

**THE EFFECT OF BIM FUNCTIONALITIES ON
THE ENVIRONMENTAL PERFORMANCE OF
SYRIAN CONSTRUCTION PROJECTS**

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2025

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SYRIAN CONSTRUCTION PROJECTS**

by

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**Thesis submitted in fulfilment of the requirements
for the degree of
Masters in Science**

July 2025

ACKNOWLEDGEMENT

As I reach the end of this journey, my heart overflows with gratitude. First and foremost, I thank Allah for giving me the strength to overcome each challenge I faced, and blessing me with many achievements and experiences.

This accomplishment is dedicated to the ideal supervisor who never stopped supporting and guiding me. I deeply appreciate your understanding, patience and big heart. Dear Dr. Izyan Yahaya, you are the sun that lightened my way.

My beloved parents, my father Abdulghani Al Sakka and my mother Rofayda Al Khen, Thank you for your prayers, trust and endless love and support. I would not be here without you.

To the good heart, the one who encouraged me during my moments of doubt and always took my hand along this road with its' ups and downs, my dearest husband Alaa', thank you for believing in me. You will always be my hero.

Without your love, smiles, and innocent faces, I would have fallen into depression and failure. My two precious sons, Jamal Eddin and Zain Eddin, thank you for being the soul to my life.

My lovely sisters: Rama, Raghad, Riwa and Juman, thank you for being there for me and always wishing me success. You are the best.

Lastly, to Dear Prof. Nor'Aini Yusof, thank you for your invaluable assistance and wise counsel in shaping the foundation of this work. May Allah bless you always.

To each of you, with all my love and gratitude, I present this work.

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LIST OF ABBREVIATIONS

BIM	Building Information Modeling: Digital representation of physical and functional characteristics of facilities.
AEC	Architecture, Engineering, Construction: Industry sectors involved in building and infrastructure projects.
LEED	Leadership in Energy and Environmental Design: Certification for sustainable building practices.
BREEAM	Building Research Establishment Environmental Assessment Method: Rating system for environmental performance of buildings.
GHG	Greenhouse Gases: Emissions contributing to global warming and climate change.

KESAN FUNGSI BIM TERHADAP PRESTASI ALAM SEKITAR DALAM PROJEK PEMBINAAN DI SYRIA

ABSTRAK

Penerapan Pemodelan Maklumat Bangunan (BIM), adalah penting untuk meningkatkan prestasi alam sekitar dan mencapai kelestarian dalam usaha pembinaan semula negara Syria. Walaubagaimanapun, ketiadaan sistem pengkategorian yang diiktiraf secara universal bagi fungsi BIM menimbulkan cabaran yang ketara bagi pengamal industri pembinaan dalam menjalankan BIM secara efektif. Penyelidikan ini bertujuan untuk menyediakan panduan mengenai kategori fungsi BIM dan manfaatnya dalam meningkatkan prestasi alam sekitar dalam projek pembinaan. Objektif penyelidikan adalah pertama, untuk menentukan amalan alam sekitar dalam projek pembinaan di Syria, kedua, untuk mengenalpasti kategori fungsi BIM dan terakhir, untuk menganalisis impaknya terhadap prestasi alam sekitar. Kaedah penyelidikan Kuantitatif digunakan, melibatkan borang soal selidik berstruktur yang diedarkan melalui Google Forms. Analisa maklumbalas daripada 109 responden dijalankan dengan menggunakan SPSS. Dapatan kajian menunjukkan bahawa amalan alam sekitar yang diutamakan oleh ahli profesional pembinaan Syria termasuklah kecekapan tenaga, pengurangan sisa dan penggunaan bahan yang lestari. Selain itu, turut didapati bahawa fungsi utama BIM, iaitu Analisis, Pengurusan, Visualisasi, dan Penyelarasan, adalah penting dalam menyokong amalan-amalan alam sekitar ini. Hasil kajian juga mendedahkan bahawa fungsi-fungsi BIM ini meningkatkan prestasi alam sekitar secara signifikan, terutamanya dari aspek kecekapan tenaga dan pengurangan sisa. Ini menunjukkan manfaat praktikal pengintegrasian BIM ke dalam projek pembinaan. Secara keseluruhan, kajian ini menjadi panduan kepada professional pembinaan dalam menangani cabaran alam sekitar dan memperbaiki penerapan BIM dalam usaha pembinaan semula negara Syria.

THE EFFECT OF BIM FUNCTIONALITIES ON THE ENVIRONMENTAL PERFORMANCE OF SYRIAN CONSTRUCTION PROJECTS

ABSTRACT

The adoption of Building Information Modeling (BIM) is crucial for enhancing environmental performance and achieving sustainability in Syria's reconstruction efforts. However, the absence of a universally recognized categorization system for BIM functionalities poses significant challenges for construction industry practitioners in effectively implementing BIM in Syria. This research aims to provide guidance on BIM functionalities categories and their benefits in improving environmental performance in Syrian construction projects. The research objectives are threefold: first, to determine environmental practices in Syrian construction projects, second, to identify categories of BIM functionalities, and last to analyze their impact on environmental performance. A quantitative approach was employed, utilizing a structured questionnaire distributed via Google Forms, with 109 responses analysed using SPSS. The findings indicate that key environmental practices prioritised by Syrian construction professionals include energy efficiency, waste reduction, and the use of sustainable materials. Additionally, it was found that key BIM functionalities, i.e. Analysis, Management, Visualization, and Coordination are instrumental in supporting these environmental practices. The result also revealed that these BIM functionalities significantly improve environmental performance, particularly in the aspect of energy efficiency and waste reduction, underscoring the practical benefits of integrating BIM into construction projects. Overall, this study serves as a guide for construction professionals in addressing environmental challenges and improving the adoption of BIM Syria's reconstruction effort.

