

**APPLICATION OF BUILDING INFORMATION MODELING FOR
GREEN BUILDING ASSESSMENT: CASE OF LEED AND MOSTADAM**

BY

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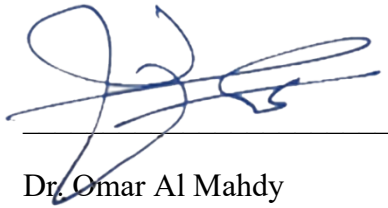
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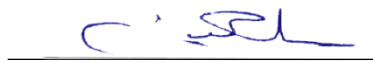
DEANSHIP OF GRADUATE STUDIES

This thesis, written by **Ahmad Nazieh Theeb Othman** under the direction of his thesis advisor and approved by his thesis committee, has been presented and accepted by the Dean of Graduate Studies, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN ARCHITECTURE.**



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Dedicated To
My Beloved Parents, Family, and Friends

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LIST OF ABBREVIATIONS

AEC	:	Architecture, Engineering, and Construction
BEM	:	Building Energy Modeling
BIM	:	Building information Modeling
LEED	:	Leadership in Energy and Environmental Design
GHG	:	Greenhouse Gas
GCC	:	Gulf Cooperation Council
SBC	:	Saudi Building Code
GBAT	:	Green Building Assessment Tool
GRS	:	Green rating system
USGBC	:	U.S. Green Building Council
SgBC	:	Saudi Green Building Code
ASHRAE	:	The American Society of Heating, Refrigerating and Air-conditioning Engineers
MEP	:	Mechanical, Electrical, and Plumbing
IFC	:	Industry Foundation Classes
LOD	:	Level of Details
HVAC	:	Heating, Ventilation, and Air Conditioning

ABSTRACT

Full Name : Ahmad Nazieh Theeb Othman
Thesis Title : Application Of Building Information Modeling for Green Building
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The construction industry, a significant energy consumer, is driving global efforts to develop sustainable and energy-efficient structures while retrofitting existing ones. Increasingly, projects are adopting Building Information Modeling (BIM) workflows and pursuing green building certifications by integrating BIM into environmental assessments. Despite the transformative potential of Building Information Modeling (BIM) in sustainable architecture, its application in green building assessment remains underexplored in Saudi Arabia, particularly regarding certification standards such as LEED and MOSTADAM. Recognizing BIM's potential to bridge gaps in sustainable design, this study evaluates Revit's capability to achieve green building credits within LEED and MOSTADAM frameworks. Using a mixed-method approach, the research combines literature review, structured assessments, and expert evaluations to analyze Revit's support for sustainable criteria across categories like Energy, Water, Health & Comfort, and Materials & Waste. The results demonstrate Revit's strong support in critical sustainability areas under LEED, with high support in 18 indicators across essential categories such as Energy, Water, and Indoor Environmental Quality. Similarly, Revit shows high support in 17 MOSTADAM indicators, reflecting its effectiveness in meeting core sustainability objectives in areas such as Energy, Water, Health & Comfort, and Materials & Waste.

ملخص الرسالة

الاسم الكامل: احمد نزيه ذيب عثمان

عنوان الرسالة: تطبيق نمذجة معلومات البناء في تقييم المباني الخضراء: حالة نظام الليد ومستدام

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صناعة البناء، التي تستهلك قدرًا كبيرًا من الطاقة، تقود الجهود العالمية لتطوير هياكل مستدامة وفعالة في استهلاك الطاقة مع تجديد المباني القائمة. وتزداد المشاريع التي تعتمد على نماذج عمل النمذجة المعلوماتية للبناء (BIM) وتتابع شهادات البناء الأخضر من خلال دمج BIM في التقييمات البيئية. وعلى الرغم من الإمكانيات التحويلية لنمذجة معلومات البناء (BIM) في العمارة المستدامة، فإن تطبيقها في تقييم البناء الأخضر لا يزال غير مستكشف بشكل كافٍ في المملكة العربية السعودية، خصوصًا فيما يتعلق بمعايير الشهادات مثل LEED و MOSTADAM. ومن خلال إدراك إمكانيات BIM في سد الفجوات في التصميم المستدام، تقوم هذه الدراسة بتقييم قدرة برنامج Revit على تحقيق اعتمادات البناء الأخضر في إطار عمل LEED و MOSTADAM. وباستخدام منهجية متعددة الأساليب، تجمع الدراسة بين مراجعة الأدبيات والتقييمات المنظمة وآراء الخبراء لتحليل دعم برنامج Revit للمعايير المستدامة عبر فئات تشمل الطاقة والمياه والصحة، والراحة، والمواد، والنفايات. وتُظهر النتائج الدعم القوي لبرنامج Revit في مجالات الاستدامة الأساسية ضمن LEED ، حيث يحقق دعمًا عاليًا في 18 مؤشرًا عبر فئات أساسية مثل الطاقة والمياه وجودة البيئة الداخلية. وبالمثل، يُظهر Revit دعمًا عاليًا في 17 مؤشرًا من مؤشرات MOSTADAM ، مما يعكس فعاليته في تلبية الأهداف الأساسية للاستدامة في مجالات مثل الطاقة والمياه والصحة، والراحة، والمواد، والنفايات.

CHAPTER 1

INTRODUCTION

1.1 Background

Diverse industries have increased their emphasis on energy efficiency and environmentally friendly practices. In the past decade or so, the emphasis on green building strategies in terms of design and construction has increased exponentially. The aim is to ensure that buildings utilize natural resources efficiently and more responsibly, in addition to improve the health and productivity of those who work and live within them. Moreover, green buildings reduce pollution and waste production. In the past four decades or so, the Kingdom of Saudi Arabia has developed rapidly. In the 1970s, the increase in oil prices greatly benefited the Saudi economy and increased the number of construction firms. Since the 1970s, the rate of urbanization has increased significantly. Due to the increased business opportunities in urban areas an increasing number of individuals are relocating to large cities in Saudi Arabia such as Riyadh and Jeddah. Consequently, the city's population has increased. The increased urbanization resulted in increased pollution and put more demand on resources related to the building industry. In the AEC industry, rating systems such as LEED, BREEM, and GBC define what is considered green. In green building assessment systems, environmental attributes such as water conservation, energy efficiency, and indoor air quality are typically prioritized over economic and social factors. Although these rating systems have some advantages, they also have some drawbacks, such

as being complicated and costly for small projects and excluding older structures. (Al-Surf et al., 2021)

The growth of the metropolitan region has had a negative effect on the environment, resulting in problems with solid waste, energy consumption, air pollution, and residential emissions. Also, increased urbanization strains infrastructure and hastens the depletion of natural resources to meet the expanding needs of the population. The urbanization rate in Saudi Arabia has increased dramatically, from 21% in 1950 to 83% in 2015. (*Saudi Cities*, 2018)

Urbanization will continue to increase greenhouse gas (GHG) emissions, which will have a negative impact on our daily lives due to climate change. High reliance on fossil fuels for transportation and energy production increases the country's greenhouse gas emissions. Given that they account for roughly 70% of carbon dioxide emissions and 80% of global energy consumption, it is astonishing that metropolitan areas comprise only 3% of the earth's surface. We may be able to reduce these emissions by switching from conventional, energy-intensive building techniques to those that are less harmful to the environment. Grading systems for sustainable and green buildings may be utilized for this purpose. (Al-Surf et al., 2021).

Saudi Arabia, the largest economy in the Gulf, makes for an interesting case study due to the waste generated during construction and demolition, its high energy intensity, and its high-water consumption. In Saudi Arabia, in particular, the LEED and Mostadam green building green building assessment tools are being implemented. Our research aims to determine how well BIM can support all LEED and Mostadam indications and

applications. Even though green buildings are being constructed in several countries around the world, Saudi Arabia lacks the same level of approval and appeal. The lack of national norms and regulations that support sustainable development and green construction has emphasized this gap. Due to the absence of a national green building assessment tool in the Kingdom of Saudi Arabia, LEED is utilized as an alternative; nevertheless, it is not relevant to Saudi infrastructure. (Costin, n.d.)

The Saudi Vision 2030 will enable coming generations to flourish and live happy lives in a stable economic environment in which the public and private sectors collaborate to boost income and natural resource availability. The AEC industry has initiated BIM integration. BIM is highly effective and has a positive effect on green building certifications. As more countries around the world mandate green building certification for construction projects, BIM will soon become the norm for all construction projects. As a result, BIM will continue to grow and be used as a tool for sustainable design and construction techniques. (Mia et al., n.d.)

The AEC industry is beginning to recognize the benefits of integrating BIM into its operations, such as improved quality assurance, reduced costs, and a more efficient project lifecycle. This recognition is already beginning to manifest itself in an increase in the number of green building certifications, as architects and engineers are utilizing BIM to aid in the design and certification process. This is especially important as green building certification has become increasingly popular in recent years.

1.2 Problem Statement

A green building is a resource-efficient and environmentally responsible building throughout its life cycle. To achieve a green building requires careful consideration of a wide range of complex information related to all aspects of the building. This information usually spans all phases of the building life cycle including site selection, pre-design and design phases, construction, material selection and handling, operation, maintenance, till the demolition and end of the building life cycle. Today, building design professionals utilize different green building assessment tools such as LEED, BREEAM, CASBEE to measure and assess the green/sustainability performance of their designs before constructing the building. These green assessment tools use a set of well-established indicators and sub-indicators organized under a group of categories to measure and assess the performance of green buildings. Unfortunately, these green building assessment tools still work independently and are not integrated with the design tools that are used to design and develop buildings such as CAD and parametric design tools, or BIM tools. This represents a major limitation/obstacle for developing and realizing green buildings.

Building information modeling (BIM) technologies are utilized extensively throughout the building design process. During the design process, they are regarded as excellent instruments for evaluating the performance of buildings. For instance, ... BIM and BIM-related technologies are efficient at integrating and processing a vast array of complicated and multidisciplinary building technical data. This material encompasses a broad variety of engineering and technical facets throughout the whole project life cycle (Guo et al., 2021).

BIM offered substantial opportunity to enhance green building practices, including acoustic analysis, carbon emission, construction and demolition waste management, lighting analysis, operational energy consumption, and water use. Unfortunately, green building evaluation tools and BIM tools that are frequently used during the design phase operate in silos and do not help or complement one another. This is a significant deficit that applied and developmental research attempts to address. If BIM tools are optimized to satisfy the criteria and requirements of green building evaluation tools, it is apparent that green building practices will acquire considerable momentum. Building Information Modeling (BIM) is a digital representation of the physical and functional characteristics of a building or infrastructure. It is a collaborative process that utilizes a 3D model to streamline the design, construction, and operation of a structure, fostering improved communication and coordination among stakeholders.

