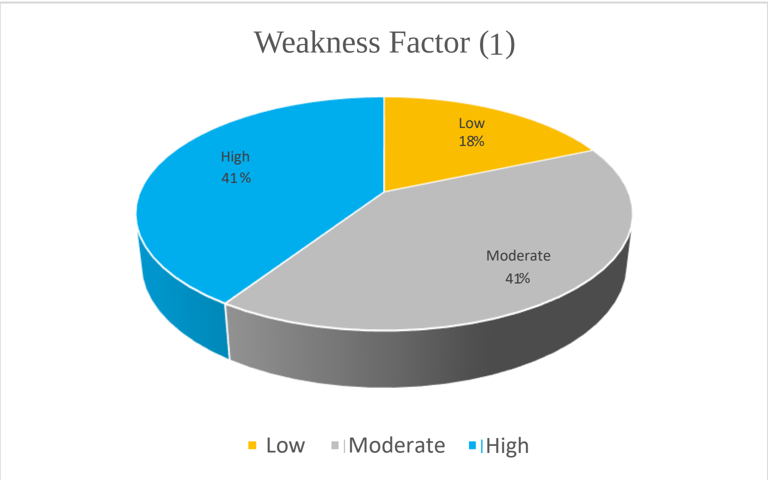

Figure 4.4: Importance Distribution by Respondent Frequency - Sustainability W (1)

Table 4.8: Sustainability Implementation Complexity - Assessment Summary

Weakness Factor (2): **Sustainability implementation complexity**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	7	12.96	5.75	1.81	2	10
	Moderate	22	40.74				
	High	25	46.30				

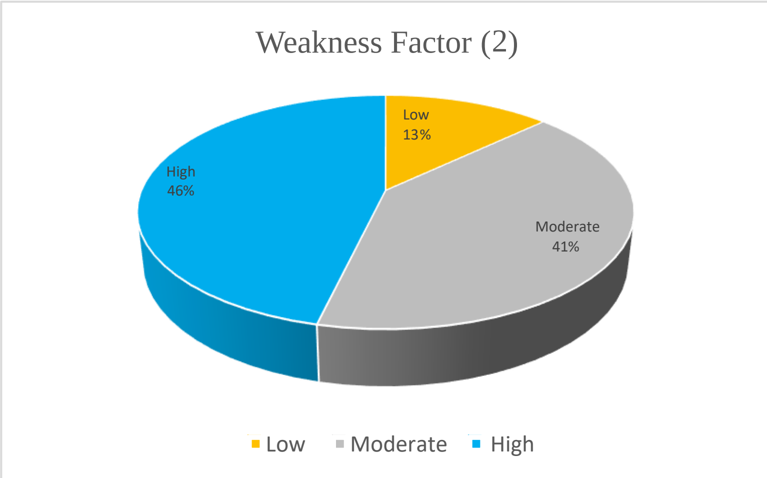

Figure 4.5: Importance Distribution by Respondent Frequency - Sustainability W (2)

Table 4.9: Overreliance on Technology - Assessment Summary

Weakness Factor (3): **Overreliance on technology**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	5	9.26	6.15	1.82	1	9
	Moderate	21	38.89				
	High	28	51.85				

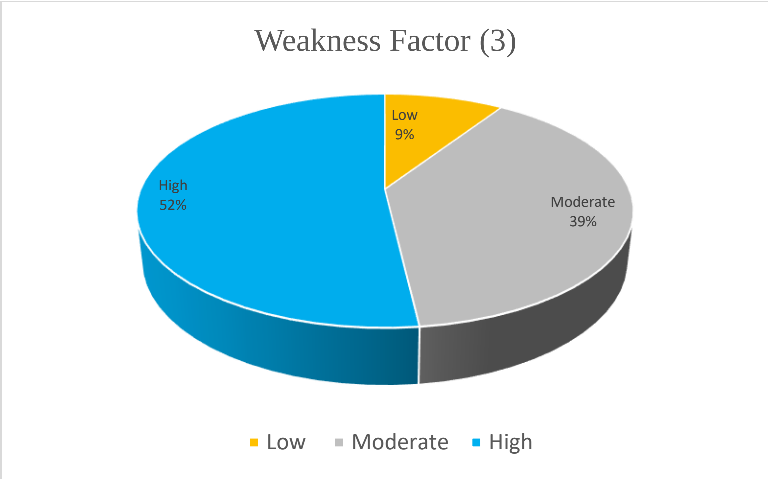

Figure 4.6: Importance Distribution by Respondent Frequency - Sustainability W (3)

The results presented in Table 4.7 to 4.9 indicate that the most critical weakness factor is "**Overreliance on technology**" with a mean value of (6.15) and a global rank (9), while the second most critical weakness factor is "**Sustainability implementation complexity**" with a mean value of (5.75) and a global rank (10), and in third place is "**Higher costs for green building practices and materials**" with a mean value of (5.42) with a global rank (12) meaning it's the least importance factor on the overall sustainability SWOT.

It can be noticed that the Weaknesses category holds two of the least important three factors in the overall sustainability SWOT which can explain that the Weaknesses category is the least important category in the sustainability SWOT matrix as it will be shown later in the study in Table 4.16.

Table 4.10: Lower Pollution Levels - Assessment Summary

Opportunity Factor (1): **Lower pollution levels**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	3	5.56	6.64	1.64	1	1
	Moderate	16	29.63				
	High	35	64.81				

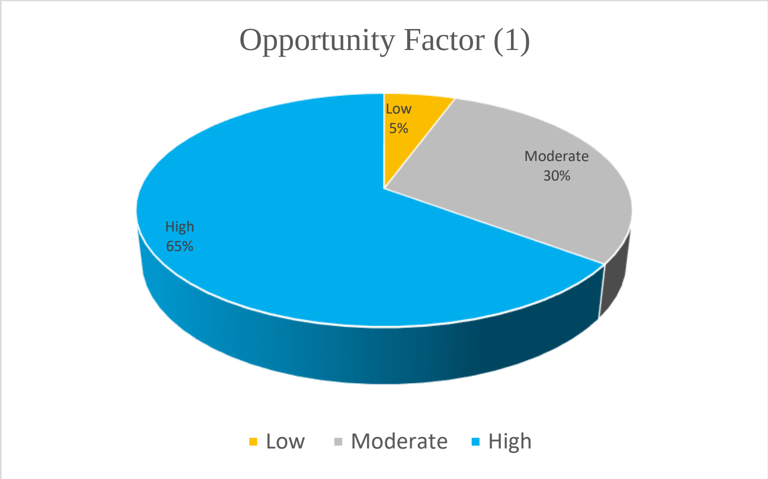

Figure 4.7: Importance Distribution by Respondent Frequency - Sustainability O (1)

Table 4.11: Protection of Natural Resources - Assessment Summary

Opportunity Factor (2): **Protection of natural resources**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	5	9.26	6.40	1.76	2	4
	Moderate	16	29.63				
	High	33	61.11				

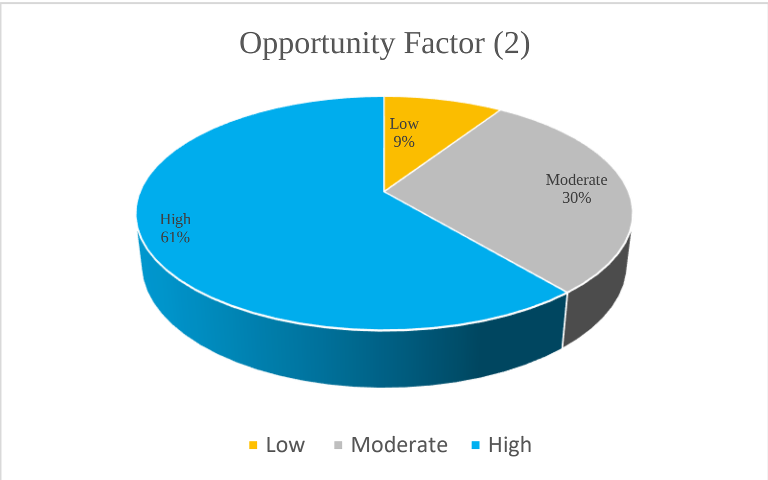

Figure 4.8: Importance Distribution by Respondent Frequency - Sustainability O (2)

Table 4.12: Citizen Engagement - Assessment Summary

Opportunity Factor (3): **Citizen engagement**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	4	7.41	6.38	1.85	3	5
	Moderate	16	29.63				
	High	34	62.96				

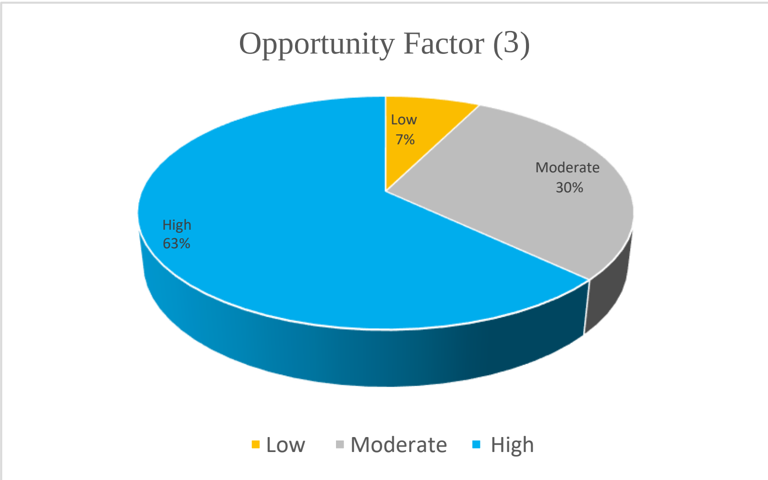

Figure 4.9: Importance Distribution by Respondent Frequency - Sustainability O (3)

The results presented in Table 4.10 to 4.12 indicate that the most critical opportunity factor is "**Lower pollution levels**" with a mean value of (6.64) and a global rank of (1) which means that it is the most critical factor in the overall sustainability SWOT, while the second most critical opportunity factor is "**Protection of natural resources**" with a mean value of (6.40) and a global rank (4), and in third place is "**Citizen engagement**" with a mean value of (6.38) and a global rank (5)