CHAPTER 1

INTRODUCTION

1.1 Introduction

This study investigates the influence of Building Information Modeling (BIM) functionalities on environmental performance practices in Syrian construction projects. It aims to assess how BIM can enhance sustainability initiatives within the context of Syria's construction industry, addressing critical gaps in current research by serving as an introductory exploration of the research topic, offering an in-depth examination of foundational concepts within the field of study. It establishes a contextual framework that clarifies the research problem, articulates specific research questions, and delineates the study's objectives. Moreover, it defines the research scope, emphasizes the study's contributions to existing knowledge, and outlines the methodological approach employed in this investigation. The thesis outline provides a comprehensive overview of the research framework, serving as a structural guide for subsequent chapters.

1.2 Research Background

The construction industry is crucial to global economic development, contributing significantly to GDP and employment across nations (Fei et al., 2021). It drives the creation of essential infrastructure - such as housing, transportation networks, and public services - that supports economic activity and improves quality of life. As urbanization increases worldwide, the demand for new construction further fuels economic growth and development (Li et al., 2021).

However, the construction industry also faces challenges, including its substantial environmental impact. As a major consumer of natural resources, the industry is responsible for significant environmental degradation. This dual impact highlights the importance of integrating sustainable practices to balance economic development with

environmental preservation (Jiang et al., 2022).

In Syria, the construction industry has been severely impacted by the ongoing conflict, which has led to widespread destruction of infrastructure and public services (Alhaffar et al., 2021). The war has created an urgent need for reconstruction, presenting both challenges and opportunities for the industry. Rebuilding efforts are complicated by safety concerns, disrupted supply chains, and a lack of access to materials (Gaafar, 2021).

Moreover, the reconstruction process poses environmental challenges, as the demand for building materials can strain Syria's natural resources. Addressing these challenges requires the adoption of modern construction techniques and sustainable practices to ensure that rebuilding efforts contribute to the country's long-term recovery and development (Dube, 2020).

The construction industry is one of the largest consumers of natural resources globally, contributing significantly to environmental degradation. It is responsible for approximately 40% of the world's energy use and generates substantial waste, with demolition and construction activities producing large quantities of debris (Omopariola et al., 2024). This sector also contributes to pollution through the emission of greenhouse gases, particularly carbon dioxide, from both construction activities and the production of building materials like cement and steel. Furthermore, construction activities often lead to the destruction of natural habitats and the loss of biodiversity, exacerbating the environmental impact (Erdoğan et al., 2021).

The unsustainable practices prevalent in the construction industry have severe consequences, including the depletion of non-renewable resources, increased energy consumption, and significant contributions to climate change. As global construction activities continue to expand to meet the demands of growing populations and urbanization, the environmental footprint of this sector is expected to rise. This highlights

the urgent need for a shift towards more sustainable construction practices that minimize environmental impacts and promote the responsible use of resources (Omopariola et al., 2024).

Syria faces unique environmental challenges in its construction industry, particularly in the context of post-conflict reconstruction (Habib, 2020). The prolonged conflict has not only devastated the country's infrastructure but has also severely disrupted its natural environment. The destruction of buildings and infrastructure has resulted in massive amounts of rubble and debris, much of which contains hazardous materials such as asbestos and heavy metals. The disposal of this debris poses a significant environmental threat, as improper handling can lead to soil and water contamination. Additionally, the urgent need for reconstruction has led to the rapid extraction of natural resources, further straining Syria's already fragile ecosystems (Said, 2021).

The reconstruction efforts in Syria also face challenges related to resource scarcity and environmental degradation. The conflict has depleted the country's natural resources, particularly in regions where large-scale destruction occurred (Gaafar, 2021). This scarcity is compounded by the lack of infrastructure and technology needed to implement sustainable construction practices. As a result, there is a risk that reconstruction efforts may prioritize speed over sustainability, leading to further environmental damage. Addressing these challenges requires a comprehensive approach that integrates environmental considerations into every stage of the reconstruction process (Safari et al., 2021).

Globally, there is a growing awareness of the environmental impacts of the construction industry and the need for sustainable development. The concept of sustainable development, which seeks to balance economic growth with environmental preservation, has gained traction as a response to the environmental challenges posed by construction

activities. This shift in focus is driven by increasing recognition of the finite nature of natural resources and the long-term consequences of environmental degradation. International agreements, such as the Paris Agreement, have also played a role in promoting sustainable practices within the construction industry by setting targets for reducing greenhouse gas emissions (Ogunmakinde et al., 2022).