However, despite the widespread adoption of BIM in the architecture, engineering, and construction industry, there remains a notable gap in research concerning the long-term impact of BIM on project performance and the overall life cycle of constructed assets. The need for comprehensive studies evaluating the effectiveness of BIM beyond the initial stages of a project and exploring its influence on facility management and maintenance is a crucial aspect that requires further attention and investigation. Closing this research gap is essential for maximizing the potential benefits of BIM throughout the entire lifespan of built assets. This study intends to fill this gap by investigating and evaluating the potential of BIM technology to meet the needs and criteria of green building evaluation tools and

how to integrate BIM-related tools to enhance the efficiency of measuring the performance of green buildings.

Green design and Building Information Modeling (BIM) are two critical components shaping the landscape of contemporary construction. Green design emphasizes sustainability, focusing on eco-friendly practices to create environmentally conscious structures, while BIM revolutionizes the design process through a collaborative and integrated digital approach.

However, the literature shows that there exists a notable gap in research concerning the seamless integration of green principles within the BIM design process. While both green design and BIM individually contribute to sustainable construction, there is a lack of comprehensive exploration into how these two entities can synergize effectively. The existing body of knowledge primarily highlights the independent merits of green design and BIM but fails to provide sufficient insight into their combined potential, leaving a void in understanding how the integration of green principles within BIM can be optimized for enhanced sustainability in the built environment. Closing this gap is essential for harnessing the full potential of these entities to create environmentally responsible and technologically advanced structures.

Research Questions:

- How are green buildings assessed and measured, specifically considering the criteria employed by LEED and MOSTDAM as case studies?

- To what extent can BIM software, particularly Revit, effectively support the requirements and criteria outlined by the green building assessment tools LEED and MOSTDAM?
- What are the results of using BIM-Revit-based simulation for evaluating the compatibility of BIM software with the criteria of LEED and MOSTDAM, particularly when applied to buildings in Saudi Arabia?
- How can the theoretical framework be developed to enhance the capability of Revit, as a BIM tool, in supporting the requirements and criteria of LEED and MOSTDAM for green building assessment?

This research aims to comprehensively examine and assess the capacity of BIM technology, using Revit as a tool, to generate analytical data and metrics that align with the requirements and criteria of green building assessment tools, with a focus on LEED and MOSTDAM.

1.3 Research Objectives

This research aims to examine and assess the ability of BIM technology to generate analytical data and metrics that support the requirements and criteria of green building assessment tools. The research will use Revit as a BIM tool while Leadership in Energy and Environmental Design (LEED), USA, and MOSTADAM, Saudi Arabia, will be used as green building assessment tools. Specifically, the research aims to achieve the following goals:

1. Extract the various criteria used to assess and measure green buildings by taking LEED and MOSTDAM as case studies.
2. Examine how well BIM software can support the requirements and criteria of the green building assessment tools.
3. Evaluate and assess the results found in objective-2 using BIM-Revit case study of one building located in Saudi Arabia.
4. Develop a theoretical framework to improve the ability of Revit, as a BIM tool, to support the requirements and criteria of the examined green building assessment tools.
5. Develop a demonstration module of a component in the proposed framework to illustrate the potential of the framework.

1.4 Research Significance

In the Architecture, Engineering, and Construction (AEC) market, a multitude of sustainability tools empowers professionals like engineers and architects to design structures meeting specific sustainability levels, as seen in certifications like LEED. Despite tool availability, a gap exists in guiding stakeholders to actively understand and contribute to sustainability throughout intricate design and construction phases, particularly in individual decision-making.

The paradigm shifts to Building Information Modeling (BIM) offers a transformative opportunity to address this gap. BIM not only provides a collaborative digital platform but also offers a holistic view of a structure's lifecycle. Through BIM, stakeholders gain insights into the sustainability implications of individual decisions, fostering a more informed and participatory approach throughout design and construction. This shift enhances communication, collaboration, and integrates sustainability seamlessly into diverse stakeholders' decision-making processes.

By leveraging BIM, the study aims to enhance stakeholder understanding and active participation in achieving sustainability goals. This aligns with the growing emphasis on sustainable practices in the AEC industry, contributing to more effective decision-making and the creation of environmentally responsible structures.

In the Kingdom, significant investments in green buildings underscore the relevance of this research. The results directly benefit the implementation of the Kingdom's sustainable vision 2030, offering guidelines on the integration of BIM and Green Building Assessment Tools (GBAT). This informs policies, programs, and projects, facilitating the AEC industry's achievement of green accreditations necessary for the 2030 vision.

The research outcomes are valuable for professionals developing building projects, decision-makers in public and private sectors, and professional bodies shaping the AEC sector. Practitioners, including contractors, architects, and engineers, will find practical insights. The results also guide researchers, academicians, and industry organizations, such as the Saudi Council of Engineers, in planning the adoption of green assessment tools, contributing to the broader vision of sustainable and green constructions.

1.5 Scope and Limitations

Scope:

This research aims to evaluate the capacity of Building Information Modeling (BIM) technology to generate analytics and metrics aligning with the criteria of green building assessment tools (GBAT). The study acknowledges the global existence of various GBATs, as detailed in Chapter 2. However, it will specifically focus on two assessment tools: Leadership in Energy and Environmental Design (LEED) from the USA and Mostadam from Saudi Arabia. Mostadam, being native to Saudi Arabia, is developed for and utilized in the assessment of buildings within the country. LEED, although an international tool, is extensively used in the Kingdom. Each of these assessment tools comprises a family of tools, with each dedicated to assessing specific building types. This study will concentrate solely on the tool versions dedicated to assessing residential and commercial buildings. The research's primary focus will be on new buildings under design, excluding those undergoing renovation or in prefabrication phases.

Limitations:

- Number of Assessment Tools: The study is limited to LEED and Mostadam and may not encompass insights applicable to other green building assessment tools.
- Building Types: The examination is restricted to residential building type, excluding other building categories.
- Geographical Focus: The geographic focus is on Saudi Arabia, with the potential variations in applicability to other regions.

- **Building Phases:** The study concentrates on new buildings under design, excluding those undergoing renovation or in prefabrication phases.

1.6 Thesis Structure

This thesis is systematically organized to guide readers through an exploration of the integration of Building Information Modeling (BIM) technology with green building assessment tools, with each chapter serving a distinct purpose to enhance understanding of the research topic.

Chapter 1: Introduction: Provides the background, articulates the problem statement, defines the research objectives, and explains the significance of the study. Together, these components lay the foundation for the research, establishing the importance of the study and outlining the direction for subsequent chapters.

Chapter 2: Literature Review: Reviews the existing literature, focusing on three main areas: BIM, green building assessment tools, and sustainability in green buildings. It synthesizes information from previous studies, introduces essential concepts, and identifies gaps in current research. This review provides a theoretical basis for understanding the role of BIM in supporting sustainable building practices.

Chapter 3: Research Methodology: Presents the methodology used to achieve the study's objectives. It includes an overview of the research design and methods employed, detailing the approach to data collection, analysis, and interpretation. This chapter serves as a bridge to the practical research conducted in Chapter 4, grounding the study in a structured methodological framework.

Chapter 4: Results and Discussion: Presents and analyzes the study's findings, providing detailed results of the data gathered. It interprets these findings in the context of the theoretical framework established in the literature review, offering insights into BIM's effectiveness in supporting green building assessments and sustainable design goals.

Chapter 5: Conclusion & Discussion: Concludes with a synthesis of key findings, reaffirmation of research objectives, and discussion of the study's implications. This chapter highlights the contributions of the research to existing knowledge, acknowledges limitations, and proposes recommendations for future studies or practical applications in the field of sustainable building design and BIM integration.

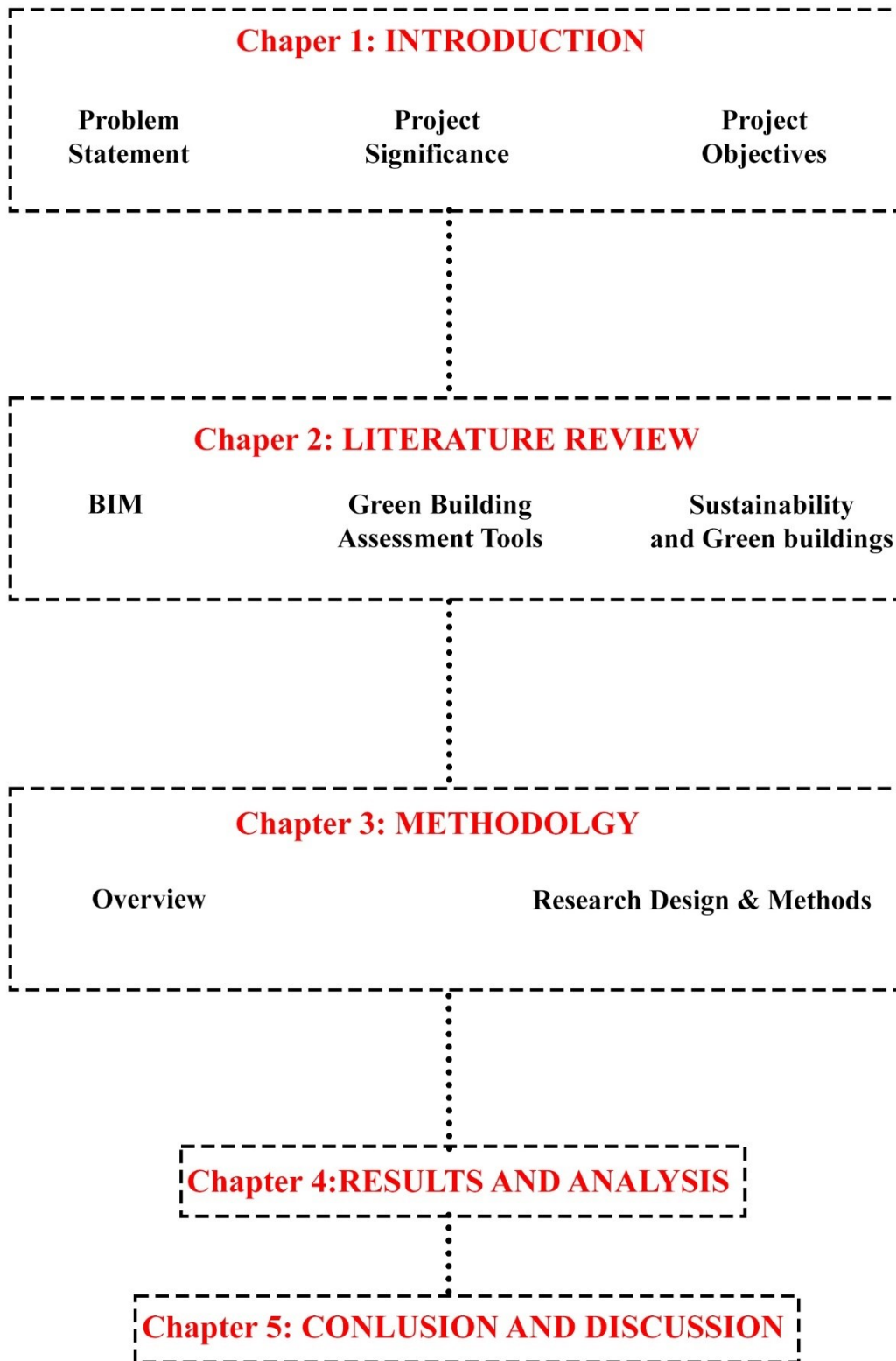


Figure 1 Diagram of the Study

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The literature review section embarks on a comprehensive exploration of key elements pivotal to shaping a responsible and resilient built environment. This multifaceted journey delves into the interconnected realms of sustainability, sustainable architecture, green building assessment tools, and the transformative force that is Building Information Modeling (BIM).