Table 4.13: Lack of Specialists in Smart and Green Buildings - Assessment Summary

<table>
<tr><th rowspan="4">Threat
Factor (1):
Lack of specialists in smart and green building</th><th>Range Scale Value</th><th>Frequency</th><th>Percentage %</th><th>Mean</th><th>Standard deviation</th><th>Local Rank</th><th>Global Rank</th></tr>
<tr><td>Low</td><td>4</td><td>7.41</td><td rowspan="3">6.23</td><td rowspan="3">1.84</td><td rowspan="3">2</td><td rowspan="3">8</td></tr>
<tr><td>Moderate</td><td>20</td><td>37.04</td></tr>
<tr><td>High</td><td>30</td><td>55.55</td></tr>
</table>

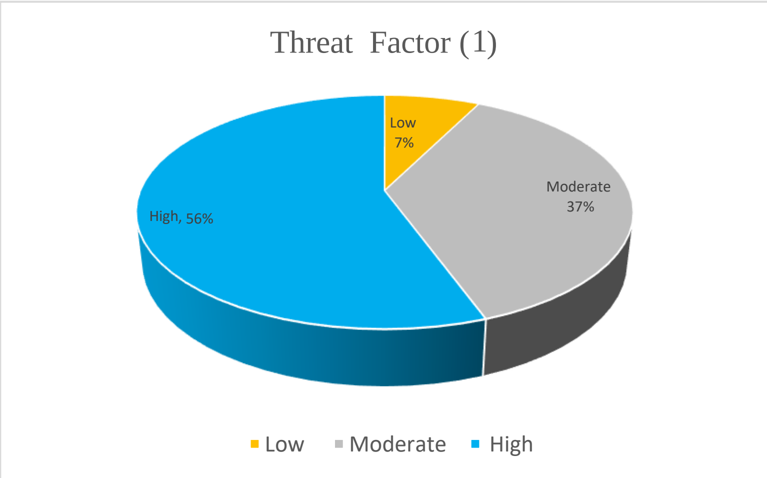

Figure 4.10: Importance Distribution by Respondent Frequency - Sustainability T (1)

Table 4.14: Increasing Energy Needs and Demand - Assessment Summary

<table>
<tr><th rowspan="4">Threat
Factor (2):
Increasing energy needs and demand</th><th>Range Scale Value</th><th>Frequency</th><th>Percentage %</th><th>Mean</th><th>Standard deviation</th><th>Local Rank</th><th>Global Rank</th></tr>
<tr><td>Low</td><td>8</td><td>14.81</td><td rowspan="3">5.66</td><td rowspan="3">2.02</td><td rowspan="3">3</td><td rowspan="3">11</td></tr>
<tr><td>Moderate</td><td>21</td><td>38.89</td></tr>
<tr><td>High</td><td>25</td><td>46.3</td></tr>
</table>

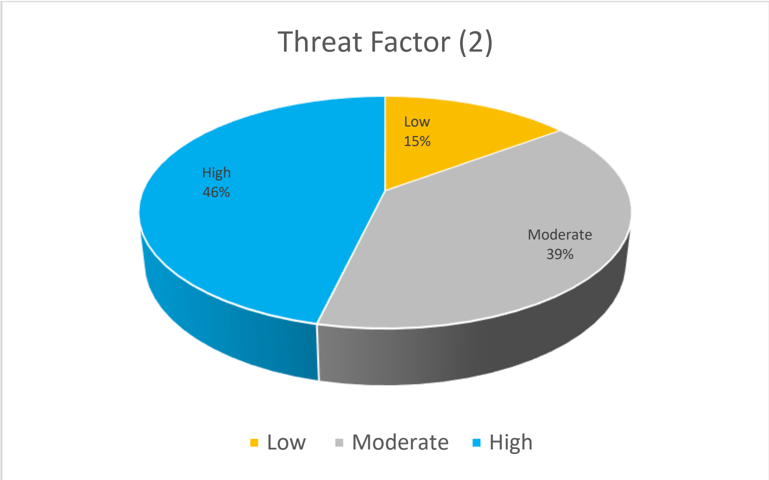

Figure 4.11: Importance Distribution by Respondent Frequency - Sustainability T (2)

Table 4.15: Low Demand for Green/smart buildings - Assessment Summary

Threat Factor (3): **Low demand for green/smart buildings**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	2	3.7	6.27	6.27	1	6
	Moderate	21	38.89				
	High	31	57.41				

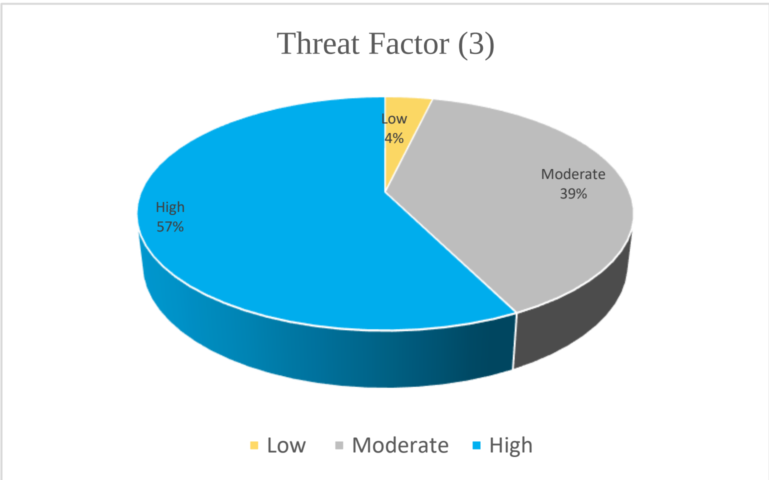

Figure 4.12: Importance Distribution by Respondent Frequency - Sustainability T (3)

The results presented in Table 4.13 to 4.15 indicate that the most critical Threat factor is "**Low demand for green/smart buildings**" with a mean value of (6.27) and a global rank (6), while the second most critical Threat factor is "**Lack of specialists in smart and green buildings**" with a mean value of (6.23) and a global rank (8), and in third place is "**Increasing energy needs and demand**" with a mean value of (5.66) and a global rank (11) which mean it's second to last important factor in the overall sustainability SWOT.

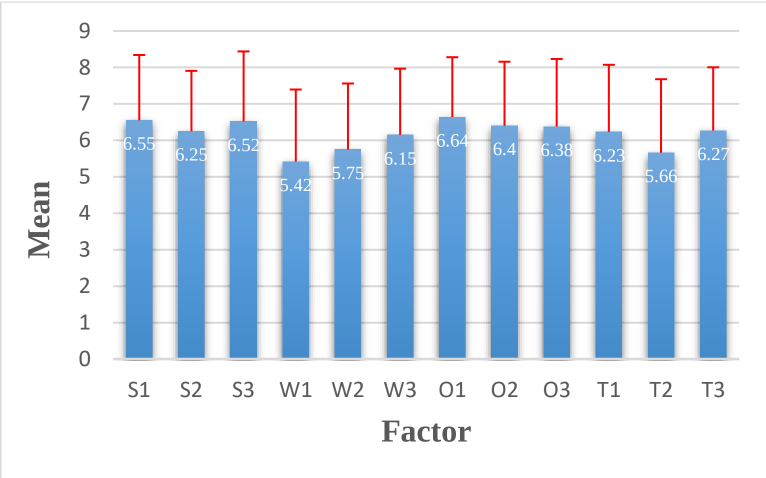

Figure 4.13: Means & Standard Deviation of Sustainability SWOT Factors

- Red lines show standard deviation

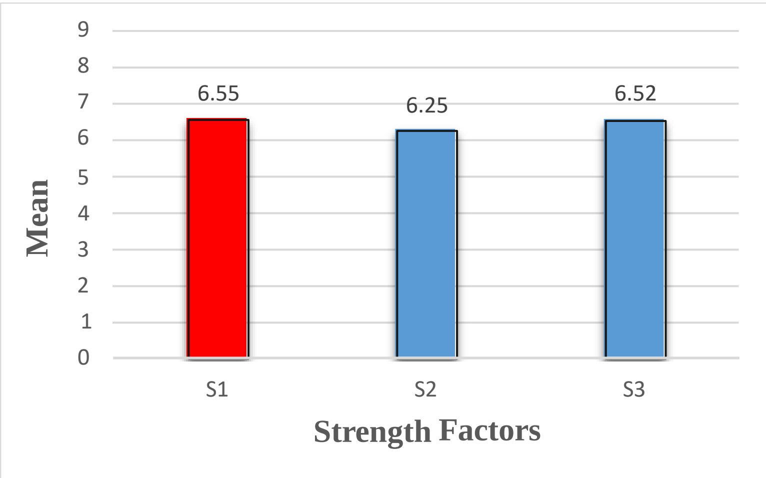

Figure 4.14 Means of Sustainability Strengths Factors

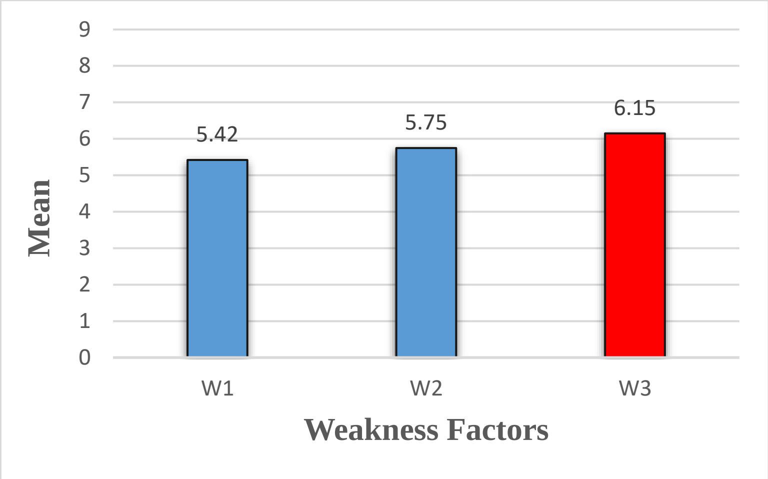

Figure 4.15: Means of Sustainability Weakness Factors

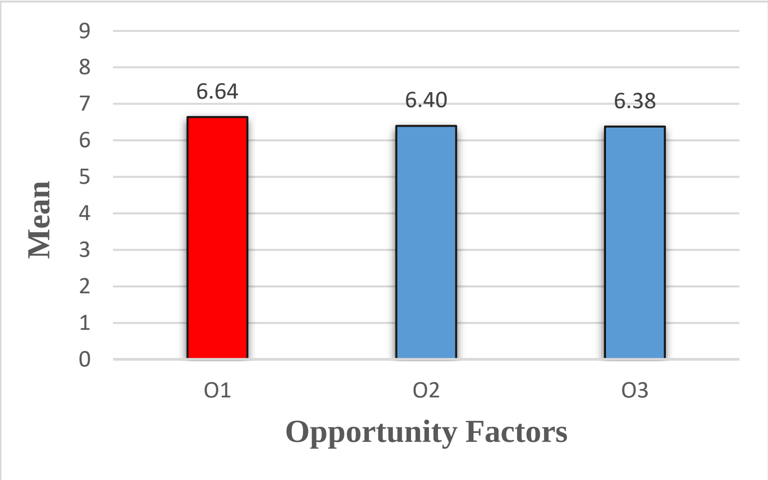

Figure 4.16: Means of Sustainability Opportunity Factors.