The push for sustainable development in the construction sector has led to the adoption of various green building practices and standards. These practices aim to reduce the environmental impact of construction activities by minimizing waste, conserving energy and water, and promoting the use of sustainable materials. Green building certifications, such as LEED (Leadership in Energy and Environmental Design), have become increasingly popular to measure and encourage sustainability in construction projects. As global awareness of environmental issues continues to grow, the demand for sustainable construction practices is expected to rise, further driving the industry's shift towards sustainability (Hossain et al., 2020).

In Syria, the integration of sustainable practices in reconstruction efforts is crucial given the country's environmental and resource challenges (Habib, 2020). Sustainable development in this context involves not only rebuilding infrastructure but also doing so in a way that minimizes environmental impact and promotes the efficient use of resources. Given the extensive damage to Syria's natural environment during the conflict, it is essential to adopt construction practices that reduce waste, conserve resources, and enhance the resilience of rebuilt structures to future environmental challenges. This approach is particularly important in a country where resources are scarce, and the need for rapid reconstruction could easily lead to unsustainable practices if environmental considerations are not prioritized (Gaafar, 2021).

In the context of post-conflict reconstruction in Syria, sustainable construction

practices must prioritize elements that address both immediate recovery needs and long-term resilience. Beyond resource conservation and waste reduction, key elements include the use of locally sourced, low-impact materials to reduce transportation emissions and support local economies; the integration of renewable energy systems, such as solar panels, to ensure energy security in areas with limited infrastructure; and the adoption of modular or prefabricated construction techniques to accelerate rebuilding efforts while minimizing environmental disruption. Additionally, water management practices, such as rainwater harvesting and reducing eutrophication potential, are critical given the region's vulnerability to water scarcity. These targeted strategies not only align with global sustainability principles but also respond to the unique socio-economic and environmental challenges faced in Syria, ensuring that reconstruction efforts are both practical and environmentally responsible.

Sustainable reconstruction in Syria also offers an opportunity to rebuild better, by incorporating modern technologies and practices that improve environmental performance (Habib, 2020). For instance, the use of energy-efficient designs, renewable energy sources, and sustainable building materials can reduce the environmental footprint of reconstruction efforts. Moreover, by focusing on sustainability, Syria can not only address the immediate need for rebuilding but also lay the foundation for long-term environmental resilience, ensuring that the reconstruction process contributes to a more sustainable and prosperous future (Azzouz, 2020).

Innovation plays a critical role in improving the environmental performance of the construction industry (Mellado et al., 2020). Technological advancements, such as Building Information Modeling (BIM), prefabrication, and the development of new, sustainable materials, are transforming the way buildings are designed, constructed, and maintained. BIM, for example, allows for more precise planning and resource

management, reducing waste and improving efficiency. Innovations in materials science have led to the creation of eco-friendly building materials that have a lower environmental impact, such as recycled steel, low-carbon concrete, and sustainable timber. Additionally, advancements in construction methods, such as modular construction, offer the potential to significantly reduce the environmental impact of building projects by minimizing waste and energy use (Malagnino et al., 2021).

The adoption of innovative technologies and practices is particularly relevant to Syria's construction sector, especially in the context of post-conflict rebuilding. The use of BIM can greatly enhance the planning and execution of reconstruction projects, ensuring that resources are used efficiently and environmental impacts are minimized (Alnafrah et al., 2020). Furthermore, innovative construction techniques, such as modular construction, can accelerate the rebuilding process while reducing waste and conserving resources. By integrating these technologies into Syria's reconstruction efforts, the country can not only address its immediate rebuilding needs but also set a precedent for sustainable construction practices in the region (Asseburg, 2020).

The specific connection between BIM and environmental performance lies in the ability of BIM to address critical sustainability challenges within the construction industry, both globally and in Syria's post-conflict reconstruction context. BIM functionalities enable precise modeling, analysis, and optimization of resources, energy consumption, and material usage, which directly contribute to reducing environmental impacts such as greenhouse gas emissions, waste generation, and resource depletion. For instance, tools for energy simulation and daylight analysis allow designers to create energy-efficient buildings, while material quantity estimation supports the selection of environmentally friendly products and minimizes material loss. In Syria, where reconstruction efforts must balance limited resources with sustainability goals, leveraging BIM functionalities can

significantly enhance environmental performance. By embedding these functionalities into a standardized framework tailored to local needs, this study underscores their potential to mitigate environmental degradation while supporting sustainable development in post-conflict settings (Omopariola et al., 2024).

Globally, BIM has demonstrated significant potential in post-conflict and disaster recovery efforts, offering valuable lessons for Syria. For instance, in Haiti following the 2010 earthquake, BIM was utilized to streamline the planning and construction of resilient housing, enabling efficient material management and reducing waste through precise modeling. Similarly, in Nepal after the 2015 earthquake, BIM facilitated energy-efficient rebuilding strategies by integrating simulations for natural lighting and ventilation, which minimized long-term energy consumption while addressing resource constraints (Niraula, 2020). These examples underscore how BIM can enhance environmental performance in recovery contexts by optimizing resource use, improving design accuracy, and supporting sustainable practices. For Syria, where reconstruction must balance environmental sustainability with pressing socio-economic needs, these global case studies highlight the transformative potential of BIM in achieving efficient, resilient, and environmentally conscious rebuilding efforts.