Sustainability, a concept embraced across disciplines, sets the stage with the foundational Bruntland definition, emphasizing intergenerational equity. Architecture, as the tangible reflection of societal values, grapples with a dual role—contributing to and mitigating unsustainability. Within this context, sustainable architecture emerges as a response to global challenges, aspiring to create eco-friendly, energy-efficient structures through an ecological design approach.

The exploration extends to green building practices, exemplified by globally recognized standards such as LEED and regionally tailored frameworks like Mostadam. These practices provide a structured framework for evaluating sustainability, emphasizing holistic methods, green competitiveness, and transformative impacts. The Green Building Assessment process, a complex undertaking, finds optimization through the intelligent data integration facilitated by BIM, particularly amid the dynamic phases of preconstruction design changes.

BIM, a transformative force in the Architecture, Engineering, and Construction (AEC) industry, takes center stage. Its evolution from the 1970s to the present reflects a journey of overcoming challenges associated with traditional CAD tools. The major BIM software—Revit, Archicad, Vectorworks, and Microstation—acts as a pivotal interface, enabling parametric geometry modeling and offering coordinated 2D and 3D perspectives. The multifaceted uses of BIM, ranging from collaborative design to facility management, underline its indispensability in modern construction practices.

In conclusion, this literature review serves as a foundational exploration, weaving together the intricate threads of sustainability, architecture, green building assessment tools, and transformative technologies. As the global community confronts challenges posed by climate change and resource constraints, this holistic approach signifies a collective shift toward responsible construction practices. The evolution of BIM and the convergence of global standards underscore the industry's commitment to innovation, collaboration, and a positive global impact. Looking forward, the advancing landscape of technology positions BIM as an increasingly vital force in shaping the future of the built environment.

2.2 Sustainable and Green Buildings

Sustainability stands as a concept widely acknowledged but often muddled and debated across various disciplines (Vogt & Weber, 2019). While its acceptance is widespread, certain fields still grapple with a less than crystal-clear understanding of sustainability. Among the numerous definitions proposed, the Bruntland definition holds a paramount position, emphasizing the inclusion of intragenerational and intergenerational equity (Throsby, 2000). Architecture, serving as a tangible influencer of our environment through

the embodiment of energy, materials, and values, serves as a reflection of societal sustainability (Author and Citation Information for “Environmental Ethics,” n.d.). Some argue that contemporary architecture both contributes to and reflects unsustainability (Grant, 2010). Hill (Lee, 2011) posits that with the ascent of modernism, architecture has evolved into a significant commodity and a locus of commodity accumulation.

Sustainable architecture, as a design approach, aims to minimize the adverse environmental impact of buildings while maximizing their positive societal contribution. This involves deploying energy-efficient technologies, resource-efficient materials, and environmentally friendly design strategies to create structures that are functional, aesthetically pleasing, and economically viable. For our purposes, we adopt a definition that extends beyond maximizing energy efficiency, encompassing environmentally friendly design strategies as a comprehensive ecological design approach.

In 1987, the United Nations Brundtland Commission formally defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs." Today, nearly 140 developing countries grapple with meeting their development needs amidst the escalating threat of climate change. It is imperative to make concrete efforts to ensure that current development initiatives do not detrimentally impact the prospects of future generations.

2.2.1 Core Dimensions of Sustainability

Although there is no agreement on one definition on sustainable architecture, there is an agreement that sustainable architecture includes their core dimensions: environment. Social and economic.

Environmental Dimension

1. ***Reducing Environmental Impact***— In recent years, carbon emissions all throughout the globe have witnessed a dramatic spike. Buildings have a substantial influence on the carbon footprint of the whole planet. Burning fossil fuels accounts for about 70 percent of the carbon footprint created by human activities on Earth. Heating systems in buildings are responsible for a large proportion of the usage of fossil fuels.

Benefits— Green building construction may reduce the world carbon footprint by 15-20% each year. This would be critical in minimizing the detrimental effects of climate change. The US Green Building Council created the Leadership in Energy and Environmental Design (LEED) GBAT. LEED-certified constructions may help to mitigate climate change. The Leadership in Energy and Environmental Design (LEED) certification program makes a substantial contribution to mitigating the negative consequences of climate change on the environment.

2. ***Biodiversity and Ecosystem Conservation***—Natural life is less likely to be disrupted by green buildings. Plant biodiversity is important and may be preserved via thoughtful planning and building practices.

Benefits—Specifically, keeping the existing tree and plant species contributes to natural cooling, minimizes noise pollution, lessens soil erosion, conserves the environment, diverts waste from landfills, and protects the unique ecosystems that have developed throughout time.

3. ***Preserving the Soil in the Area***—Exposing the topsoil after eradicating non-ligneous and ligneous plants leads to a vicious cycle of increased water use and chemical reliance.

Benefits—Reduced need for fertilizers and pesticides, improved soil health, reduced storm water runoff, and protection of water quality are all benefits of "green" construction.

4. ***Minimization of Wastes***—The elimination of rubbish is currently the most pressing issue confronting society, especially in urban areas. When constructing a structure, it is feasible to produce less potential waste and design more energy efficiently by utilizing as little resources as is humanly possible. Instruments are employed in order to lessen the risk of producing trash and to make operations that are friendlier to the environment.

Benefits—It decreases the harmful effects that are caused by the production of solid trash as well as hazardous waste. The fact that the trash produced by one company may be used as a resource by another helps to keep the expenses of waste management in check while also fostering the growth of other businesses.

5. ***Reduction in Wastage of Water***—In order to ensure that the soil is able to absorb the maximum amount of water possible, contemporary irrigation techniques provide water directly to the root zone of plants. This results in a significant reduction in the volume of water that is lost due to unnecessary spraying. The use of sub-surface drip, low-flow drip, or low-flow sprinklers, as well as the collection of rainwater, are all examples of this. Rainwater harvesting is another case in point.

Benefits—High-efficiency irrigation systems not only save water, but also limit weed development and shield communities from the deadly illnesses that may spread in open water storage.

6. ***Enhance the Quality of Indoor Air***—It's the air that people in a building breathe on a regular basis. The indoor air quality is affected by the quality of the air that is recirculated within a structure. The symptoms of building sickness, which is often the result of subpar ventilation, might include lethargy, fretfulness, diverted attention, and tension. Ventilating a building and maintaining a temperature that is comfortable for people requires around 15–16 cubic feet per minute (cfm) of air from the outside. The rate of carbon dioxide production caused by the breathing of people within a building may be slowed down by increasing the amount of ventilation in the structure.

Benefits—Ventilation is improved in green buildings because more outside air is let in and the quantity of carbon dioxide in the air within is decreased. The exhaust systems that have been constructed have a big beneficial influence since they eliminate harmful gases, prevent the use of wood products that contain formaldehyde, regulate the temperatures inside the structure, and more.

Social Dimension

Green buildings have a positive impact on society since they improve the overall level of life as well as the health of their tenants. This encompasses activities such as bringing back harmony to the neighborhood and transmitting information across buildings. Feelings of ease and contentment may be traced back to sensory and cognitive processes that reflect data about the surrounding environment and how it influences our immediate requirements and personal preferences. These processes are a product of the mind's ability to adapt to its surroundings. A psychological evaluation of the environment may be obtained by analyzing factors such as the inhabitants' levels of productivity and stress. It is possible for

the same environmental stimuli to have different impacts on different people due to the intrinsic diversity that exists among people's psychological responses. Employees who report higher levels of work satisfaction, better productivity, and good health will have a positive effect not just on themselves but also on the community. It's possible that the advantages of environmentally friendly buildings go beyond the workplace. It comprises an increase in the use of environmentally friendly design strategies in addition to adjustments to the overall wellbeing of the inhabitants of the building. Buildings that are environmentally friendly sometimes serve as examples for other types of construction. For instance, visitors can tell the difference between conventional and green constructions thanks to ecologically friendly structures. They conduct workshops and provide visits for local professionals and residents who are interested in developing their own buildings.

Economic Dimension

Building using sustainable materials comes with several financial and economic benefits. For homeowners, this can mean lower utility bills because of improved energy and water consumption; for building developers, this can mean lower construction costs and more prestigious real estate prices; and for building owners, this can mean higher occupancy rates or higher operational expenses.

2.2.2 Sustainable Buildings

Sustainable buildings are increasingly recognized as high-performance structures due to their commitment to enhancing resource efficiency and minimizing the environmental impact of constructed facilities. Owners and occupants are now more insistent on integrating sustainable features into new buildings, driven by benefits such as reduced life

cycle costs, lower energy consumption, improved occupant health and productivity, and enhanced marketability. This growing demand is reflected in the substantial increase in buildings registered under the U.S. Green Building Council's LEED (Leadership for Energy Efficient Design) rating system, from 12 pilot projects in 2000 to 820 registered projects and 53 certified projects by 2003.

The term "sustainable building" signifies a structure's compatibility with the environment throughout its entire life cycle, emphasizing efficient use of natural resources (Shaabani et al., 2020). This practice, defined as Sustainable Building (SB), involves creating structures and employing processes that are environmentally responsible and resource-efficient from siting to design, construction, operation, maintenance, renovation, and deconstruction (Darko et al., 2018). While SB has garnered attention for its potential to mitigate environmental impacts, enhance user well-being, and yield long-term financial benefits, its adoption remains limited, and its performance is not always satisfactory. Challenges include delays, changes, wasteful rework, and overproduction, as well as environmental performance falling below design levels during operational stages (Horman et al., n.d.; Huang et al., 2018; Hwang et al., 2015).