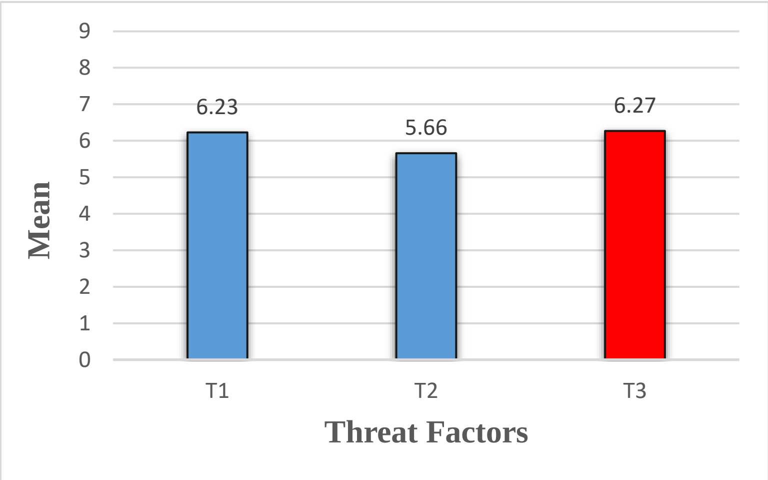

Figure 4.17: Means of Sustainability Threat Factors.

Table 4.16: Relative Priority and the Total Prioritization of Sustainability Factors

SWOT category	RW	Category Rank	Factor	RP	TP
Strengths	0.270	1	S1	0.339	0.092
			S2	0.324	0.087
			S3	0.337	0.091
Weaknesses	0.226	4	W1	0.313	0.071
			W2	0.332	0.075
			W3	0.355	0.08
Opportunities	0.266	2	O1	0.342	0.091
			O2	0.329	0.088
			O3	0.328	0.087
Threats	0.237	3	T1	0.343	0.081
			T2	0.312	0.074
			T3	0.345	0.082

RW: Relative Weight, RP: Relative Priority, TP: Total Prioritization

TP = RW × RP

Total Prioritization = Relative weight of the category × Relative priority of the factor within the category

4.3.2 Disaster Management

Table 4.17: Developed Disaster Management System - Assessment Summary

Strength Factor (1): **Developed disaster management system**	Range Scale Value	Frequency	Percentage %	Mean	Standard deviation	Local Rank	Global Rank
	Low	2	3.7	7.16	1.54	1	1
	Moderate	5	9.26				
	High	47	87.04				

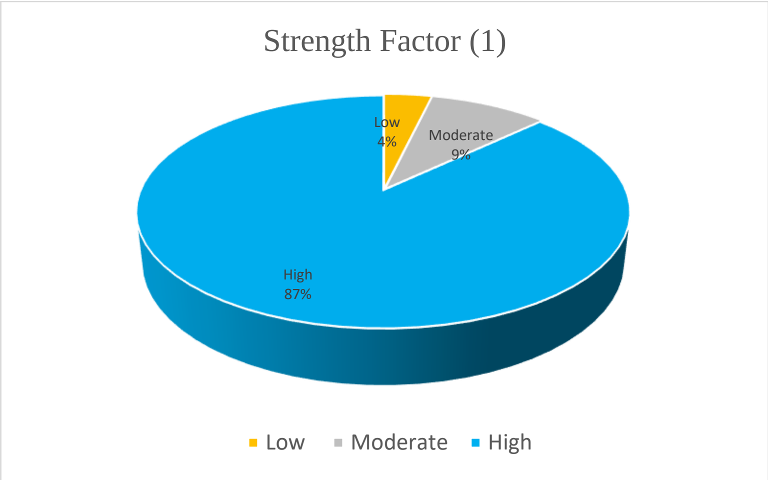

Figure 4.18: Importance Distribution by Respondent Frequency - Disaster Management S (1)

Table 4.18: Resilient Smart Structure - Assessment Summary

Strength Factor (2): **Resilient Smart structure**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	4	7.41	6.40	1.86	3	6
	Moderate	14	25.92				
	High	36	66.67				

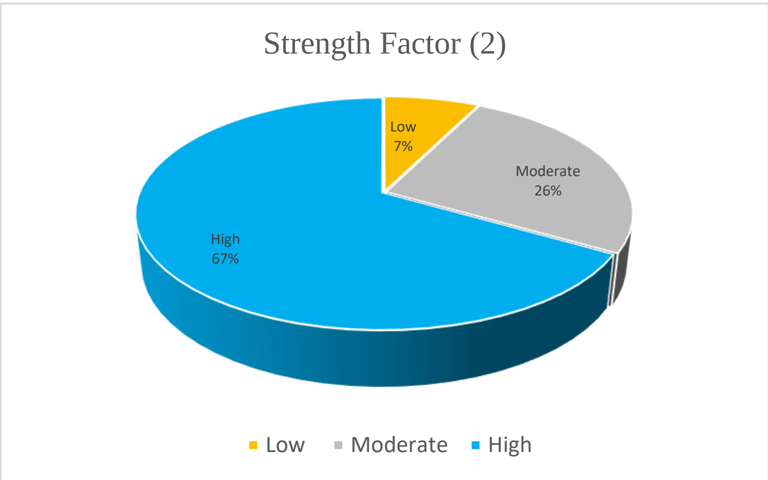

Figure 4.19: Importance Distribution by Respondent Frequency - Disaster Management S (2)

Table 4.19: Real-time Disaster Control System – Assessment Summary

Strength Factor (3): **Real-time disaster Control System**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	2	3.70	6.75	1.65	2	5
	Moderate	9	16.67				
	High	43	79.63				

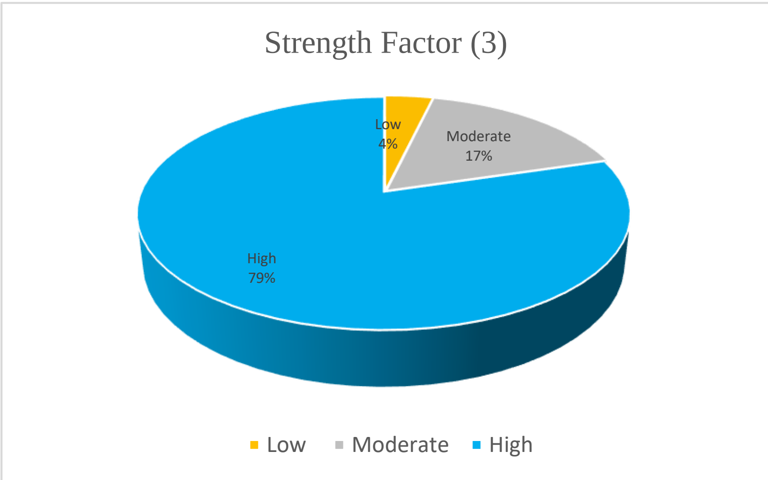

Figure 4.20: Importance Distribution by Respondent Frequency - Disaster Management S (3)

The results presented in Table 4.17 to 4.19 indicate that the most critical strength factor is the **"Developed disaster management system"** with a mean value of (7.16) and a global rank of (1) which mean that it is the most critical factor in the overall disaster management SWOT, while the second most critical strength factor is **"Real-time disaster control system"** with a mean value of (6.75) and a global rank (5), and in third place is **"Resilient smart structure"** with a mean value of (6.40) with global rank (6).

Table 4.20: The High Cost of Disaster Management Technologies – Assessment Summary

Weakness Factor (1): **The high cost of disaster management technologies**	Range Scale Value	Frequency	Percentage %	Mean	Standard deviation	Local Rank	Global Rank
	Low	7	12.96	5.89	2.24	3	12
	Moderate	18	33.33				
	High	29	53.7				

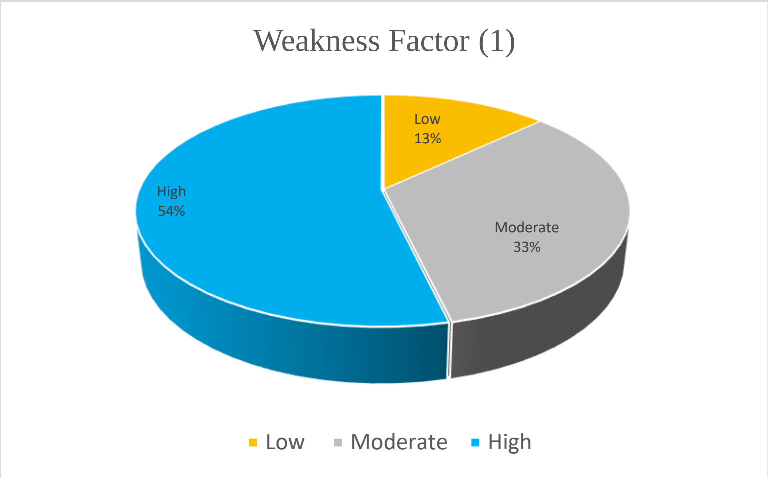

Figure 4.21: Importance Distribution by Respondent Frequency - Disaster Management W (1)