Building Information Modeling (BIM) presents a complex challenge when it comes to definition, primarily due to its multifaceted nature. The term "BIM" is often used interchangeably to refer to different aspects of the construction process, leading to varying interpretations (Shirowzhan et al., 2020). For some, BIM is merely a software application that supports design and modeling tasks, facilitating the creation of detailed digital representations of physical structures. Others view BIM as a comprehensive tool that integrates multiple facets of a construction project, from design and construction to maintenance and eventual decommissioning. Additionally, there is a broader interpretation

of BIM as a process or methodology, one that revolutionizes traditional construction practices by promoting collaboration and information sharing among all stakeholders involved in a project. This divergence in interpretations can create confusion and complicates the establishment of a universally accepted definition of BIM (Wildenauer, 2020).

Traditional construction practices have long been the backbone of the industry, but they come with significant limitations that contribute to environmental degradation (Sandanayake, 2022). These methods often rely on outdated techniques and materials that are not optimized for sustainability, leading to excessive waste, high energy consumption, and increased carbon emissions. For instance, conventional building processes frequently involve over-ordering materials, which results in unnecessary landfill waste, while inefficient designs can lead to higher energy demands for heating, cooling, and lighting. Additionally, the lack of precise planning in traditional construction often leads to delays, cost overruns, and resource inefficiencies, all of which exacerbate the environmental impact. Highlighting these shortcomings underscores the urgent need for innovative approaches that prioritize sustainability and resource optimization (Aiguoarueghian et al., 2024).

Building Information Modeling (BIM) emerges as a transformative solution to address these challenges by distinguishing itself as both a process and a set of outputs (Kassem et al., 2022). As a process, BIM fosters collaboration and integration among all stakeholders, enabling more accurate planning, design, and execution of construction projects. This minimizes errors, reduces waste, and ensures that sustainable practices are embedded at every stage of development. The outputs of BIM, such as detailed 3D models and data-rich simulations, allow for better decision-making by providing insights into material efficiency, energy performance, and lifecycle costs. By leveraging BIM, the

construction industry can transition from traditional, fragmented practices to a more cohesive, environmentally conscious approach that aligns with modern sustainability goals (Likita et al., 2025).

Despite these definitional challenges, BIM is widely acknowledged as an innovative technology that significantly enhances the efficiency and effectiveness of construction projects (Godager et al., 2021). Its innovation lies in its ability to integrate and manage information across the entire lifecycle of a building, from the initial design phase through to construction, operation, and even demolition. In post-conflict scenarios such as in Syria, where the reconstruction of infrastructure is both urgent and complex, BIM's role becomes even more critical. It enables better coordination among various teams, reduces the likelihood of errors, and ensures that projects are completed on time and within budget. The ability of BIM to centralize data and facilitate real-time updates is particularly valuable in such contexts, where accurate and up-to-date information is crucial for the successful completion of projects. In essence, BIM not only streamlines construction processes but also supports the rebuilding of communities in a sustainable and resilient manner (Acar et al.).

Understanding the dimensions of BIM is essential for fully grasping its capabilities and potential. BIM is traditionally categorized into several dimensions, each representing a different aspect of the construction process (Jia et al., 2022). The most basic level is 2D, which involves traditional drafting and documentation. Moving to 3D, BIM incorporates three-dimensional modeling, allowing for a more comprehensive visualization of the project. The 4D dimension adds the element of time, enabling the integration of scheduling information with the 3D model to better plan construction sequences. The 5D dimension introduces cost analysis, helping project managers to track and control expenses more effectively. The 6D dimension focuses on sustainability and facilities management,

providing data that supports the building's long-term performance and maintenance. However, as more dimensions are proposed, such as 7D for safety and 8D for energy management, there is growing confusion about their precise definitions and applications. This complexity highlights the need for clearer guidelines and standardized practices in the use of BIM dimensions (Shehzad et al., 2021).

The functionalities of BIM extend across all stages of a construction project, making it a versatile and powerful tool. In the design phase, BIM enhances visualization and allows for the simulation of various design options, enabling architects and engineers to optimize their plans before construction begins (Wijekoon et al., 2020). During the construction phase, BIM facilitates better coordination among different teams, reducing the risk of errors and ensuring that the project stays on schedule and within budget. BIM also plays a crucial role in the operational phase, where it provides valuable data for the maintenance and management of the building throughout its lifecycle. This continuous flow of information from design to demolition not only improves efficiency but also contributes to more sustainable construction practices. By integrating various aspects of a project into a single digital model, BIM allows for more informed decision-making and better overall project outcomes (Abruzzini et al., 2022).