Sustainable architecture, as an approach to architectural design, aims to minimize environmental impact by creating energy-efficient and eco-friendly buildings that prioritize environmental preservation, resource efficiency, and occupant comfort. It represents a commitment to a sustainable future, considering not only ecological infrastructure but also the well-being of future generations (De Monfront University, 2023). For a building to be deemed sustainable, it must account for all resources involved

in its construction, including materials and energy sources, and meet the requirements of its occupants. Sustainable architecture is a dynamic process that adapts to changing circumstances, values, and technological capabilities, with the overarching goal of producing well-designed buildings that are healthy, have minimal negative environmental impacts, efficiently use natural resources, are economically viable, and endure over an extended period. The terms "sustainable architecture," "green building," "high-performance buildings," and "environmentally aware design" are used interchangeably, recognizing that each conveys a nuanced perspective within the broader concept of sustainability.

In addition to striving to design a structure that is beautiful and unforgettable, architects are required to adhere to all applicable regulations and standards, create an environment that is secure for people to inhabit and structurally sound, and do all of this while adhering to stringent time and financial constraints. It is not a simple procedure. Nevertheless, constructing with sustainability in mind should not be seen as only an additional effort to be made. On the other hand, it presents a whole fresh perspective on the entirety of the design process, including the ultimate plan, placement, and composition of the building. Many of the components of environmentally friendly architecture have been in use for conventional buildings for millennia. The notion of sustainable architecture may today be understood by drawing on these principles as well as recent advances in technology innovation. It provides a chance to create and build a project that is one of a kind, traditional, and environmentally beneficial. (Solanki et al., 2021)

2.2.3 Green Buildings

The United States Green Building Council defines a "green building" as one that reduces environmental impact throughout the length of its existence (USGBC). Green buildings have two primary goals at their core, which are the preservation of natural resources and the improvement of human health. The effect of a building on its surrounding environment, the quality of the air within the structure, the use of materials that minimize waste, as well as the amount of water and electricity used, are all components of green buildings. Safety, longevity, sustainability, intelligent and effective management of the whole building life cycle, and efficient use of financial resources are just a few of the many ways in which "green" buildings benefit their inhabitants.

. Utilizing specific rules and performance grading systems may help one determine what constitutes "green" for a certain project. Not just the technical blueprints, which are very important, but also all the other processes that go into ensuring sure a project is sustainable are referred to as "guideline papers." These standards outline the fundamentals of environmentally responsible building practices, together with the goals of the concepts and a strategy for accomplishing those goals. This necessitates a comprehensive review of the design and building processes. Even though there are a lot of great recommendations to choose from, none of them can possibly cover every possible circumstance. Numerous universities and colleges, as well as non-profit organizations, commercial corporations, and government agencies on all levels, including local, state, and federal, have taken the initiative to develop their very own sustainability standards. This serves the purpose of addressing their own building types, local rules and regulations, geographical and climatic challenges, stakeholder interests, and conceptions of what it means to be "green." A

different set of procedures was used by each organization in the process of developing its rules or scoring system. Because of this, they were developed with a specific audience in mind, one that consists of developers and builders, architects and consultants, administrators and building owners, as well as authorities from the government. Although it would be useful to have a single document to refer to, that is not going to be practical. The regulations imposed by each entity are different and, in their very nature, serve a specific function. Environmental performance assessment rating systems have been available for some time alongside legislation. These systems include BREEAM in Canada and the United Kingdom and LEED in the United States (created by the U.S. Green Building Council). These grading techniques, which are significant resources, recognize and institutionalize the requirement of assessing buildings based on a broad variety of parameters. As a result, the necessity has been institutionalized. They provide a means to ensure that structures are constructed with care for the surrounding environment in mind.

The environmental effect of the building's life-cycle activities is something that should be reduced as much as possible thanks to the green design. The most significant bearing on both production and cost is provided by the concept of environmentally friendly architecture for long-lasting buildings. The stages of conception and design are responsible for laying the groundwork for any building plan. The EPA of the United States states that the most significant effect on production and cost is exerted at the idea or concept stage of a lifecycle plan. This is because this is the first phase (2014). In contrast, construction methods might change from building to building and are seldom as efficient as mass-production methods. Instead of just accumulating the most cutting-edge eco-friendly materials and technology, designing a green building means optimizing each individual

part of the system, then merging those parts and maximizing their combined effect. Interactions between construction sites for green buildings, the location of the sun, architectural components like windowpanes, and external shading patterns are some examples of the kinds of interactions that may influence the kind of daylight. There are several elements that may potentially influence the linear solar content as well as the total energy usage for the growth of the environmentally friendly building. To remove the boundary between internal and outside areas via the use of design, more components of what is known as "green architecture" employ plants as the primary component of the building covering and roof layouts. Depending on the relative life process levels of each structure, a change in the design variability might potentially influence the surrounding environment.

2.3 Green building assessment tools

While the definition of sustainable or green buildings lacks consensus, there is unanimity on the methods to measure them. Green Building Assessment Tools (GBATs) offer a systematic approach to achieving sustainable buildings. They serve various purposes, including providing guidance for design and operations, documenting progress toward performance targets, facilitating comparisons between buildings using certification systems, and documenting the strategies employed in design and operations (Wang et al., 2012).

The Green Building Assessment process is often characterized by its laborious and time-consuming nature. Its complexity stems from the need for large volumes of interdisciplinary information to demonstrate compliance with certification requirements,

distributed among different project stakeholders. Consequently, information management becomes challenging. Additionally, Architectural, Engineering, and Construction (AEC) projects undergo multiple design changes in the preconstruction phase, necessitating repeated assessments. This is where Building Information Modeling (BIM) becomes invaluable. A unique selling point of BIM lies in its promise of intelligent data integration in an otherwise fragmented industry.

Recent research has increasingly focused on methods to facilitate green building assessments using BIM, driven by three practical reasons. First, this integration can assist designers in selecting effective strategies for achieving sustainability goals during the early design stages. Second, it aids sustainability experts in assessing design compliance with green building certification requirements more rapidly and efficiently. Third, it streamlines the massive document management necessary for achieving these certifications (Lu et al., 2017).

Green Building Assessment Tools (GATs) operate based on specific core dimensions, forming a comprehensive framework to assess the sustainability and environmental performance of buildings. These dimensions cover crucial aspects contributing to a building's overall ecological footprint and efficiency. The key core dimensions include:

- **Energy Efficiency:** This involves evaluating the building's energy consumption, utilization of renewable energy sources, and overall efficiency in managing energy.
- **Water Conservation:** This dimension assesses the building's water usage, efficiency in water management, and the implementation of technologies to save water.

- **Material Selection and Resources:** This dimension examines the selection of materials, considering their environmental impact, and emphasizes efficient resource use, including recycling and waste reduction.
- **Indoor Environmental Quality:** This focuses on aspects such as indoor air quality, thermal comfort, and lighting to ensure a healthy and productive indoor environment.
- **Site Sustainability:** This dimension involves assessing the building's impact on its surroundings, considering factors like land use, biodiversity, and transportation accessibility.

Within each core dimension, Green Building Assessment Tools organize specific criteria into broader domains. These domains offer a structured breakdown of various aspects related to sustainability, facilitating a detailed and nuanced evaluation. Common categories or domains include:

Energy and Atmosphere:

- Renewable energy use
- Energy performance
- Carbon footprint reduction

Water Efficiency:

- Water conservation measures
- Water recycling and reuse

Materials and Resources:

- Sustainable material selection
- Waste reduction and recycling practices.

Indoor Environmental Quality:

- Indoor air quality
- Thermal comfort
- Lighting quality

Site and Location:

- Sustainable site planning
- Ecological impact
- Access to public transportation

By systematically categorizing assessment criteria into specific domains, Green Building Assessment Tools (GATs) offer a structured approach to evaluating the diverse dimensions of sustainability within the built environment. This methodical breakdown enhances the efficiency of assessments and promotes comprehensive sustainable practices in the design and construction of buildings.

Various green building rating and assessment systems, such as LEED and BREEAM, are employed globally, as discussed earlier. Sustainability has become a paramount concern in the MENA region, particularly in GCC countries like Saudi Arabia, UAE, and Qatar. These nations have developed their own green building rating systems to integrate specific socio-economic, environmental, and cultural considerations, aligning with the geopolitical characteristics of their regions.

However, for the purposes of this paper, the discussion and analysis will focus on LEED and the recently developed Saudi green building rating system, Mostadam. The following two sections will provide a detailed overview of these two rating systems, laying the essential groundwork for this paper.

2.3.1 LEED

Leadership in Energy and Environmental Design (LEED), a green building assessment tool and accreditation system, encourages the design, development, and operation of structures to lessen their impact on the environment while also increasing their performance and the well-being of their occupants. LEED is an acronym that stands for Leadership in Energy and Environmental Design. The United States Green Building Council (USGBC), the organization that was responsible for developing LEED, asserts that it is the most well-known and frequently used tool in the whole world and has become synonymous with both sustainability and leadership (USGBC, 2022).

The Leadership in Energy & Environmental Design (LEED) was introduced by the U.S. Green Building Council in 1998 through its initial version, LEED v1.0, aiming to become the foremost global green building rating system [8]. Over the subsequent 27 years, LEED has undergone expansions to encompass various building types, undergoing periodic updates and revisions to address emerging issues and elevate performance standards. Today, LEED stands as the most widely utilized green building rating system worldwide [42]. Primarily focused on environmental considerations, LEED evaluates aspects such as

Sustainable Sites, Water Efficiency, Energy and Atmosphere, Material and Resources, and Indoor Environmental Quality categories.

Provisions have been incorporated into the system to take into consideration regional aims and variations, and several countries all over the world have established green building councils with the intention of promoting LEED. In the latter half of 2013, LEED v4 was made available to the public. It was not an upgrade to a whole new version; rather, the version that is already in use received a minor update in 2019 with version number v4.

The US Green Building Council gives the following explanation of the goals of the LEED standards:

- Encourage the use of methods that are integrated and holistic in nature.
- acknowledge those in the building business who are environmentally responsible.
- support green competitiveness.
- raise the level of awareness among consumers about the benefits of green buildings.
- The building market will undergo a transformation.
- Establishing a standard of measurement that everyone uses can help you define "green construction."

The guidelines place a significant amount of attention on each and every aspect of the construction of commercial buildings, including ecologically appropriate sites, water efficiency, energy and atmosphere, interior and outdoor quality, materials and resources, innovation, and the design process (Liebowitz, 2001). The grading system assesses 69 criteria in 6 main categories connected to the construction of commercial buildings. Points

are awarded for each requirement that is satisfied, and the higher the score, the better the building is considered. A structure is either certified or it is not, and based on its overall score, it is given one of the following labels: Certified, Silver, Gold, or Platinum.