Table 4.21: Reliance on Energy for Operating - Assessment Summary

Weakness Factor (2): **Reliance on energy for operating**	Range Scale Value	Frequency	Percentage %	Mean	Standard deviation	Local Rank	Global Rank
	Low	8	14.81	6.00	2.03	2	10
	Moderate	15	27.78				
	High	31	57.41				

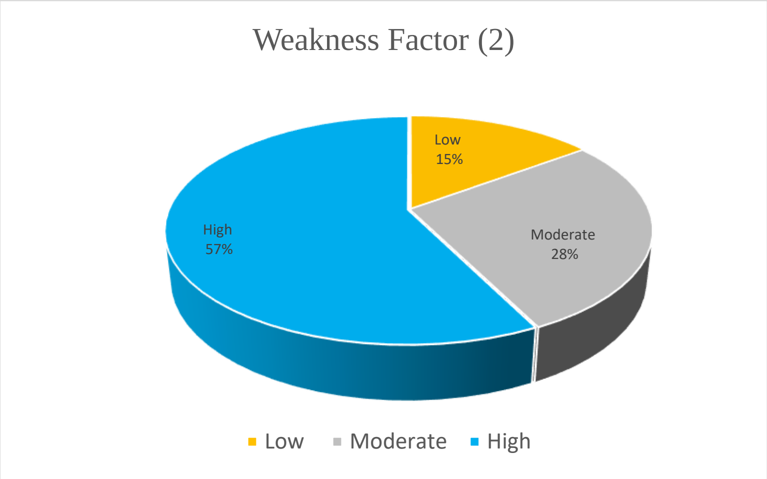

Figure 4.22: Importance Distribution by Respondent Frequency - Disaster Management W (2)

Table 4.22: Lack of Experience and Training in Smart Disaster Management - Assessment Summary

Weakness Factor (3): **Lack of experience and training in smart disaster management**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	6	11.11	6.14	2.20	1	8
	Moderate	18	33.33				
	High	30	55.56				

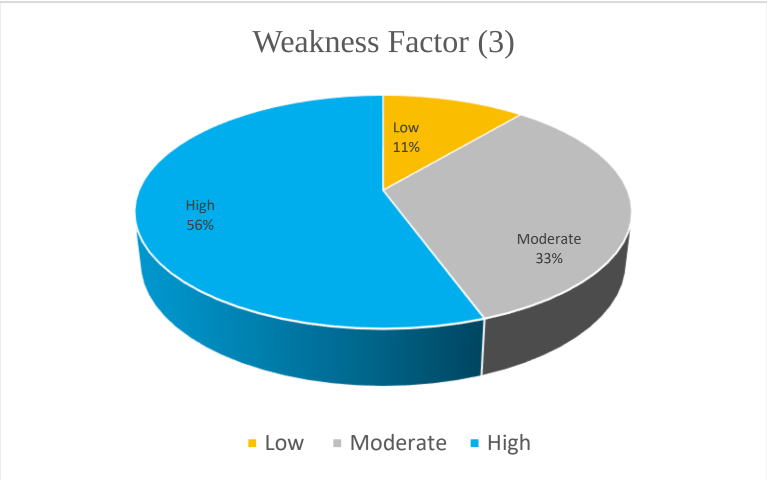

Figure 4.23: Importance Distribution by Respondent Frequency - Disaster Management W (3)

The results presented in Table 4.20 to 4.22 indicate that the most critical weakness factor is **"Lack of experience and training in smart disaster management"** with a mean value of (6.14) and a global rank (8), while the second most critical weakness factor is **"Reliance on energy for operating"** with a mean value of (6.00) and a global rank (10), and in third place is **"The high cost of disaster management technologies"** with a mean value of (5.89) and a global rank (12) meaning it's the least importance factor on the overall disaster management SWOT.

It can be noticed that the Weaknesses category holds two of the least important three factors in the overall disaster management SWOT which can explain that the Weaknesses category is the least important category in the sustainability SWOT matrix as it will be shown later in the study in Table 4.29.

Table 4.23: Post-disaster Rescue Systems - Assessment Summary

Opportunity Factor (1): **Post-disaster rescue systems**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	3	5.56	6.76	1.70	3	4
	Moderate	11	20.37				
	High	40	74.07				

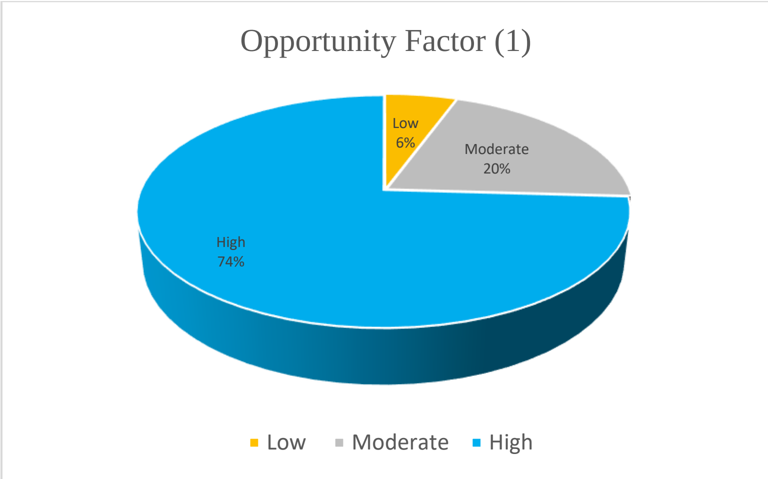

Figure 4.24: Importance Distribution by Respondent Frequency - Disaster Management O (1)

Table 4.24: Faster Emergency Response - Assessment Summary

Opportunity Factor (2): **Faster emergency response**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	2	3.70	6.89	1.63	1	2
	Moderate	12	22.22				
	High	40	74.07				

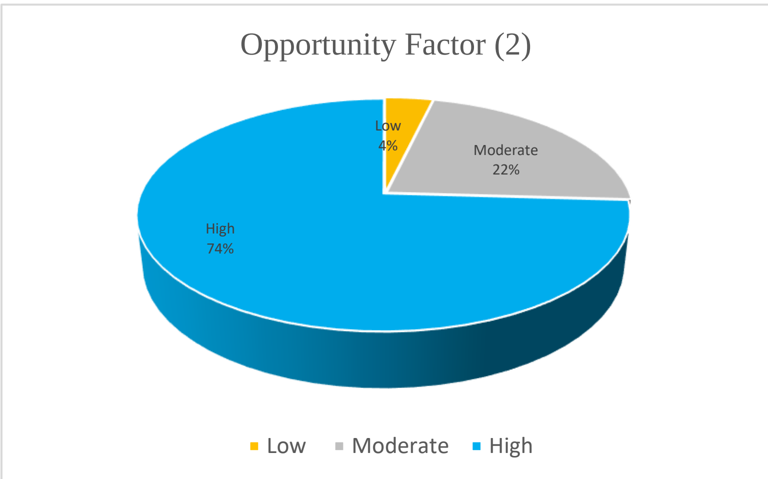

Figure 4.25: Importance Distribution by Respondent Frequency - Disaster Management O (2)

Table 4.25: Early Warning Systems - Assessment Summary

Opportunity Factor (3): **Early warning systems**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	3	5.55	6.76	1.79	2	3
	Moderate	10	18.52				
	High	41	75.93				

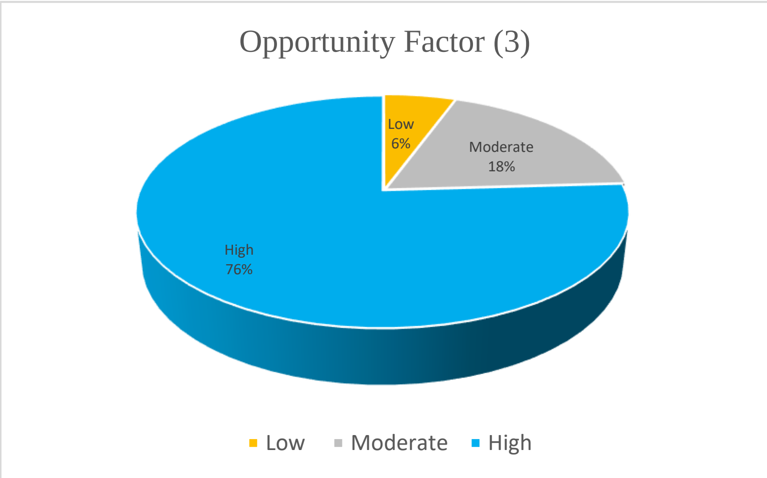

Figure 4.26: Importance Distribution by Respondent Frequency - Disaster Management O (3)

The results presented in Table 4.23 to 4.25 indicate that the most critical opportunity factor is "**Faster emergency response**" with a mean value of (6.89) and a global rank (2) meaning it's the second most critical factor in the overall disaster management SWOT, while the second most critical opportunity factor is "**Early warning systems**" with a mean value of (6.76) and a global rank (3) meaning it's the third most critical factor in the overall disaster management SWOT, and in third place is "**Post-disaster rescue systems**" with a mean value of (6.76) and a global rank (4). It can be noticed that the Opportunities category holds two of the top three factors in the overall SWOT, which can explain that the opportunities category is the most important category in the disaster management SWOT matrix as it will be shown later in the study in Table 4.29.