BIM's contribution to environmental performance is particularly relevant in the context of Syria's reconstruction efforts (Al-Mohammad et al., 2024). One of the key benefits of BIM is its ability to perform energy analysis during the design phase, which can lead to the creation of more energy-efficient buildings. This is crucial in a country like Syria, where resources are limited, and the environmental impacts of reconstruction are a significant concern. Additionally, BIM's capacity to conduct life cycle assessments (LCA) allows for a thorough evaluation of a building's environmental footprint, from construction to eventual demolition. By identifying opportunities to reduce waste, conserve resources,

and minimize the carbon footprint, BIM can help ensure that Syria's rebuilding efforts are not only effective but also sustainable. In a post-conflict setting, where the focus is often on rapid reconstruction, the integration of sustainability through BIM can make a significant difference in the long-term viability of the rebuilt infrastructure (Saeed et al., 2021).

However, the adoption of BIM in Syria faces numerous challenges. The ongoing conflict has severely disrupted the construction industry, leading to a lack of technological infrastructure and skilled personnel necessary for the effective implementation of BIM (Mishra et al., 2024). Furthermore, the urgency of reconstruction efforts might lead to resistance against adopting new technologies that require significant time and investment to deploy. Despite these challenges, the potential benefits of BIM in Syria's reconstruction are considerable. By improving project efficiency, reducing waste, and enhancing environmental performance, BIM can play a pivotal role in helping Syria rebuild in a way that is both sustainable and resilient. The adoption of BIM could also provide long-term benefits by establishing more modern construction practices within the country, which would be beneficial for future projects beyond the immediate reconstruction needs (Ghaffarianhoseini et al., 2017).

To Sum up, the adoption of Building Information Modeling (BIM) is crucial for enhancing environmental performance and achieving sustainability in Syria's reconstruction efforts. As Syria embarks on the complex task of rebuilding its infrastructure, BIM offers a comprehensive solution that integrates information across all stages of a construction project. This integration not only improves efficiency and reduces costs but also supports the development of sustainable building practices that are vital for Syria's long-term recovery. By embracing BIM, Syria can ensure that its reconstruction efforts are not only responsive to the immediate needs of its population but also resilient

and sustainable, laying the groundwork for a more stable and prosperous future.

1.3 Problem Statement

The integration of Building Information Modeling (BIM) into environmental practices has considerable potential to significantly enhance the sustainability and energy efficiency of buildings and infrastructure (Akhanova et al., 2021). BIM is a multifaceted tool that offers a wide array of features and applications that enables professionals to optimize building designs and construction processes in a way that promotes sustainability. However, despite its potential, the adoption and effective implementation of BIM in Syria's construction industry remain limited, particularly in the context of environmental performance practices. Researchers agree that there is a need to enhance BIM adoption and utilization in Syria (Abdulhadi, 2019).

However, one of the primary challenges in leveraging BIM for environmental project performance is the absence of a standardized classification system for BIM features which in this thesis will be indicated as BIM functionalities categorization (Acar et al.; Adamus, 2014). The term "standardized categorization for BIM" refers to the systematic organization and classification of Building Information Modeling (BIM) elements, processes, and data into a unified and consistent framework. This framework ensures that all stakeholders in the architecture, engineering, and construction (AEC) industry can communicate effectively, share information seamlessly, and collaborate without ambiguity. By standardizing the categorization of BIM components, the framework promotes interoperability, reduces errors, and enhances the overall efficiency of construction projects.

Building Information Modeling (BIM) adoption rates between Syria and global or regional trends. While 62% of small-scale firms and 80% of large-scale firms in the UK actively use BIM, Syrian adoption remains significantly lower due to economic instability and lack of regulatory frameworks. Although specific Syrian data is scarce, proxy data

from neighboring countries like Iraq and Lebanon, where BIM adoption rates are approximately 15% and 20%, respectively (Al Hammoud, 2021), provide a reasonable estimate for Syria's situation. This reliance on traditional methods exacerbates inefficiencies, as projects using BIM reduce cost overruns by up to 15% and error rates by 50% compared to traditional approaches (Ali et al., 2024). The use of proxy data is justified given the similarities in socio-economic challenges faced by Syria and its neighbors, strengthening the argument for addressing this gap through standardized categorization frameworks.

In the Syrian context, the absence of a standardized categorization framework has resulted in significant challenges for the adoption and implementation of BIM technologies. The lack of a unified system has led to fragmented workflows, inconsistent data exchange, and difficulties in collaboration among project teams. This study addresses this critical gap by developing a region-specific framework tailored to the unique needs and constraints of the Syrian AEC industry.

The BIM functionalities categorization challenges are compounded by broader issues within Syria's construction industry, such as a general lack of awareness and understanding of contemporary sustainable building practices and technologies. Many professionals are unfamiliar with the capabilities of BIM and how it can be utilized to advance sustainability and energy efficiency within the built environment. Additionally, the lack of incentives and regulatory frameworks that promote environmentally sustainable practices further hinders the adoption and implementation of both BIM and environmental performance methodologies (Al-Mohammad et al., 2024).

The absence of a standardized categorization system for BIM functionalities is particularly pressing in Syria, where the adoption and integration of BIM have been slower compared to global counterparts. Therefore, there is an urgent need to accelerate the

adoption and implementation of BIM within Syria's construction sector to promote sustainability and energy efficiency. The lack of a standardized classification system for BIM features complicates efforts by practitioners in Syria who seek to embrace and effectively implement BIM, potentially slowing its acceptance and limiting its optimal deployment in the Syrian construction industry (Ahmed et al., 2018).