To get certified, you must earn a minimum of 26 points, and you must earn at least 52 points to advance to the next level, platinum certification. To assist city authorities, developers, architects, engineers, and contractors in quantifying the myriad variables that go into the development of a sustainable building is the primary objective of the standards.

The Leadership in Energy and Environmental Design (LEED) system recognizes projects that meet or exceed defined standards and requirements. When prior versions of LEED were in operation, point allocation was handled by the LEED Technical Advisory Committees. To improve the process of determining what should be done by a project, the US Green Building Council (USGBC) has defined LEED impact categories that match USGBC sustainability standards. Reversing human activity that causes climate change; improving personal health and wellbeing; preserving and restoring water resources; preserving, enhancing, and restoring biodiversity and ecosystem services; promoting sustainable and regenerative material resource cycles; developing a greener economy; and improving social equity, environmental justice, and community quality of life are among the impact categories. One of the most significant areas of effect is reversing human behavior that promotes climate change. Other categories include safeguarding and restoring water resources, as well as safeguarding, augmenting, and restoring.

A weighting method was devised with the publication of LEED 2009 by statistically measuring and weighting those categories as a form of assessment. This was done in order

to provide a standard for comparison. The six basic credit categories that make up the LEED grading system are: Transportation (LT), Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Materials and Resources (MR), and Indoor Environmental Quality (IEQ) (EQ). Both the pre-requisites, which represent required strategies, and the credits, which represent elective strategies, are rewarded with point values.

LEED Credits

Figure 2 LEED V 4.1 BD+C criteria list.

Category	Indicators	Points/Requirement
Location and Transportation (LT)	LEED for Neighborhood Development Location	8-16
	Sensitive Land Protection	1
	High-Priority Site	1-2
	Surrounding Density and Diverse Uses	1-5
	Access to Quality Transit	1-5
	Bicycle Facilities	1
	Reduced Parking Footprint	1
	Green Vehicles	1
Total		32
Sustainable Sites (SS)	Construction Activity Pollution Prevention	Prerequisite
	Site Assessment	1
	Site Development - Protect or Restore Habitat	1-2
	Open Space	1
	Rainwater Management	2-3
	Heat Island Reduction	1-2
	Light Pollution Reduction	1
Total		10
Water Efficiency (WE)	Outdoor Water Use Reduction	Prerequisite
	Indoor Water Use Reduction	Prerequisite
	Outdoor Water Use Reduction	1-2
	Indoor Water Use Reduction	1-6
	Cooling Tower Water Use	1-2
	Water Metering	1
Total		11
Energy and Atmosphere (EA)	Fundamental Commissioning and Verification	Prerequisite
	Minimum Energy Performance	Prerequisite
	Building-Level Energy Metering	Prerequisite
	Fundamental Refrigerant Management	Prerequisite
	Enhanced Commissioning	2-6
	Optimize Energy Performance	1-18
	Advanced Energy Metering	1
	Demand Response	1-2
	Renewable Energy Production	1-3
	Enhanced Refrigerant Management	1
	Green Power and Carbon Offsets	1-2
Total		33
Materials and Resources (MR)	Storage and Collection of Recyclables	Prerequisite
	Building Life-Cycle Impact Reduction	2-5
	Building Product Disclosure and Optimization - Environmental Product Declarations	1-2

	Building Product Disclosure and Optimization - Material Ingredients	1-2
	Building Product Disclosure and Optimization - Sourcing of Raw Materials	1-2
	Construction and Demolition Waste Management	1-2
Total		13
Indoor Environmental Quality (IEQ)	Minimum Indoor Air Quality Performance	Prerequisite
	Environmental Tobacco Smoke Control	Prerequisite
	Enhanced Indoor Air Quality Strategies	1-2
	Low-Emitting Materials	1-3
	Construction Indoor Air Quality Management Plan	1
	Indoor Air Quality Assessment	1-2
	Thermal Comfort	1
	Interior Lighting	1-2
	Daylight	1-3
	Quality Views	1
	Acoustic Performance	1
Total		16
Overall Total		100

Additionally, additional points were awarded for the areas of innovation (IN) and regional priority (RP). The Integrative Design Process was awarded one point since meeting the requirements for certification is a prerequisite for doing so. It is required that the total score for the credits be at least forty points for the verification process to be successful. If your score is greater than average, you may be eligible for a higher level of LEED certification, such as LEED Certified, LEED Silver, LEED Gold, or LEED Platinum, each of which is worth 40 points. When credits are assigned to the LEED impact category, the quantity of points that are awarded for each credit is decided by the outcome weight of those credits. In the next step, LEED version 4 moved on to define impact categories explicitly by splitting them into discrete and restricted pieces known as key indicators. This was done so that the method could be meaningful. Credits were reviewed and correlated with regard to the seven impact essential aspects for the purposes of awarding points and producing a transparent scorecard that was to be utilized for the purpose of totaling points for the project (*U.S. Green Building Council Announces 2013 LEED for Homes Award Winners* | *U.S. Green Building Council*, n.d.).

Alternative Compliance Paths for International Projects Outside the United States are published by USGBC. These Alternative Compliance Paths include LEED v4 BD+C Alternative Compliance Paths for Europe (Gävle & Sabir Ali,)

2.3.2 MOSTADAM

The Saudi Ministry of Housing created the Mostadam GBAT, which is presently administered by the Sustainable Building organization. Vision 2030's stated development targets are important to the creation of the new grade system. Considering the local climate and topography, this grading system for buildings was developed. The Saudi economy benefits from this, and so do Saudi workers, because of the new jobs that are created.

The Saudi Building Code (SBC), also known as Mostadam, is intended to be compliant with the laws that are now in effect. Although Mostadam may be used just as it is, other grading systems will need some kind of adjustment in order to be in accordance with Saudi standards. There is an acknowledgement of the geographical differences that exist, which makes it feasible to recognize the local principles. As an added bonus, it accounts for geographical variations, allowing regional priorities to be set. Mostadam is expected to have a major effect on the neighborhood. After all, Saudi Arabia is now engaged in the construction of more than 5,200 projects with a combined value of USD 819 billion. That's about a third of all construction projects in the Gulf Cooperation Council (GCC). By rewarding Saudi companies for buying and using domestic goods and services, Mostadam encourages the growth of the Saudi economy and the creation of new employment opportunities. The book focuses on the local architecture and lifestyle of its characters.

Eventually, Mostadam will have a great deal of influence. The GBAT's goal is to have a positive social and environmental effect while also boosting productivity in the regional building industry.

The maximum number of storey permitted for an Individual Dwelling is three. Buildings that house many families often have four or more floors. Mostadam for Residential Buildings is not applicable to the following kind of structures:

- 1- Developments that are only intended to be short-term and have a lifespan of less than two years.
- 2- Residence halls on campus of a university
- 3- hotel-style accommodations with a variety of services
- 4- Residential care homes
- 5- Housing for temporary workers as guests

Key credits may be earned in the following areas:

1. Site Sustainability
2. Transportation and Connectivity
3. Region and Culture
4. Energy
5. Water
6. Health & Comfort
7. Policies, Management, and Maintenance
8. Materials & Waste
9. Education & Innovation



Figure 3 Figure SBC and Mostadam Relationship for Residential Buildings D+C

Mostadam and the SBC

The Saudi Building Code (SBC) sets out the basic requirements for designing and constructing buildings in the Kingdom of Saudi Arabia (KSA), incorporating legislative, administrative, and technical restrictions. The Saudi Green Building Code (SgBC), which is a component of the SBC, was established to ensure that buildings conforming to the code have a lesser impact on the environment. The Mostadam for Residential Structures was designed with the objective of exceedingly even the most basic standards set forth by the SBC, aiming to achieve an even higher level of environmental friendliness in residential

buildings. The SBC, and more specifically, the SgBC, is the organization with which it is affiliated.

MOSTADAM Residential Buildings D+C Credits

The following is a list of available credits in each category:

Figure 4 MOSTADAM Criteria List

Category	Indicators	Points
Site Sustainability (SS)	Sewage, Flood and Rainwater Management (Keystone)	2
	Ecological Assessment and Protection (Keystone)	2
	Construction Environmental Management	1
	Ecological Enhancement	1
	Heat Island Effect	2
	Light Pollution	1
	Total	9
Transportation and Connectivity (TC)	Electric Vehicle Provisions	1
	Access to Public Transportation	2
	Access to Amenities	2
	Home	1
	Individual Sustainable Transport	1
	Total	7
Region and Culture (RC)	Thriving Economy	2
	Heritage & Culture	2
	Vibrant Society	1
	Regional Focus	2
	Total	7
Energy (E)	Energy Performance (Keystone)	15
	Systems Commissioning (Keystone)	1
	Envelope Commissioning	1
	Energy Metering (Keystone)	1
	Energy Efficient Appliances	1
	Renewable Energy	7
	Ozone Impact	1
	Total	27
Water (W)	Indoor Water Performance (Keystone)	10
	Outdoor Water Performance (Keystone)	10
	Alternative Water Solutions	3
	Water Metering (Keystone)	1
	Total	24
Health and Comfort (HC)	Outdoor Thermal Comfort (Keystone)	2
	Indoor Thermal Comfort (Keystone)	2
	Ventilation	1
	VOCs and Low-Emitting Materials	2
	Access for All	1
	Daylight and Visual Comfort	2
	Acoustics	1
	Indoor Air Quality	1
	Active Residents	1
	Outdoor Space	1
	Total	14
Materials and Waste (MW)	Construction Waste Management	1
	Non-Polluting Insulation Materials	1
	Recycled Materials	2
	Total	4
Education and Innovation (EI)	Innovation	2
	Mostadam Guide (Keystone)	2
	Total	4
Policies, Management and Maintenance (PMM)	Residential Waste Management (Keystone)	1
	Sustainable Procurement	1
	Building Performance Monitoring	2
	Total	4

Figure 5 Mostadam for Residential Buildings D+C categories



The Mostadam system is flexible enough to be utilized in both single-family homes and multi-family homes of varying sizes. It is possible for mixed-use complexes to be classified as multi-residential structures so long as the residential component constitutes at least 90 percent of the gross floor area of the building. This criterion must be met in order for the possibility to exist (GFA). When a project does not meet these criteria, Sustainable Building conducts an in-depth analysis of the situation in order to determine how to proceed in the most efficient manner possible.