Table 4.26: Communication Systems Breakdowns and Fails - Assessment Summary

Threat Factor (1): **Communication systems breakdowns and fails**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	7	12.96	6.08	2.10	2	9
	Moderate	16	29.63				
	High	31	57.41				

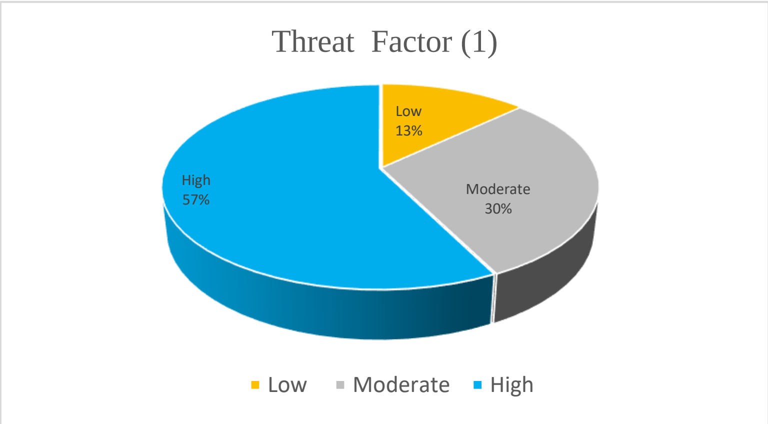

Figure 4.27: Importance Distribution by Respondent Frequency - Disaster Management T (1)

Table 4.27: Cyber Security Threats - Assessment Summary

Threat Factor (2): **Cyber security threats**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	7	12.96	6.18	2.16	1	7
	Moderate	17	31.48				
	High	30	55.55				

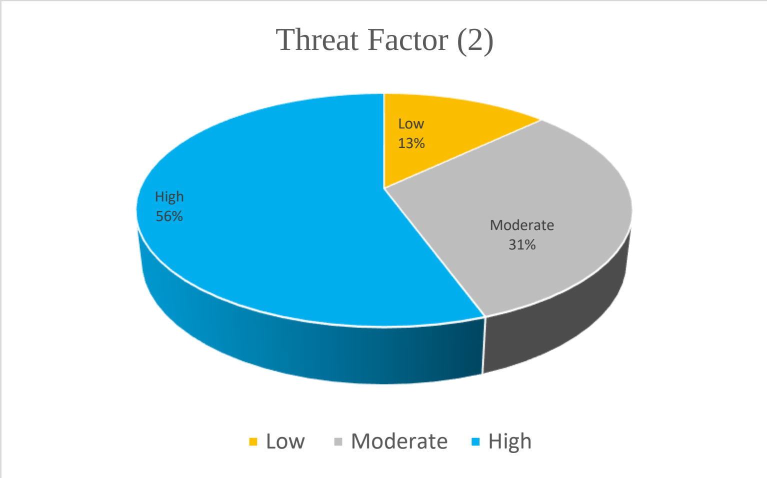

Figure 4.28: Importance Distribution by Respondent Frequency - Disaster Management T (2)

Table 4.28: Sensors and Monitoring Devices Get Damaged During Hazards - Assessment Summary

Threat Factor (3): **Sensors and monitoring devices get damaged during hazards**	**Range Scale Value**	**Frequency**	**Percentage %**	**Mean**	**Standard deviation**	**Local Rank**	**Global Rank**
	Low	9	16.67	5.98	2.26	3	11
	Moderate	15	27.78				
	High	30	55.55				

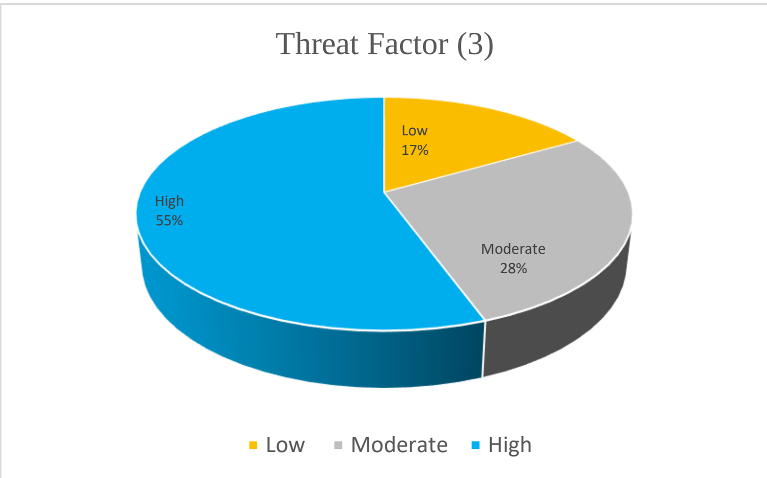

Figure 4.29: Importance Distribution by Respondent Frequency - Disaster Management T (3)

The results presented in Table 4.26 to Table 4.28 indicate that the most critical Threat factor is "**Cyber security threats**" with a mean value of (6.18) and a global rank (7), while the second most critical Threat factor is "**Communication systems breakdowns and fails**" with a mean value of (6.08) and a global rank (9), and in third place is "**Sensors and monitoring devices get damaged during hazards**" with a mean value of (5.98) and a global rank (11) meaning it's the second to last least important factor in disaster management SWOT.

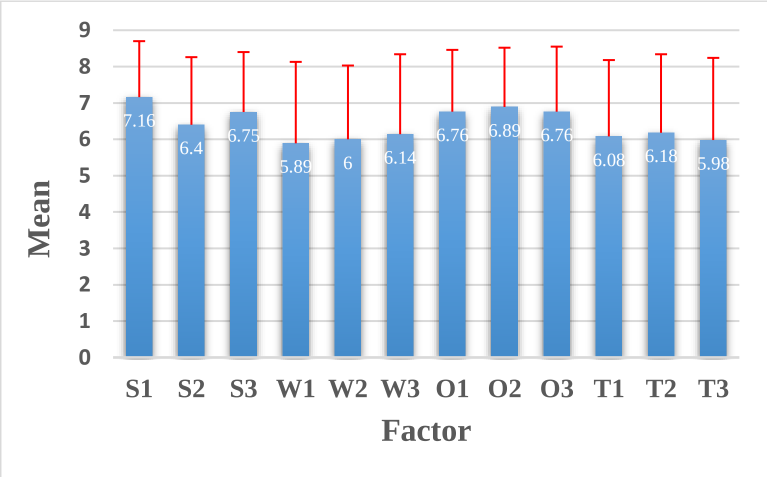

Figure 4.30: Means & Standard Deviation of Disaster Management SWOT Factors

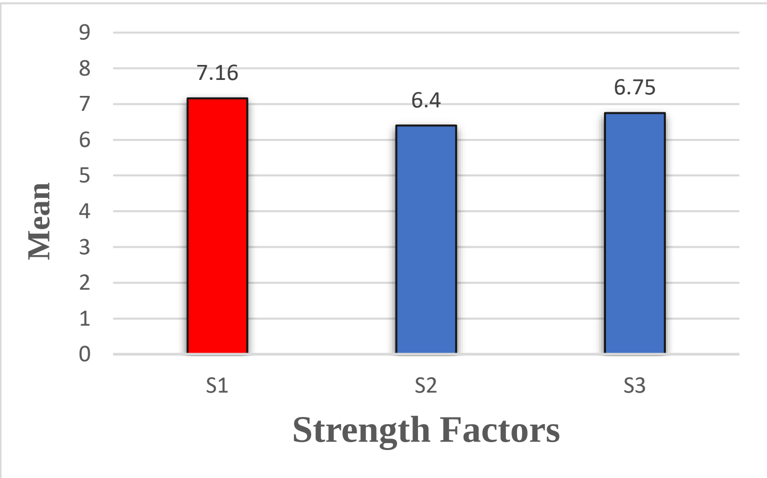

Figure 4.31: Means of Disaster Management Strengths Factors.

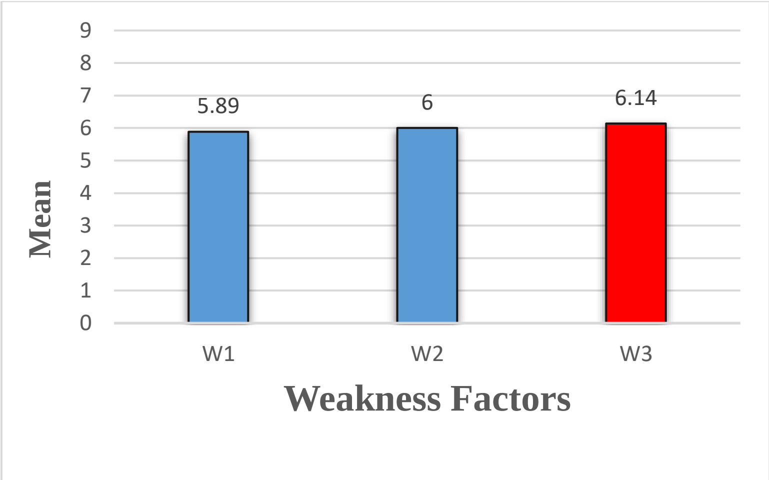

Figure 4.32: Means of Disaster Management Weakness Factors.

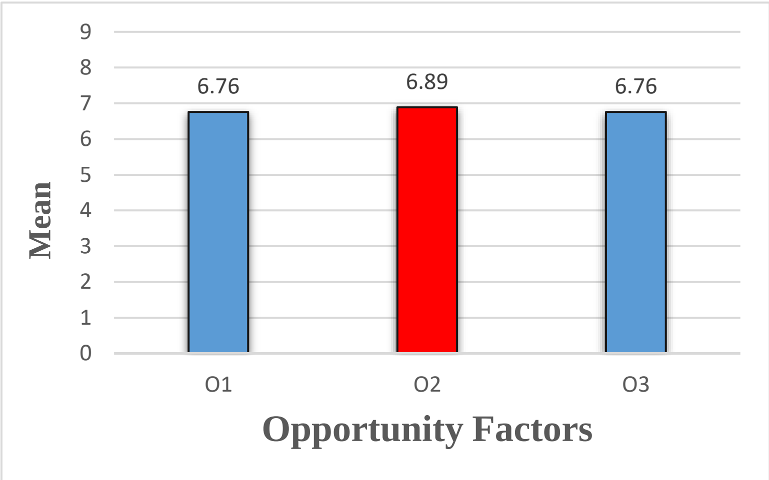

Figure 4.33: Means of Disaster Management Opportunity Factors.