Although there is an increasing recognition of the significance of environmental performance practices within the built environment, their integration and execution continue to be limited. This issue poses a considerable obstacle to the development of sustainable and energy-efficient buildings and infrastructure, which are crucial for the long-term welfare and prosperity of individuals. The problem is particularly severe in Syria, where there is a pressing need to enhance the adoption and implementation of environmental performance methodologies to foster sustainability and optimize energy usage (Al Hammoud, 2021).

A significant obstacle in the incorporation and execution of environmental performance practices in Syria pertains to the lack of awareness and understanding among professionals in the construction industry. Many professionals are unfamiliar with contemporary sustainable building practices and technologies, and consequently, they lack the requisite knowledge and competencies to implement them effectively. This constraint limits their capacity to advance sustainability and energy efficiency within the built environment (Amino et al., 2022).

The inadequate implementation of environmental performance measures poses a significant obstacle to establishing sustainable and energy-efficient structures and infrastructure within the built environment in Syria (Khaddour et al., 2023). Addressing this issue requires enhancing awareness and understanding among construction professionals, as well as developing incentives and regulations that encourage the adoption

and implementation of environmental performance methodologies. By overcoming these challenges, it is possible to facilitate the development of sustainable and energy-efficient buildings and infrastructure, which are essential for the long-term welfare and vitality of individuals (Gaafar, 2021).

The inadequate integration of Building Information Modeling (BIM) and environmental performance practices poses a substantial obstacle that impedes the capacity of BIM to enhance the sustainability and energy efficiency of buildings and infrastructure (Datta et al., 2023). BIM has the potential to play a pivotal role in advancing sustainable building design and construction practices. However, its integration with environmental performance practices is currently limited. This issue is particularly pronounced in Syria, where the adoption and implementation of BIM and environmental performance practices lag behind those of other nations. Therefore, there is a necessity to improve the integration and efficacy of these practices (Al Hammoud, 2021).

In summary, the inadequate incorporation of BIM and environmental performance methodologies poses a considerable obstacle that impedes the ability of BIM to enhance the ecological sustainability and energy efficiency of buildings and infrastructure in Syria. The slow adoption and implementation of BIM and environmentally sustainable practices in Syria, compared to other nations, is a significant concern. Addressing this issue requires improving the interoperability of various software and tools used in sustainable building design and construction. Additionally, developing standardized data exchange protocols to streamline their integration is imperative. Enhancing the expertise and competencies of practitioners in integrating BIM and environmental performance methodologies is also crucial to facilitate their effective implementation in the construction industry.

1.4 Research Questions

This section presents the research questions guiding this study on the interplay between Building Information Modeling (BIM) functionalities and environmental

performance practices in Syrian construction projects. The primary objective is to understand how BIM can be effectively utilized to support and enhance sustainable building practices in Syria.

The major research question is as follows:

How can Building Information Modeling (BIM) functionalities be integrated to improve environmental performance practices in Syrian construction projects?

Following are the sub-questions that would be derived from the major question to be answered in this research

1. What are the most important environmental performance practices in construction projects according to Syrian construction professionals?
2. What are the most important BIM functionalities categories in construction projects according to Syrian construction professionals?
3. What are the significant BIM functionalities categories that impact the environmental performance practices in construction projects according to Syrian construction professionals?

1.5 Research Aim and Objectives

The primary aim of this research is to provide guide on BIM functionalities and benefits to improve environmental practices in Syrian construction project.

The research objectives are set as below:

1. To determine the most important environmental performance practices in construction projects according to Syrian construction professionals.
2. To identify the most important BIM functionalities categories in construction projects according to Syrian construction professionals.
3. To analyze the significant BIM functionalities categories that impact the environmental performance practices in construction projects according to Syrian construction professionals.

1.6 Research Significance

The primary significance of this research is to identify the potential use of BIM functionalities categorization—Analysis, Management, Visualization, and Coordination—and their major role in enhancing project environmental performance in Syria. This significance is discussed from two perspectives: the theoretical point of view, which elaborates the added value of this research to the current literature on both BIM functionalities and environmental performance, and the practical point of view, which illustrates the importance of this research to managers and policymakers in the construction industry.

1.6.1 Theoretical Significance

This study aims to provide substantial contributions to the existing body of literature on BIM functionalities and environmental performance. By proposing a proper categorization of over ninety BIM functionalities mentioned in related literature, this research bridges a critical gap in the literature. Additionally, it significantly contributes to the understanding of these functionalities by linking them to the environmental aspects of construction projects.

Furthermore, this research examines the expected influence of the proposed functionalities on the environmental performance of construction projects. It highlights the significant effect of four main categorizations of BIM functionalities—Analysis, Management, Visualization, and Coordination—on the environmental performance in Syrian construction projects from the perspective of AEC (Architecture, Engineering, and Construction) stakeholders. This theoretical framework provides a comprehensive understanding of how BIM functionalities can be leveraged to improve environmental outcomes in construction projects.

1.6.2 Practical Significance

Practically, this research offers valuable guidelines for managers, policymakers, and

major stakeholders in construction projects. It equips stakeholders with the necessary information to make informed decisions, impose appropriate policies, and set specific rules to maintain high levels of environmental performance in construction projects. By identifying specific BIM functionalities with high environmental potential, this research enables the optimal performance of construction projects within the Syrian AEC industry.