Mostadam Certification Levels:

- 1- Mostadam Green (20 points),
- 2- Mostadam Bronze (35 points),
- 3- Mostadam Silver (50 points),

- 4- Mostadam Gold (65 points),
- 5- Mostadam Diamond (80 points)

are the different Mostadam rating levels for Design + Construction and Operations + Existing (except for Commercial Design + Construction).

Figure 6 MOSTADAM Certification Levels



2.3.3 MOSTADAM and LEED

To effectively map LEED and MOSTADAM categories and indicators, we'll create a comparative table 1. highlighting the main categories and key indicators for each certification system. This will help in understanding the parallels and unique aspects of each system.

Table 1 Mapping LEED and MOSTADAM categories and indicators.

Category	LEED Indicators	MOSTADAM Indicators
Energy and Atmosphere	- Optimize Energy Performance- On-Site Renewable Energy- Enhanced Commissioning	- Energy Performance- Renewable Energy- Energy Management
Water Efficiency	- Water Use Reduction- Innovative Wastewater Technologies- Water Efficient Landscaping	- Indoor Water Use Reduction- Outdoor Water Use Reduction- Water Management
Indoor Environmental Quality	- Minimum Indoor Air Quality Performance- Low-Emitting Materials- Thermal Comfort- Daylight	- Indoor Air Quality- Low-Emitting Materials- Thermal Comfort- Quality of Views
Materials and Resources	- Recycled Content- Regional Materials- Certified Wood	- Sustainable Materials- Recycled Content- Local/Regional Materials

Sustainable Sites	- Site Selection- Development Density and Community Connectivity- Brownfield Redevelopment	- Site Selection- Community Connectivity- Ecological Impact
Innovation	- Innovation in Design- LEED Accredited Professional	- Innovation in Design- Sustainability Innovations
Location and Transportation	- Access to Quality Transit- Bicycle Facilities- Reduced Parking Footprint	- Public Transportation Access- Sustainable Transportation- Reduced Parking
Regional Priority	- Regional Priority Credits (specific to the project's location)	- Local Context Considerations- Region-Specific Sustainability Goals
Integrated Process	- Integrative Process (encourages early analysis of the interrelationships among systems)	- Integrated Design Process- Early Sustainability Assessments

Energy and Atmosphere:

- LEED focuses on optimizing energy performance, using renewable energy, and ensuring enhanced commissioning.
- MOSTADAM emphasizes energy performance, renewable energy, and effective energy management.

Water Efficiency:

- LEED includes indicators for reducing water use, implementing innovative wastewater technologies, and landscaping efficiently with water.
- MOSTADAM covers both indoor and outdoor water use reduction and overall water management.

Indoor Environmental Quality:

- LEED mandates minimum indoor air quality performance, use of low-emitting materials, thermal comfort, and maximizing daylight.
- MOSTADAM aligns with indoor air quality, low-emitting materials, thermal comfort, and ensuring quality views.

Materials and Resources:

- LEED promotes the use of recycled content, regional materials, and certified wood.
- MOSTADAM emphasizes sustainable materials, recycled content, and the use of local/regional materials.

Sustainable Sites:

- LEED addresses site selection, development density, community connectivity, and brownfield redevelopment.
- MOSTADAM covers site selection, community connectivity, and ecological impact considerations.

Innovation:

- Both LEED and MOSTADAM encourage innovation in design and reward sustainable innovations.

Location and Transportation:

- LEED includes access to quality transit, bicycle facilities, and reduced parking footprint.
- MOSTADAM focuses on public transportation access, sustainable transportation options, and reduced parking.

Regional Priority:

- LEED offers credits specific to the project's location to address regional priorities.
- MOSTADAM includes local context considerations and region-specific sustainability goals.

Integrated Process:

- LEED encourages an integrative process that considers the interrelationships among systems early on.
- MOSTADAM promotes an integrated design process with early sustainability assessments.

This comparative mapping helps in understanding how each system approaches sustainable building practices and highlights areas where they align or differ.

Table 2 Summary of Mostadam and LEED Certification Levels

Rating System	Certification Level	Points
Mostadam Five levels	Mostadam Green,	(≥ 20 points)
	Mostadam Bronze	(≥ 35 points)
	Mostadam Silver	(≥ 50 points)
	Mostadam Gold	(≥65 points)
	Mostadam Diamond	(≥ 80 points)
LEED Four levels	Certified,	40-49
	Silver,	50-59
	Gold or	60-79
	Platinum.	80+

Table 3 Comparison of LEED v4.1 and the Mostadam Rating systems Categories. Source: (Balabel, 2021)

Item No.	Category in LEED v4.1	Total Points	Category in Mostadam Rating System_Element #1.1 (Res. Buildings D + C)	Total Points
1	Integrative Process	1		0
2	Location and Transportation	9	Transportation and Connectivity	7
3	Sustainable Sites	9	Site Sustainability	9
4	Water Efficiency	11	Water	24
5	Energy and Atmosphere	35	Energy	27
6	Materials and Resources	19	Materials and Waste	4
7	Indoor Environmental Quality	16	Health and Comfort	14
8	Innovation	6	Education and Innovation	4
9	Regional Priority	4	Region and Culture	7
10			Policies, Management& Maintenance	4
	Total points	110		100

2.4 Building Information Modeling

A Building Information Model (BIM) is "a digital representation of a building's physical and functional attributes serving as a shared knowledge resource for information about a facility, establishing a reliable basis for decisions throughout its life cycle from inception on," according to the Whole Building Design Guide (WBDG, 2022). BIM is defined by

the American Institute of Architects (AIA) as "a digital three-dimensional model connected to a database of project information, incorporating all information from design conception through facility maintenance." BIM is defined by Autodesk as "an integrated process based on coordinated accurate information about a project from design through construction and operations" (Autodesk, 2022). According to the American Institute of Architects (*AIA*, n.d.), BIM is "a digital three-dimensional model connected to a database".

The building information modeling (BIM) idea dates to the 1970s. Around the middle of the 1980s, Simon Ruffle was the first person to use the phrase "building model." in the year 1992, G.A. van Nederveen and Tolman F came up with the term "building information model." (Van Nederveen & Tolman, 1992)

The shift from manual drawings to digital AutoCAD has greatly enhanced efficiency in design, but the adoption of 3D and 3D CAD software poses certain challenges (Smith, 2018).

A significant hurdle is the steep learning curve associated with mastering these tools, potentially hindering widespread adoption (Jones et al., 2019). High-quality 3D modeling demands powerful hardware, which can lead to increased costs for equipment upgrades (Brown, 2020). Licensing fees for 3D CAD software are often high, limiting access for smaller firms or individual designers (Johnson, 2017).

Compatibility issues may arise when different 3D CAD software is used, affecting collaborative efforts (Lee & Wang, 2018). Security concerns emerge as design data becomes vulnerable to cyber threats, risking unauthorized access or data breaches (Roberts, 2019). Achieving realistic rendering in 3D models remains a challenge (White, 2021).

Implementing 3D CAD software requires a substantial initial investment in terms of cost and time (Taylor, 2018). Users are dependent on software developers for updates, introducing potential delays in responsiveness to user needs (Anderson, 2020).

Despite these challenges, ongoing developments in 3D and CAD technologies are addressing many limitations, making them increasingly powerful tools in design and drafting (Brown & Garcia, 2022). While obstacles exist, the benefits in terms of enhanced efficiency and capabilities make the transition to 3D CAD a transformative leap in design practices (Smith et al., 2023).

BIM (Building Information Modeling) emerges as a natural evolution of CAD, offering users the ability to seamlessly construct 3D models and shapes within the software using various applications like Revit, Tekla Structures, and numerous other software tools. This technology marks a significant advancement beyond traditional CAD capabilities.

BIM facilitates the development of 3D models, and these models can serve as the foundation for creating designs suitable for 2D printing. This feature enhances the versatility of BIM, allowing users to translate intricate 3D designs into practical 2D formats for documentation or other purposes.

Design and construction companies extensively utilize BIM throughout the entire lifecycle of a project, from the initial stages of design and planning to the construction, operation, and ongoing management of diverse buildings and infrastructures. BIM acts as a comprehensive digital platform, fostering collaboration and providing a holistic approach to the various facets of the AEC (Architecture, Engineering, and Construction) industry.

Objective and Uses of BIM:

- The primary objective of BIM is to enable a more integrated and collaborative approach to the entire lifecycle of a built environment. Some key uses and benefits of BIM include:
- Collaborative Design: BIM facilitates collaboration among different stakeholders, including architects, engineers, contractors, and facility managers, ensuring that all aspects of a project are considered and integrated.
- Improved Visualization: BIM allows for the creation of detailed 3D models, providing a visual representation of the project that aids in better understanding and decision-making.
- Clash Detection: BIM helps identify and resolve clashes or conflicts in the design phase, minimizing errors and reducing the need for costly changes during construction.
- Efficient Planning: The software supports accurate quantity take-offs, cost estimation, and scheduling, enabling more efficient project planning and resource allocation.
- Lifecycle Management: BIM supports the entire lifecycle of a project, from design and construction to operation and maintenance. This facilitates better asset management and long-term planning.
- Energy Analysis: BIM tools can analyze the energy performance of a building, allowing designers to optimize energy efficiency and sustainability.
- Facility Management: BIM provides valuable data for facility management, assisting in maintenance, renovations, and future planning.

By encompassing these capabilities, BIM stands as a transformative tool in the AEC industry, streamlining processes, improving collaboration, and enhancing the overall efficiency and sustainability of construction projects. (Nezamaldin, 2019)

The digital representation of a facility's physical and functional characteristics is kept in a BIM, which acts as a shared knowledge resource and a reliable basis for decision-making throughout the entirety of the facility's life cycle, beginning with its initial design and continuing all the way through its eventual decommissioning (Chen et al., 2015). The malleable BIM platform makes it possible to share data over the entirety of the building's life cycle. BIM is an acronym that stands for building information modeling. This software offers an integrated design tool that can evaluate the whole building life cycle. Additionally, BIM encourages cooperation as well as integration and interoperability within the AEC sector. In addition to this, it offers detailed information as well as a picture of how well the structure operates. The various life cycle data from the various tools may be simply integrated using BIM's add-in applications designed specifically for the software.

Definition of BIM

There is a lot of ambiguity surrounding BIM and its meaning and interpretation has taken many forms over the years. The most used versions, as cited in Bouw Informatie Raad (2015) are:

1. Building Information Models – This version focusses on the representation part; A digital representation of the design and as-built scenario.

2. Building Information Modeling – Here, the focus is shifted towards the process of creating the digital models in close collaboration with other stakeholders using a set of digital tools.
3. Building Information Management – In this version, information is the central aspect of BIM. Using BIM is all about the creation, use and re-use of building information.