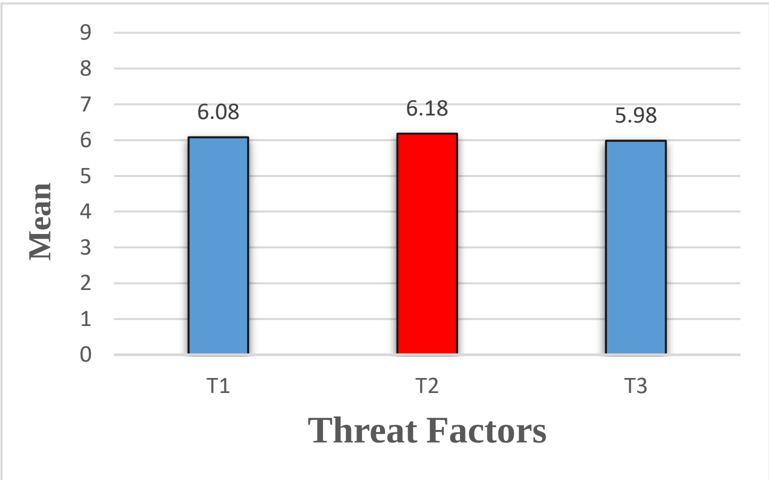

Figure 4.34: Means of Disaster Management Threat Factors.

Table 4.29: Relative Priority and the Total Prioritization of Disaster Management Factors

SWOT category	RW	Category Rank	Factor	RP	TP
Strengths	0.262	2	S1	0.353	0.092
			S2	0.315	0.083
			S3	0.332	0.087
Weaknesses	0.227	4	W1	0.327	0.074
			W2	0.333	0.076
			W3	0.340	0.077
Opportunities	0.267	1	O1	0.331	0.088
			O2	0.338	0.090
			O3	0.331	0.089
Threats	0.244	3	T1	0.333	0.081
			T2	0.339	0.083
			T3	0.328	0.080

RW: Relative Weight, RP: Relative Priority, TP: Total Prioritization

TP = RW × RP

Total Prioritization = Relative weight of the category × Relative priority of the factor within the category

4.4 TOWS Strategies

4.4.1 Sustainability TOWS Strategies

SO1

S1 - Sustainable Infrastructure and smart building.

S3 - Green Construction

O1- Lower pollution levels

O2- Protection of natural resources

Strategy:

Implement green construction practices, sustainable infrastructure, and smart buildings which use technologies promoting sustainability.

The adoption of green construction practices and the development of green infrastructure and smart buildings that utilize advanced technology are key approaches for achieving the sustainability of natural resources and reducing pollution levels in smart cities. These approaches work together to reduce environmental impact, create ecological balance, and promote effective resource management within the framework of smart city development.

Actions:

Installing pollution monitoring systems into the city infrastructure and smart buildings.

One of the primary elements of sustainability that smart cities aim to accomplish is environmental sustainability. As a result, a smart city aims to become a pollution-free city through its Sustainable Infrastructure and smart buildings.

IoT-based air quality and pollution Monitoring sensors are widely used for smart cities' environmental management. The general concept for these kinds of sensors is to measure the levels of various parameters in real-time such as temperature, some gases levels, dust particle density in the air, air humidity levels, and noise levels, then send the data to the pollution Monitoring Systems for analysis and feedback (Siregar et al., 2016).

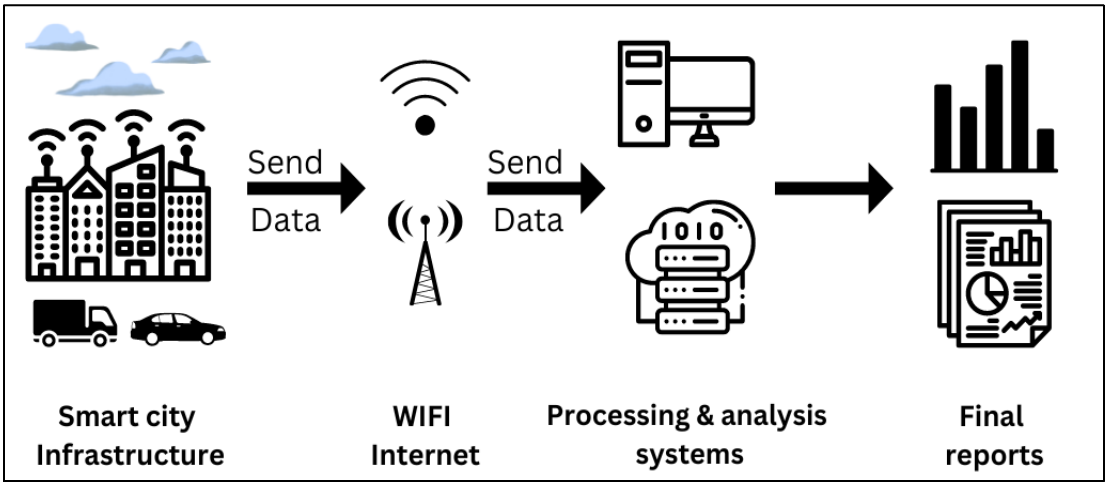

Figure 4.35: Smart cities Air Quality Monitoring System

For predicting pollutant concentrations and assessing environmental and health risks associated with air pollution, artificial intelligence (AI) and machine learning (ML) approaches can be used in smart cities (Krupnova et al., 2022). One of the common practices that can be used in smart cities is integrating AI, machine learning, and deep learning models for pollution and air quality prediction. This area is actively developing, and there have been an increasing number of studies on the use of machines and deep learning in this area.

Implementing smart energy grids and renewable energy into the city infrastructure and buildings.

By implementing smart energy grids to manage energy consumption and utilizing renewable energy sources, smart cities strive to produce clean renewable energy, decrease the consumption of fossil fuels, and minimize greenhouse gas emissions.

Implementing smart sustainable transportation systems.

Smart cities strive to provide their citizens with the best mobility while reducing the environmental impact of traditional fuel-based transportation while at the same time providing the best access to public transportation services for its citizens.

Bamwesigye & Hlavackova (2019) Showed case the relationship between sustainable transportation and smart cities, they demonstrated that smart cities utilize smart mobility by providing user-friendly transportation services and integrating ICT through several applications such as inelegant lighting systems for car parking and providing special services for disabled people. Also providing transportation infrastructure with intelligent energy services through electric cars, motor-free transportation, and public charging systems.

Ideally, the governments of smart cities would adopt regulations to limit fuel-based transportation as much as possible while making shared public transportation easy to access for the public. Also providing motor-free transportation such as bicycles for public access can aid in reducing the number of cars and help toward the greener approach for sustainable transportation and less air pollution.

Even though several developed countries adopt smart city inelegant transportation systems that leverage IoT and big data to mitigate traffic and other transportation problems. However, it should be mentioned that this approach can be quite costly for developing countries (Zhao & Jia, 2021). Thus, when studying the implementation of intelligent transportation in developing countries, a detailed cost management assessment should be conducted.

Incorporating green practices into city infrastructure.

Smart cities successfully lower pollution levels by cooperating with city urban planners to develop and implement green infrastructure practices, which include distributing green spaces and areas throughout the city. Furthermore, bringing together architecture and civil engineering to arrive at designs that incorporate greenery into open spaces, parking lots, transport areas, and residential buildings to make them more environmentally friendly.

Integrating sustainable and green construction practices which is resource efficient.

- Utilizing green environmentally friendly concreting green materials such as silica fume, fly ashes, slags, recycled materials, etc.
- implementing green construction management to improve resource efficiency and reduce the impact of building practices on the environment.

Implementing anti-pollution construction solutions.

Incorporating zero-emission construction sites

A zero-emission construction site is one where construction activities do not emit any direct or indirect greenhouse gases (GHGs) (Fufa et al., 2019).

Utilizing efficient and sustainable resources management plans

- Implementing efficient and smart waste-management-plan to reduce materials waste in construction sites.
- Utilizing recycled material and byproduct materials and wastes for more sustainable construction and less natural resource consumption.
- Utilizing renewable energy sources and minimizing electricity and fuel usage for construction operations.

SO2

S1-Sustainable Infrastructure and smart building.

S3-Green Construction

O3- citizens engagement.

Strategy:

Enhance public awareness and engagement in smart cities' sustainability initiatives.

Actions:

- Government should put in place the necessary regulations and protocols that oblige citizens to adopt green construction methods.
- Offering public education campaigns on the benefits of green building methods and sustainable infrastructure strategies.
- Establishing online platforms for citizens to provide feedback and recommendations on sustainable city infrastructure and civil projects.
- Providing free education and training programs for sustainable practices and skills such as recycling, smart energy consumption, and water conservation to enhance citizens' ability to adopt sustainable behaviors.
- Spreading awareness about the smart city's sustainability initiatives and their positive impact on both citizens' surrounding environment and lifestyle.

ST1

S1 - Sustainable Infrastructure and smart building

S3 - Green Construction

T1 - Lack of specialists in smart and green building

T3 – Low demand for green/smart buildings

Strategy:

Increase the knowledge and awareness of smart cities' green sustainable practices for specialists and citizens.

By Implementing green construction practices, sustainable infrastructure, and smart buildings which use technologies sustainability can be promoted. However, the successful execution of these components requires the collaboration of engineering expertise and a professional workforce versed in implementing green practices and smart technologies with efficiency and precision. In addition, it is essential to increase citizen awareness of the advantages of sustainable infrastructure and smart, environmentally friendly structures in enhancing the quality of life and promoting environmental preservation. Therefore, accomplishing sustainability goals requires a comprehensive and coordinated strategy that maximizes both specialists' and citizens' knowledge and awareness.

Actions:

Emerging modern advancement in construction technology, sustainable and green practices, and smart building technologies in civil engineering education and training.

This can be achieved by Integrating training and educational programs for the role of smart cities and new advancements in civil engineering such as IoT, ICT, AI, Big data, etc. in sustainability. Furthermore, Conduct collaboration programs between Civil engineering and:

-Urban Engineering -Architecture -Software Engineering -Computer Engineering -Energy Engineering -Electrical Engineering -Mechanical Engineering

Integrating comprehensive education and training programs for smart and green construction.

- Integrating green and sustainable construction practices into civil teaching and training programs to achieve a sustainability approach in construction practices.
- Collaboration between Civil, Environmental, and Architectural Engineering departments to share knowledge and experience to design sustainability and green construction specialized courses or workshops.
- Gaining experience and references from successful sustainable smart city experiences in developed countries.
- Exchange and internship programs to gain valuable insight and obtain the necessary training and knowledge about smart city sustainability.

Raising awareness of green and smart building long-term sustainable benefits.