The practical implications of this study are far-reaching. By providing a clear understanding of how BIM functionalities can enhance environmental performance, the research aids in the development of strategies and policies that promote sustainability and energy efficiency. This, in turn, supports the broader goal of achieving sustainable development in Syria's construction industry, ensuring that construction projects are not only efficient but also environmentally responsible.

1.7 Thesis structure

The structure of this thesis is designed to comprehensively address the research objectives and systematically present the findings. Chapter 1 begins with an introduction that establishes the research context and outlines the importance of the study. It then details the research background, identifying the core issues and gaps that the study aims to address. The problem statement articulates the specific challenges and questions that the research seeks to resolve. This is followed by a presentation of the research questions and the aim and objectives of the study, which guide the research direction and methodology. The significance of the research is then discussed, highlighting both its theoretical and practical contributions. Finally, the chapter concludes with an overview of the thesis structure, outlining the organization of subsequent chapters and their respective contents.

Chapter 2 provides a comprehensive literature review, starting with an overview of the construction industry and its evolution in the Syrian context. This includes a historical perspective on the industry before the conflict and an examination of the transition to the reconstruction phase. The chapter further explores the environmental performance of the

construction industry, delving into sustainability practices, definitions, and environmental performance measures. It then focuses on Building Information Modeling (BIM), covering its definitions, dimensions, and functionalities as described in previous studies. The chapter also addresses the relevance of BIM in the Syrian context and its role in enhancing environmental performance, leading to the development of a proposed conceptual framework.

Chapter 3 outlines the research methodology, detailing the research design and methods employed in the study. It describes the population and sampling techniques, as well as the data collection methods used. The development of survey questions is explained, including measurements for general information, BIM functionalities, and environmental performance. The chapter concludes with a discussion on data analysis techniques, setting the stage for the examination of results in subsequent chapters.

Chapter 4 presents the analysis and results of the study. It begins with a description of the data, including quality assessments, and proceeds to present descriptive statistics on various factors such as respondent demographics and BIM functionalities. The analysis covers different aspects of BIM functionalities, including analysis, management, visualization, and coordination. The chapter also explores the impact of BIM functionalities on environmental performance through correlation and regression analyses, and it concludes with a summary of key findings and their implications.

Chapter 5 provides a discussion of the findings, integrating them with the research objectives. It addresses the identification of key BIM functionalities, the determination of environmental performance practices, and the analysis of the impact of BIM on environmental performance. The chapter also discusses the advancement of BIM practices in Syria and presents the contributions of the research, including theoretical, practical, and policy impacts. It concludes by acknowledging the limitations of the study, offering

recommendations for further research, and summarizing the overall conclusions drawn from the research. The thesis is finalized with references and an appendix for additional materials.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews existing literature on the intersection of Building Information Modeling (BIM) functionalities and environmental performance practices in the construction industry, with a focus on Syria. It outlines key aspects of the construction sector, its environmental impacts, and BIM's role in improving sustainability and energy efficiency in Syrian construction projects.

The chapter begins by describing the current state of the construction industry, followed by an analysis of its environmental effects. It then defines environmental performance and highlights best practices before exploring BIM functionalities and their relevance to sustainability. Finally, a conceptual framework integrating BIM with environmental performance is proposed to guide the study's analysis.

As a foundational component of the research, this literature review provides the theoretical and empirical basis for investigating how BIM can enhance environmental performance in Syria. Amid ongoing conflict and reconstruction challenges, adopting sustainable approaches like BIM is critical. The chapter aims to bridge knowledge gaps and offer insights for both academics and practitioners.

The Syrian construction industry faces significant challenges due to conflict and instability, which have disrupted infrastructure and urban planning (Al Hammoud, 2021). In this context, innovative solutions such as BIM are essential for enabling efficient and sustainable reconstruction (Amino et al., 2022). Given the environmental impacts of construction—such as resource depletion, waste generation, and emissions—integrating BIM with environmental practices becomes crucial (Asseburg, 2020; Habib, 2020). BIM can help address these issues effectively, ensuring that rebuilding efforts are both efficient and environmentally responsible (Gaafar, 2021).

Syria's reconstruction phase offers a unique opportunity to embed sustainability into its construction industry (Okan, 2020). By leveraging BIM tools, stakeholders can support long-term resilience and sustainable development (Saada et al., 2022). This chapter sets the stage for a detailed exploration of how BIM can contribute to environmental performance in the Syrian context, aligning with the study's objectives and research questions.

2.2 Construction Industry

Construction is an industry involving a wide variety of activities that can be hazardous. However, the construction industry has economical potentials to be invested. It is an important player in the economy worldwide, comprising various different activities including construction, repair and renovation of several building types and infrastructure such as residential construction, bridge construction, and roadway paving etc. (Saad et al., 2019).