Other versions encompass the multidisciplinary nature of BIM and therefore, in the context of this study, BIM stands for Building Information Modeling, and is defined as:

“A set of interacting policies, processes and technologies that generate a methodology to manage the essential building design and project data in a digital format throughout the building’s lifecycle” - Penttila (2006) as cited in Succar et al., (2012).

Scope of its use today

BIM use can be defined as “A method of applying Building Information Modeling during a facility’s lifecycle to achieve one or more specific objectives” (Kreider & Messner, 2013). Based on the purpose of implementation, BIM uses can be primarily classified into five types, as shown in Figure 7.

Primary BIM Use	GENERATE	GATHER	ANALYSE	COMMUNICATE	REALIZE
Secondary BIM Use	Design, prescribe, arrange etc	Capture, Monitor, Quantify, Classify	Coordinate, Evaluate, Predict, Validate	Visualize, draw, document etc	Fabricate, assemble, regulate etc

Figure 7 Classifications of BIM

1. **Generate:** The purpose of this BIM use is to create information about the building. Examples include prescribing the arrangement of zones or type of walls to be used

in the design phase, or specifying the materials or equipment used in the construction phase. Every time a new model is authored, or new information is added to the BIM model, information is generated.

2. **Gather:** To collect and organize information about a building at any lifecycle phase. Examples of such BIM uses include capturing the status of the facility, quantifying the amount of material present in a facility etc. The objective of this BIM use is to merely observe and gather information about the building, but not to make any analysis or inferences from this data.
3. **Analyze:** The purpose of this use is to examine the features of a design or facility to evaluate or predict its performance. To implement this BIM use, information must be first generated and then gathered.
4. **Communicate:** To share the information about the building and the analysis results with other stakeholders involved in the project. This is often a by-product of the other BIM uses. The medium of communication may include 3D realistic visualizations or 2D drawings or other project related documents.
5. **Realize:** The purpose of this last use is to produce a physical element using BIM data. Still in the initial stages of its implementation, this BIM use will give the industry the power to remove human input in the production, assembly, and control of facility elements.

2.4.1 Major BIM Software and its Uses

There are several BIM authoring tools available on the market today, some of which are Vectorworks, which was developed by Nemetschek, Microstation, which was

developed by Bentley Systems, Revit, which was developed by Autodesk, and Archicad, which was developed by Graphisoft. These authoring tools are what make up the Graphical User Interface (GUI) for a parametric geometry model of a building that is represented by coordinated 2D and 3D perspectives (Gävle & Sabir Ali, n.d.). The model may be seen from either perspective. A relational database is populated with the data generated by the applications using the modeled building components. Some of these applications include simulation engines, which may be used in order to perform various engineering analyses. Revit and Archicad are the two Building Information Modeling (BIM) applications that are most widely recognized and utilized. Because Revit is completely interchangeable with other Autodesk products, most notably AutoCAD, which has led the way in the CAD industry for many years, it has attracted a larger number of customers than its competitors. Revit and Archicad both come with energy analysis modules that may be purchased separately.

There is a wide range of BIM software. This is commercial Revit is one of the most popular/used building information modeling software. Below in figure 8 is a list that includes the top 20 BIM software applications currently available (Finance B2B Directory - Trusted SaaS Software Reviews | FinancesOnline.Com, n.d. Online) //ignore this reference and use respected sources such as research papers

- | | |
|-----------------------------|--------------------------|
| 1 Revit | 11 BIMobject |
| 2 Navisworks | 12 BIMx |
| 3 Autodesk BIM 360 | 13 Archicad |
| 4 SketchUp | 14 Vectorworks Architect |
| 5 Tekla BIMsight | 15 PriMus IFC |
| 6 Procore | 16 Edificius |
| 7 Dassault Systèmes BIM | 17 midas Gen |
| 8 Trimble Connect | 18 Allplan Architecture |
| 9 AECOsim Building Designer | 19 Buildertrend |
| 10 Hevacomp | 20 BricsCAD BIM |

Figure 8 BIM software.

2.4.1.1 Previous Studies BIM

Table 4 Previous studies in BIM

Study	Model generating Tool	Energy Analysis Tool	Case	Location
(Bahdad, et al., 2021)	Revit	Design Builder/Energy Plus	Residential building	Yemen
(Galiano-Garrigós, et al., 2019)	Revit	Green Building Studio / Sefaira / Design Builder / IES VE / HULC	Detached House	Spain
(Lin, et al., 2019)	Revit	IES VE	Public retail market	China
(Galiano-Garrigós, et al., 2021)	Revit	Cypetherm HE Plus / Design Builder	School building, Lecture Hall and Research lab	Spain
(Vergas & Hamui, 2021)	Design Builder	Design Builder	Attached Home	Mexico
(Antón, et al., 2019)	Revit	Design Builder	Multi-story apartment Building	Spain
(Ugliotti, et al., 2016)	Revit	Ediclima	Library	Italy

Table 5 Previous Studies in BIM

PAPER NO.	Number of Case studies	Type of case study (real / theoritical)
(Abdulhamid et al., 2019)	two	theoretical
(Romano & Riediger, 2019)	one	real
(Akçay & Arditi, 2017)	one	theoretical
(Alhilli & Burhan, 2021)	one	real
(Wei & Chen, 2020)	one	real
(Majeed et al., 2019)	one	real
(Abdelalim & Abo.elsaud, 2019)	one	theoretical
(Abouhamad & Abu-Hamd, 2021)	three	real
(Raimondi & Aguerre, 2018)	one	real
(Alfalah et al., 2021)	two	real
(Veselka et al., 2020)	one	real
(S. Y. Chen, 2019)	one	theoretical
(Abdulrasool & Raoof Mahjoob, 2020)	one	real
(Ryu & Park, 2016)	two	real
(Marzouk et al., 2016)	one	theoretical
(Reeves et al., 2015)	two	real
(Alwan et al., 2015)	one	real
(Nguyen et al., 2010)	one	theoretical
(Olawumi & Chan, 2021)	one	theoretical

2.4.1.2 BIM – Revit

Revit is a 3D modeling tool that can be used to model the numerous components of a structure. This allows the engineer to see the design of the building before it is shown in drawings. The user may have a mental picture of the finished structure in its entirety before changing the individual pieces or designs into drawings. After that, the contractor may build the structure by following the designs.

Revit is used by various types of engineers, including structural engineers, MEP engineers, landscape architects, and architects. Autodesk releases new versions of Revit on an annual basis, and the most recent releases are compatible with Dynamo. The version of Revit that is being used for this project is 2023.

The Revit Hierarchy

The structure of all Revit objects is the same. These items make use of the same leveling system for their components. They are broken up into four individual parts.

Category

The list of categories that are available in Revit cannot be customized or altered in any way. When using Revit, every component should be placed into the appropriate category.

Family

In Revit, every element belongs to a family, and every family falls under a certain category. Revit's families are split up into three groups.

System Families: (walls, floors, roofs and ceilings).

These are constructed within a project.

Loadable Families: (Components such as desks, parking space and trees).

These are constructed independently of the project.

In-Place Families: built directly into a project.

Type

Different types of households can be distinguished from one another. A specific member of the family is referred to as a type, and it is distinguished from other members of the family by its size and other features.

Instance

An instance is a term used to describe a tangible product that is the result of the project. Because an instance is part of the system at its most fundamental level, it can assume a wide variety of forms.

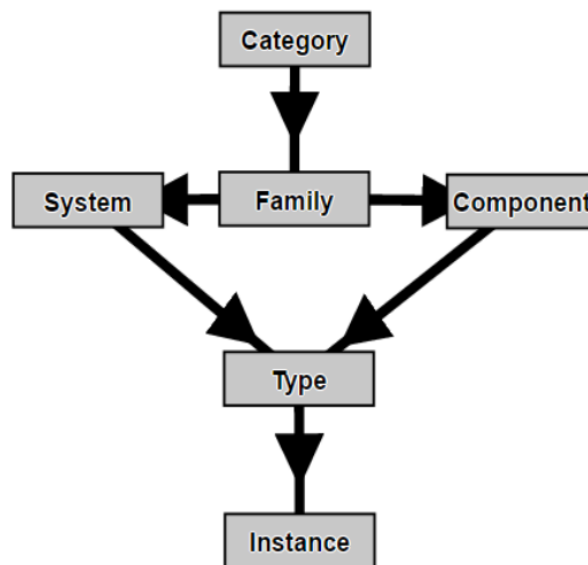


Figure 9 The Revit Hierarchy (Modelical, 2016)

2.4.2 Building Energy Modelling (BEM)

Building Energy Modeling (BEM) has proven to be highly beneficial across various stages of the building lifecycle, providing critical insights and functionality. In the pre-construction phase, BEM acts as a powerful analytical tool that enables eco-conscious designers to develop sustainable building solutions. During construction, it aids contractors in selecting materials and components that meet specific performance criteria. Additionally, BEM's incorporation into facilities management during the operational phase of buildings allows for the assessment of system modifications to improve energy efficiency. This makes BEM applicable in both managing existing facilities and in undertaking renovation or retrofit projects (US General Services Administration, 2009).

BEM tools fulfill a dual function in the design and construction of green buildings—as both a design instrument and a measurement resource. In the early design stages, when elements such as building massing, orientation, and geometry are being formulated, BEM is crucial. It enables designers to iteratively test and refine different conceptual models, steering the development of the building's form towards more sustainable versions (Krygiel & Nies, 2008).

The effective use of BEM, especially when used in conjunction with Building Information Modeling (BIM), is noteworthy. BIM acts as a comprehensive database for diverse building-related data (e.g., geometry, material properties, cost), facilitating a smooth integration with BEM. This synergy allows designers to evaluate the environmental impacts of modifications made to the building model (Schlueter & Thesseling, 2009).

As the design process advances and the building form is solidified, with material and system selections underway, BEM tools take on a detailed role pertaining to design specifications. At this later stage or even during building occupancy and facilities management, BEM tools provide precise measurements of various loads and aid in fine-tuning design specifications. For example, they can evaluate the thermal performance of different window types and calculate potential annual cost savings (US General Services Administration, 2009).

2.4.3 BIM in Sustainable Building Design and Assessment

Building Information Modeling (BIM) plays a pivotal role in advancing green building design by providing a comprehensive platform for analyzing lighting, energy, material usage, and costs, facilitating the delivery of optimal solutions for sustainable design and construction (Wong & Zhou, 2013) (Eadie et al., 2013). BIM is characterized by attributes such as high speed, simplicity, precision, and visual analysis capacity, contributing significantly to sustainability assessments (Wong & Zhou, 2013) (Eadie et al., 2013). The integration of BIM with building sustainability assessment, as highlighted by Wong and Zhou (2013), leads to an enhancement in overall building performance.