- Spreading awareness among citizens of the long-term economic and environmental sustainability that can be obtained by applying this kind of structure.
- Holding educational conferences for the city's capital stakeholders and contractors to demonstrate the long-term economic aspect of green\smart building.

Applying the required regulations and policies by the government to encourage the adoption of green\smart buildings.

- Reducing taxes on green construction materials and supplies and smart construction technologies.

- Implementation of mandatory laws for the use of green building methods on stakeholders and contractors.

WO1

W1- Higher costs for green building practices and materials

O2 - Protection of natural resources

Strategy:

Utilizing low-cost green concreting materials:

Actions:

Utilizing recycled materials such as:

Recycled aggregate: Several studies such as (Malešev et al., 2010), (Jain et al., 2015) have demonstrated that by using the right kind of recycled aggregate in concrete in a particular amount and with the addition of some admixtures, and proper mix design, concrete can be durable with satisfactory properties while achieving more economic and environmental benefits, leading to a more sustainable and green approach.

Recycled glass: Several research studies debated the sustainability benefits of utilizing glass waste powder in concrete as a cement replacement. (Guo et al., 2020) Stated that glass can be incorporated into concrete for large-scale civil infrastructure to improve its sustainability, mechanical characteristics, long-term durability, and performance in large-scale civil infrastructure besides the significant economic benefit. Furthermore, in comparison to cement production, the production of glass powder concrete reduces CO_2 emissions, as well as particulates and greenhouse gases significantly according to (Islam et al., 2017).

Utilizing waste materials

By utilizing waste materials in concrete, several sustainable outcomes can be achieved, such as reducing CO2 emissions, reducing environmental pollution, and protecting natural resources according to **(**Ahmad et al., 2021)**.** The type of waste can be selected based on availability and the intended use.

Some examples of waste materials that can be used in concrete: Construction demolition.

WO2

W3- Overreliance on technology.

O1 - Lower pollution levels

O3- Citizen engagement

Strategy:

Promote a comprehensive approach to smart city sustainability that goes beyond technology-based solutions while raising the human and non-technological approaches' roles in the city's operations system.

Technology is the main driver for the operations of smart cities, as it can be said that smart cities depend on technology to a large extent, and as a result, some technologies used in monitoring and analysis systems and key operations in the city’s infrastructure may require a source of energy to continue its work smoothly, and it is known that power plants for energy and its products contribute significantly to raising pollution rates in general, hence the need to adopt a strategy for the sustainability development which take technologies usage.

The strategy emphasizes two key areas of focus:

Actions:

Combining the implementation of technology-based and non-technology-based sustainability solutions.

This can be done by examining the city's overall sustainability status. The city's infrastructure, energy usage, waste management, and transportation systems should all be evaluated. This evaluation can give a clear view of the areas where technology-based and non-technology-based can be integrated for more efficiency.

- Implementing alternative energy sources that are cleaner and greener.

Energy is needed in smart cities to guarantee that technology operates effectively, and this energy is often obtained from traditional energy sources. Adopting cleaner and greener alternative energy sources like renewable energy, is essential for sustainability and minimizing the environmental harm caused by traditional energy production, which results in pollution.

increasing the role of citizens and non-technical techniques in the city operations system.

- Engaging humans' expertise in the city's infrastructure-related decision-making and management process, and not relying entirely on technologies in decision-making.
- Engaging the smart city's citizens by collecting their feedback and suggestions on the efficiency of the smart city infrastructure operations and utilizing their input in the decision-making process.

WT1

W2- Sustainability Implementation Complexity

W3 - Overreliance on technology

T1 - Lack of specialists in smart and green buildings

T2- Increasing energy needs and demand

Strategy:

Increase the number of specialists in both technology and non-technology sustainability solutions.

A strategy that takes into consideration two aspects should be drawn when considering the lack of specialists in smart and green building and the increase in energy needs and demand associated with the increasing number of technologies, along with the overreliance on technology for smart city operations.

Actions:

Increasing the number of specialists and experts in smart cities sustainability and smart building technologies.

Civil engineers must be well-trained and educated on the use of smart city technology to achieve sustainability. Civil engineers should be able to comprehend how smart city solutions can promote sustainability, increase resource efficiency, and overcome environmental concerns.

Increasing the number of specialists and experts in non-technological green building practices.

This can be achieved by encouraging the use of green building materials, sustainable construction practices, and urban planning strategies that prioritize human well-being and environmental protection.

Increasing the number of specialists in green energy and integrating smart energy grids and renewable green energy sources.

The issue of increased energy demand by smart city infrastructure, buildings, and various sectors could be encountered by implementing a smart energy grid and using greener energy solutions, such as renewable energy. This would involve providing clean, sustainable sources of energy that promote sustainability.

Educating and training civil engineers in decision-making and designing tools and software.

- Building Information Modeling (BIM) for achieving sustainable design and aiding in decision-making and complex analysis.
- Life Cycle Assessment (LCA) for decision-making and building's environmental impacts assessment.

A life cycle assessment is an analytical tool used to analyze the environmental impact of products and services (Hauschild et al., 2005). Life cycle assessment (LCA) can be used to increase sustainability in the construction industry according to (Ortiz et al., 2009).

Table 4.30: Sustainability Strategies Ranking

Strategy	Factors used for each strategy	TW	Rank
SO1	S1, S3, O1, O2	0.033	1
SO2	S1, S3, O3	0.016	3
ST1	S1, S3, T1, T3	0.015	4
WO1	W1, O2	0.006	6
WO2	W3, O1, O3	0.014	5
WT1	W2, W3, T1, T2	0.024	2

TW total weight

4.4.2 Disaster Management TOWS strategies

SO1

S1- Developed disaster management system

S3- Real-time disaster control system

O2- Faster emergency response

O3- Early warning systems

Strategy:

Enhance the city infrastructure communication system by implementing advanced and real-time smart disaster technologies.

This strategy aims to take advantage of smart cities Developed disaster management systems and real-time disaster control systems to achieve reliable early disaster warning systems and aid in achieving faster emergency response for disasters.

This will allow a better emergency response by providing fast and efficient information circulating during hazards, use of the smart technologies and communication systems can play a vital role in achieving the optimum emergency response to various hazards in smart cities.

This can be achieved by:

- Applying big data systems for more reliable data storage and analytics.
- Connecting city infrastructure and buildings by IoT sensing systems for enhanced and reliable collection of data, which can be necessary for the early detection of disasters.
- Using artificial intelligence (AI) machine learning software, analytics of big data systems, and pattern learning methods for early disaster prediction

Communication and information technologies (ICT) should be integrated into the city's infrastructure to ensure that the city has a reliable communication network so that warning systems and early response actions can be implemented.

- Utilizing real-time monitoring and equipping the infrastructure with (IoT) sensors and actuators and other monitoring tools such as surveillance cameras and citizen-oriented reporting tools. (Berglund et al., 2020) Stated that with the help of IoT, city decision-makers can implement actuators that respond to smart meter data in real-time, improving efficiency and responding to emergencies.
- Enhancing the Early warning systems for any potential hazards can significantly improve the response time, this can be achieved by ICT and IoT monitoring systems, sensors and information processing tools, and reliable and quick reporting tools to the concerned authority. And also, by utilizing AI prediction for potential hazards.
- Utilizing Unmanned Aerial Systems and drone technology for Emergency Response. Drones can play a critical role in smart cities’ disaster management and response, several studies reviewed the role of drones in disaster management,

and the role that drones can play to aid in disastrous situations against both natural and man-made disasters, (Khan et al., 2018) reviewed several uses of drones in smart cities in several emergencies, firefighting and rescue operation and how smart cities can utilize drones as a very effective tool in its disaster management.

- Citizens' privacy should be taken into consideration when looking into drones' utilization in smart cities.
- A collaboration between civil engineers and city urban planning should be presented to ensure a strategic placement for hazard response stations .and for implementing a smart transformation framework that allows the fastest disaster to reach emergency vehicles.

SO2

S1- Developed disaster management system

O1-Post-disaster rescue systems

Strategy:

Invest in smart post-disaster rescue systems and AI-based technologies and robotics.

Actions:

- Utilizing Unmanned Aerial Vehicles (UAVs) and emergency drones for more efficient victim detection and damage assessment.
- Utilizing search and rescue (SAR) robots, which utilize a wide range of sensors and imaging technologies to aid in the detection of victims and the access to hard-to-reach areas post-disaster.

- Utilizing autonomous thermal mapping, which can help detect victims by capturing heat from living beings using sensors.

ST1

S1- Developed disaster management systems.

S2- Resilient Smart structure

T1- Communication systems breakdowns and fails.

T3- Sensors and monitoring devices get damaged during hazards.

Strategy:

Integrate Disaster-Resilient Infrastructure, smart structure, and Communication System.

By implementing a comprehensive strategy maximizing the resilience of the smart city's structures, infrastructure, and communication systems, disaster preparedness could significantly be enhanced along with disaster response and recovery.

Actions:

Adapting Smart structures disaster resilient design:

- Incorporating disaster-resilient construction practices and materials, such as fireproof concrete, into smart buildings.
- Implementing structural seismic proofing methods such as seismic dampers and base isolation in seismically active regions.
- Installing waterproofing and smart drainage systems in city infrastructure and buildings.
- Equipping structures with IoT smart sensors, actuators, and real-time monitoring systems for structure health and external environmental factors

- Connect structures with control centers by utilizing communication and information technologies.
- Equipping structures with early warning systems

Securing wired communications lines and implementing wireless communications:

- Installing underground wire cable systems, which provide greater resilience against disasters and harsh environmental conditions, are more visually appealing than overhead contact systems (OCS), and are more stable, which may contribute to enhanced connectivity.
- Establish a wireless communication infrastructure to enable communication between devices, sensors, and infrastructure elements through the Internet of Things (IoT).

Enhancing the durability of sensors and monitoring devices and providing them with physical protection:

- Isolate sensors and monitoring devices using special durable boxes, shields, foams, rubber barriers, etc.
- Applying vibration isolation and shock protection to reduce the impact of vibrations caused by seismic activity and other hazards.

Invest in high-durability and waterproofing sensors and monitoring devices.

ST2

S1 - Developed disaster management system

T2 - Cyber security threats

Strategy:

Create a well-developed framework for managing cyber security threats.