Across both developed and developing countries, the construction industry is a significant sector that influence and connect many other sectors in a country, it is strongly related to the economic sector by providing job opportunities, creating new financial resources regardless the available skills are, and enhancing the economic growth of the nation. In other words, construction industry has a considerable importance on socio-economic development by the ability of harnessing the local production and workforce in its vast range of activities, especially in developing countries (Khan et al., 2014; Yap et al., 2019).

Construction industry is considered by the governments of developing countries as an efficient platform to promote the national economic growth toward reaching the economic status of developed countries (Yap et al., 2019), as well as supporting the gross domestic product (GDP) worldwide (Berardi, 2013). According to Hung et al. (2019), it has been confirmed that there is a positive relationship between the output of the

construction industry and the economic output of the country. Delgado et al. (2019) stated that the construction industry is the most significant sector in supporting the economic globally; it is contributing by 9%-15% to the GDP of most countries around the world. While, about half of the countries investments are in the construction sector.

Not to mention the major role construction industry has in responding to the societies needs for built environment and infrastructure that embrace their everyday social activities and demands such as houses, firms, health care, cultural and entertainment centers, offices and commercial buildings, as well as providing high quality life standards (Musa, 2019; Shola et al.; Ustinova et al., 2020).

2.2.1 Pre-conflict Era: Overview of the Syrian Construction Industry

Before the onset of conflict, the Syrian construction industry played a pivotal role in the country's economy and societal development (Okan, 2020). Historically, Syria boasted a robust construction sector characterized by substantial investment in infrastructure and architectural projects. Major urban centers such as Damascus, Aleppo, and Homs saw extensive development of residential complexes, commercial buildings, and public infrastructure. Noteworthy architectural landmarks, blending ancient traditions with modern designs, underscored Syria's rich cultural heritage and architectural prowess (Black et al., 2021). The construction sector was a major contributor to Syria's GDP, generating employment opportunities and driving economic growth through investments in housing, infrastructure, and commercial ventures. The industry's vitality extended beyond domestic boundaries, attracting international contractors, architects, and investors who contributed to the sector's dynamism and innovation. Figure 2.1 illustrates the Map of Syria showing the locations of major cities and neighboring countries (Najjar, 2018).

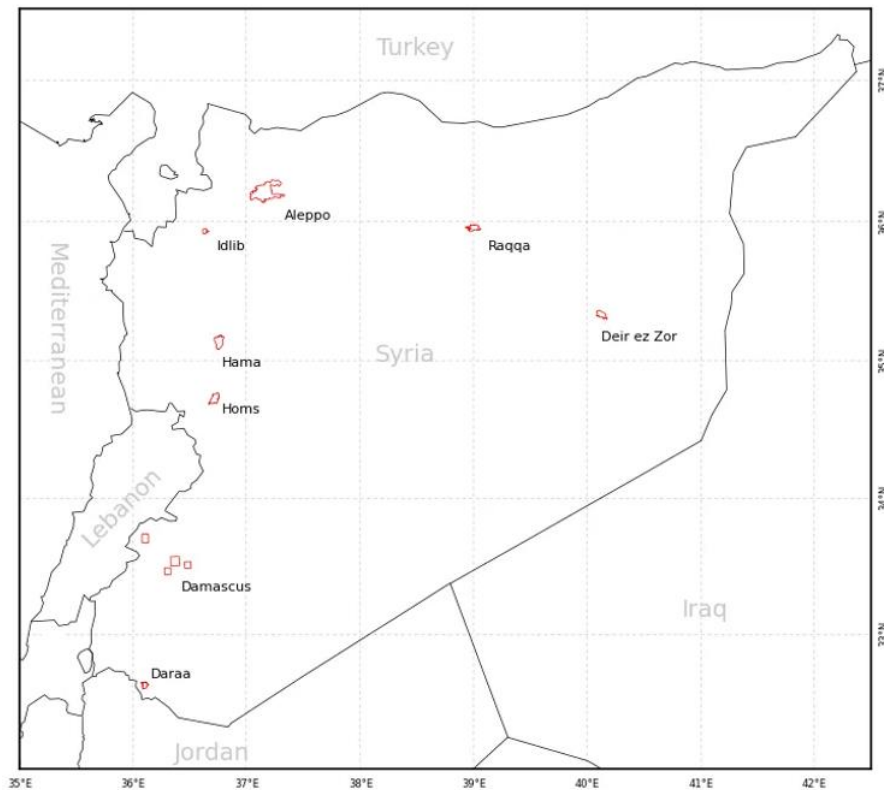


Figure 2.1 Syrian Cities

The eruption of conflict in Syria in 2011 had a devastating impact on the construction industry, leading to widespread destruction, displacement, and economic disruption. The sector, once a cornerstone of economic development, became a casualty of armed conflict, facing unprecedented challenges that continue to hinder its recovery and reconstruction efforts (Madi et al., 2019). The conflict inflicted severe damage on critical infrastructure, including residential buildings, hospitals, schools, and transportation networks. Urban areas such as Aleppo and Homs witnessed extensive destruction, with historical landmarks and cultural sites ravaged by bombing and armed confrontations. The loss of infrastructure not only disrupted daily life but also undermined future economic prospects and social stability. The following figure 2.2 shows the assessment of total damage to construction of Syrian cities till 2017 by UNOSAT assessment (Najjar, 2018).