Actions:

- Securing vital (IoT) monitoring devices and sensors with the required security solutions and measures, such as appropriate security software with ongoing updates, to maintain privacy and prevent data theft.
- Collaborating with ethical hackers to test the cybersecurity system and uncover and fix any gaps in it. Pike (2013) defined "ethical hackers" as hackers who devote themselves entirely to practicing legal and regulatory laws as well as the ethical standards that apply to the task at hand.
- Developing legislation and protocols related to electronic crimes related to smart cities' cyber security.

Physical access to data collection devices and infrastructure components must be secured to prevent unauthorized intervention.

WO1

W3 - Lack of experience and training in smart disaster management

O1- Post-disaster rescue systems

Strategy:

Provide training and educational programs in post-Disaster Rescue Systems utilizing smart technologies

Actions:

- Promoting the utilization of advanced technologies in disaster management. Civil engineers may make use of smart technology like drones, IoT devices, and data analytics to enhance situational awareness and rescue operations during disasters.
- Collaboration between civil engineering organizations responsible for disaster management with those responsible for rescue operations in disaster situations to develop a more comprehensive understanding of how to utilize and operate smart technology in rescue operations during hazards.
- Conducting regular disaster simulation exercises and drills to provide emergency responders with practical training and get them prepared to provide effective and coordinated responses during real disasters.

WT1

W1 The high cost of disaster management technologies

W2 - Reliance on energy for operating

T1 - Communication systems breakdowns and fails.

T3 Sensors and monitoring devices get damaged during hazards.

Strategy:

Establish resilient and cost-effective smart disaster management and Energy frameworks.

Smart city disaster management systems can be costly to implement and operate, which poses a significant challenge for procurement and maintenance. Additionally, because these systems depend on energy to function, they are vulnerable to power outages during hazardous scenarios. Furthermore, the process of producing energy itself can be costly. To solve these issues, it is crucial to adopt a comprehensive strategy aimed at reducing expenses, increasing energy efficiency, and improving disaster resilience in smart cities. Multiple dimensions must be included in the approach to disaster management in smart cities in terms of resilience, economics, and energy challenges.

Actions:

Limiting the use of high-cost sensing and monitoring technologies for only critical buildings and infrastructure.

Diversifying energy sources and developing backup power plans.

- Diversifying energy sources and finding alternatives to electrical energy such as renewable energy.
- Implementing energy storage systems, such as backup generators and battery backup systems, to ensure continuity of operations in the event of power outages during hazards.
- A more sustainable and environmental approach can be achieved by using solar and wind generators.

Creating a holistic strategy and framework for the implementation of smart energy grids and renewable energy in the city.

- Implementing a smart energy grid in the city.

  Smart energy grids are a common practice in smart cities. A smart energy grid utilizes Smart Meters and other sensors linked to a broad communication infrastructure, The technology allows 2-way communication between utilities and consumers in real-time and manages energy usage through software (Simmhan et al., 2010).

- Considerations such as energy demand, environmental impact, city land and infrastructure availability, and economic capabilities should be made while designing the smart energy grid.

Integrating renewable energy sources:

- Studying the type of renewable energy source that is available and can be implemented in the city considering the city's geographical location, available natural resources, and the availability of necessary technologies and funding.

  Examples of renewable energy sources:

  Solar energy, wind power, hydropower, hydroelectricity, and biomass.
- Solar panels can be installed in suitable locations, such as buildings' rooftops, which can maximize efficiency and enhance the aesthetics of the building.
- Utilize modern monitoring and control systems for energy usage and distribution to ensure flawless integration of renewable energy sources into smart energy grids in smart cities.

WT2

W3 Lack of experience and training in smart disaster management

T2 Cyber security threats

Strategy:

Establish a partnership with cybersecurity authorities to gain experience and references.

Actions:

- Cooperating with cybersecurity experts to gain insight, guidance, and external assessment.
- Collaborating with research institutes, professional organizations, and cybersecurity firms to stay updated on emerging cyber risks, trends, and best practices.

Table 4.31: Disaster Management Strategies Ranking

Strategy	Factors used for each strategy	TW	RANK
SO1	S1 S3 O2 O3	0.032	1
SO2	S1 O1	0.008	4
ST1	S1 S2 T1 T3	0.028	2
ST2	S1 T2	0.008	5
WO1	W3 O1	0.007	6
WT1	W1 W2 T1 T3	0.024	3
WT2	W3 T2	0.006	7

Chapter 5

CONCLUSION AND RECOMMENDATION FOR FUTURE STUDIES

5.1 Introduction

This chapter contains conclusions and recommendations for further study. The first part is the conclusion, which summarizes the overall findings of the study. The second part contains the author's recommendations for future studies based on the study results, in order to improve smart city implementation in developing countries.

5.2 Conclusions

The conclusion drawn from the work done can be summarized as follows:

As a result of an intensive review of the literature related to smart cities, key internal factors (strengths and weaknesses) and external factors (opportunities and threats) were identified that may influence the development of smart cities in developing countries, factors then were drawn to a SWOT matrix. A questionnaire survey was then conducted targeting academics and Ph.D. students in civil engineering to determine the level of importance which each factor holds when looking into implementing smart cities in developing countries. Then a TOWS matrix was conducted to link the SWOT external and internal factors to form strategies and actions which can be followed to enhance the prosses of implementing smart cities initiative. In light of the preceding, the study recommended a set of strategies and actions that developing countries can follow to enhance the process of smart city creation and development in both sustainability and disaster management aspects.

By thoroughly analyzing the questionnaire survey responses to determine the significance of the SWOT factors as well as critically evaluate the total weight of TOWS strategies within this complex domain as it was aimed to and mention earlier in the study in section 3.4 in the research methodology. By adeptly bridging the gap between our survey findings and strategic formulation, the study seamlessly fused data-driven insights into actionable strategies. The beneficial connection between the outcomes of the questionnaire survey and the formulation of the strategies highlights the solid empirical basis on which the thoughtfully developed recommendations are established. It can be stated that the strategies and actions presented in this study are solidly based on the real views and specifications of those who are actively involved in creating smart cities that are sustainable and resilient in the face of disasters.

5.2.1 Sustainability

Regarding the sustainability aspect of smart cities and based on analyzing the questionnaire survey, the following results were obtained:

- Internal strengths are the most important category affecting sustainability, in second place are external opportunities, in third place are external threats, and finally in fourth place are internal weaknesses.

- Regarding the sustainability SWOT factors the rank is shown in table 5.1 below.

Table 5.1: Importance Rank of Sustainability SWOT factors

Factor	Category	Rank
Lower pollution levels	Opportunities	1
Sustainable Infrastructure and smart building	Strengths	2
Green construction	Strengths	3
Protection of natural resources	Opportunities	4
Citizen engagement	Opportunities	5
Low demand for green/smart buildings	Threats	6
Disasters resiliency	Strengths	7
Lack of specialists in smart and green building	Threats	8
Overreliance on technology	Weaknesses	9
Sustainability Implementation Complexity	Weaknesses	10
Increasing energy needs and demand	Threats	11
Higher costs for green building practices and materials	Weaknesses	12

- Sustainability Strategies rank based on the Total Weight is shown in Table 5.2 below (1 is the most important, 6 is the least important)

Table 5.2: Sustainability Strategies Rank

Strategy	Rank
Implement green construction practices, sustainable infrastructure, and smart buildings which use technologies promoting sustainability.	1
Increase the number of specialists in both technology and non-technology sustainability solutions.	2
Enhance Public Awareness and engagement in smart cities' sustainability initiatives.	3
Increase the knowledge and awareness of smart cities' green sustainable practices for specialists and citizens.	4
Promote a comprehensive approach to smart city sustainability that goes beyond technology-based solutions while raising the human and non-technological approaches roles in the city's operations system.	5
Utilize Low-cost green concreting materials.	6

5.2.2 Disaster Management

Regarding the Disaster management aspect of smart cities and based on analyzing the questionnaire survey, the following results were obtained:

- External opportunities are the most important category Disaster management, in second place is internal strengths, in third place is external threats and finally in fourth place is internal weaknesses.

- Regarding the Disaster management SWOT factors, the rank is shown in Table 5.3 below

Table 5.3: Importance Rank of Disaster Management SWOT Factors

Factor	**Category**	**Rank**
Developed disaster management system	Strengths	1
Faster emergency response	Opportunities	2
Early warning systems	Opportunities	3
Post-disaster rescue systems	Opportunities	4
Real-time disaster Control System	Strengths	5
Resilient Smart structure	Strengths	6
Cyber security threats	Threats	7
Lack of experience and training in smart disaster management	Weaknesses	8
Communication systems breakdowns and fails	Threats	9
Reliance on energy for operating	Weaknesses	10
Sensors and monitoring devices get damaged during hazards	Threats	11
The high cost of disaster management technologies	Weaknesses	12

- Disaster management Strategies rank based on the Total Weight is shown in Table 5.4 below (1 is the most important, 7 is the least important)

Table 5.4: Disaster Management Strategies Rank

Strategy	**Rank**
Enhance the city infrastructure communication system by implementing advanced and real-time smart disaster technologies	1
Integrate Disaster-Resilient Infrastructure, smart structure, and Communication System	2
Establish a resilient and Energy and cost-effective smart disaster management framework	3
Invest in smart post disasters rescue systems and AI-based technologies and robotics	4
Create a well-developed framework for managing cybersecurity threats	5
Provide training and educational programs in post-Disaster Rescue Systems utilizing smart technologies	6
Establish a partnership with cybersecurity authorities to gain experience and references	7

5.3 Recommendations for future studies

The following recommendations are pointed out by the author and can be used for further studies:

- Future studies should take a more inclusive approach by including stakeholders' and regular individuals" viewpoints, as this study used an academic-centric approach.

- Future studies should take into consideration the integration of additional factors in order to enhance the comprehensiveness and depth of the SWOT analysis. While the current study emphasized three key factors in each SWOT category, extending the scope to include a wider variety of relevant factors can result in a broader understanding of the subject matter.
- Future research should seek collaboration with specialists from various engineering backgrounds, such as software and computer engineering, to enhance the depth of understanding of the subject. Furthermore, researchers are advised to investigate a wider variety of smart city technologies and applications.

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