The Green Building Assessment process is acknowledged for its inherent challenges, marked by laborious and time-consuming procedures. The complexity arises from the substantial interdisciplinary information required to demonstrate compliance with certification requirements, distributed among various project stakeholders. Moreover, frequent design changes in the preconstruction phase necessitate repetitive assessments.

Herein lies the value of BIM, with its unique selling point lying in intelligent data integration within the traditionally fragmented industry.

Research on methods to facilitate green building assessments using BIM has gained increasing attention for practical reasons. Firstly, this integration supports designers in selecting effective sustainability strategies during early design stages. Secondly, it aids sustainability experts in efficiently assessing design compliance with green building certification requirements. Thirdly, it streamlines the extensive document management necessary for certification achievement (Lu et al., 2017).

The existing body of research in this domain can be broadly categorized into two groups: BIM-based Green Building Assessment (GBA) tools and BIM-based GBA processes. Subsequent sections will present the findings from the literature within each of these groups.

BIM-based GBA tools

Green Building Assessment (GBA) tools have undergone notable developments since their inception. Early endeavors in this field concentrated on establishing connections between sustainability indicators and REVIT project parameters (Barnes & Castro-Lacouture, 2009; Nguyen et al., 2010; Azhar et al., 2011; Wong & Kuan, 2014). Notably, Azhar et al. (2011) proposed a conceptual framework for integrating BIM into the LEED certification process, mapping diverse sustainability analyses achievable through various BIM tools to corresponding LEED credits. This seminal work has maintained prominence in the domain.

Subsequent research in this area has expanded in terms of the variety and quantity of credits linked to BIM, integration with diverse external databases, and the exploration of various automation tools. Automated assessment modules have been developed using platforms such as REVIT API (Chen & Nguyen, 2017; Jalaei & Jrade, 2015), Microsoft Excel Macros (Akçay & Arditi, 2017), and Dynamo for REVIT (Bergonzoni et al., 2016). However, these studies often focused on specific aspects of various green certifications. Currently, comprehensive software tools capable of automating all assessments for a given green certification system based on BIM models are not readily available.

Autodesk REVIT in BIM authoring tools and IESVE in BIM-based performance analysis tools stand out as the most commonly utilized software for automation (Ansah et al., 2019 & Carvalho et al., 2020). While these advancements showcase progress, achieving a fully automated, comprehensive tool for green certification assessments remains an ongoing challenge in the realm of BIM-based GBA tools.

BIM-based GBAT process

In the context of BIM-based Green Building Assessment tools (GBAT) processes, technological advancements offer the potential for automation. However, the practical implementation of such advancements necessitates changes in existing processes and associated roles. Wu & Issa (2013) conducted a comprehensive examination of Green BIM practices and introduced an Integrated Green BIM Process Map (IGBPM), providing a structured framework for integrating Green BIM practices, particularly in the early design

phase. Utilizing LEED credits as a case study, they further developed a detailed step-by-step operational guide, illustrating the implementation of specific Green BIM practices.

Taking a practical orientation, Zanni et al. (2014 & 2016) offered a management perspective on a BIM-enabled sustainability framework. Through in-depth interviews with industry practitioners, they identified typical sustainability tasks and aligned them with BIM requirements. It is important to note that while these studies provide valuable insights into the integration of Green BIM practices, they do not delve into the specifics of assessments and documentation processes required for green certifications. Further research is needed to bridge this gap and establish more comprehensive guidelines for incorporating BIM into the broader GBA process.

Challenges and barriers to BIM based GBAT

Despite significant strides in academic research on the potential applications of Building Information Modeling (BIM) for green building assessments (GBA) and integration strategies, several challenges hinder its practical implementation. On the technological front, barriers such as interoperability issues between BIM tools and limitations in replicability and scalability, as observed in scholarly works, impede the broader adoption of BIM for GBA (Ansah et al., 2019). In a comprehensive review of Green-BIM applicability and future research directions, Lu et al. (2017) highlighted not only technological hurdles but also the absence of clear standards for effective green BIM implementation in the industry.

While much academic focus has been on technological aspects, there is a notable gap in research concerning the execution aspects of BIM-based GBA. A shift to a BIM-based assessment process necessitates changes in the roles and responsibilities of stakeholders, requiring adjustments in contractual agreements and BIM protocol documents. Insufficient attention has been given to policy-related aspects essential for the effective integration of BIM and GBA. Alsehrawy et al. (2020) emphasized that, in addition to BIM and GBA challenges, factors such as lack of awareness among practitioners, resistance to change, and budget constraints can impede practical implementation.

Lu et al. (2017) underscored that existing research on BIM-GBA integration primarily adopts a theoretical standpoint and lacks industry perspective. Further research should delve into the needs of industry practitioners concerning green BIM applications to bridge this gap. Addressing these challenges will be crucial for realizing the full potential of BIM in the context of green building assessments.

2.5 BIM Optimization to Support Green Building Design & Assessment.

Building Information Modeling (BIM) has become a pivotal tool in green building design and assessment, facilitating more efficient and sustainable construction processes. Several efforts have been made to optimize the use of BIM for enhancing green building outcomes. These efforts can be categorized into various main areas, including energy performance analysis, sustainability certification, lifecycle assessment, and integration with green building standards.

Energy performance analysis is a significant focus within BIM optimization efforts. Studies have demonstrated how BIM can streamline the evaluation of energy consumption and efficiency, allowing for more accurate and dynamic modeling of building performance. For instance, Kim et al. (2015) explored how BIM can be used to simulate energy performance scenarios, resulting in more sustainable design decisions.

Sustainability certification is another area where BIM has shown promise. Researchers like Wu and Issa (2012) have investigated the integration of BIM with certification systems like LEED and BREEAM, highlighting how BIM tools can automate the documentation and submission processes required for certification, thus improving the efficiency and accuracy of achieving sustainability goals.

Lifecycle assessment (LCA) within BIM frameworks has been examined to ensure that environmental impacts are considered throughout the building's lifespan. Research by Azhar et al. (2011) demonstrated how BIM-based LCA tools can assess the environmental performance of buildings, providing comprehensive insights into materials' impacts, construction processes, and operational phases.

Integration with green building standards is a critical aspect of BIM optimization. Studies such as those by Nguyen et al. (2010) have focused on aligning BIM capabilities with specific green building criteria, enhancing compliance and facilitating better design practices that meet sustainability benchmarks.

One notable effort in optimizing BIM for green building design is the use of Revit plugins. Revit, a widely used BIM software, offers numerous plugins designed to enhance sustainability analysis and compliance. Plugins like Insight 360, Green Building Studio,

and Tally are instrumental in providing advanced simulation capabilities, real-time feedback, and comprehensive lifecycle assessments. For instance, the Insight 360 plugin allows designers to perform energy and environmental performance simulations directly within Revit, providing valuable insights during the early design stages (Autodesk, 2019).

Green Building Studio, another powerful Revit plugin, facilitates whole-building energy analysis by leveraging cloud computing to run simulations, analyze energy consumption, and evaluate renewable energy potential (Autodesk, 2019). Tally, on the other hand, integrates lifecycle assessment into the BIM workflow, enabling designers to measure the environmental impact of building materials and make informed decisions to minimize ecological footprints (KT Innovations, 2014).

These plugins exemplify how Revit extensions can significantly enhance the capabilities of BIM in promoting green building design and assessment. They offer a seamless integration of advanced analysis tools, making it easier for architects and engineers to incorporate sustainability considerations into their projects.

In addition to using existing plugins, creating custom add-ins for Revit can further optimize BIM for specific green building requirements. Developing an add-in using Visual Basic or C# within the Revit API framework allows for tailored functionalities to meet unique project needs. Visual Studio is commonly used for developing these add-ins, providing a robust environment for writing, debugging, and deploying code.

To create an add-in, a developer would set up a project in Visual Studio, referencing the Revit API libraries. The Revit API offers extensive documentation and samples to guide developers through the process. Key steps include defining the commands and user

interface elements, implementing event handlers, and ensuring the add-in integrates seamlessly with Revit's workflow. The resulting tool can automate repetitive tasks, enhance data extraction, or integrate advanced analysis features directly into the Revit environment, significantly improving efficiency and accuracy in green building design.

For example, Hergunsel (2011) developed a custom Revit add-in to automate the extraction of material quantities for environmental impact assessment, showing how tailored tools can enhance BIM's capability in sustainability analysis. Similarly, Santos et al. (2019) created a Revit add-in to streamline the process of checking compliance with green building standards by automating data extraction and analysis from the BIM model. These studies highlight the potential of custom add-ins to not only streamline design processes but also significantly enhance the sustainability of building projects.

In summary, optimizing BIM for green building design encompasses various efforts, from energy performance analysis to lifecycle assessment and integration with green building standards. The use of Revit plugins, alongside the development of custom add-ins using Visual Basic or C#, represents significant advancements in this domain. These tools provide sophisticated capabilities that streamline sustainability assessments and support environmentally conscious design practices.

Table 6 Approaches for BIM-Based Sustainability Improvements

Improvement Type	Approach	Reference
Energy Performance Analysis	Dynamic modeling of energy consumption scenarios	Kim et al. (2015)
Sustainability Certification	Integration with LEED and BREEAM systems	Wu and Issa (2012)
Lifecycle Assessment (LCA)	BIM-based tools for assessing environmental impacts	Azhar et al. (2011)

Integration with Green Standards	Aligning BIM capabilities with sustainability criteria	Nguyen et al. (2010)
Revit Plugins	Tools like Insight 360, Green Building Studio, Tally	Autodesk (2019); KT Innovations (2014)
Custom Revit Add-ins	Developing tailored functionalities using Visual Basic or C#	Hergunsel (2011); Santos et al. (2019)

2.6 Summary of the Chapter

In summary, the exploration of sustainability, sustainable architecture, green building assessment tools, and Building Information Modeling (BIM) underscores the interconnectedness of these elements in shaping a responsible and resilient built environment.

Sustainability, a concept widely embraced yet occasionally vague across disciplines, finds a cornerstone in the Bruntland definition, emphasizing equity across generations. Architecture, as a mirror reflecting societal sustainability, grapples with a dual role of contributing to and mitigating unsustainability. Adopting an ecological design approach, sustainable architecture responds to global challenges, aiming for eco-friendly, energy-efficient buildings.

Green building practices, exemplified by LEED and Mostadam, offer a structured framework for evaluating sustainability. The Green Building Assessment process, though complex, benefits from BIM's intelligent data integration, streamlining assessments, especially amid preconstruction design changes.

LEED and Mostadam, while regionally distinct, share goals of holistic methods, green competitiveness, and transformative impacts. The global push for environmentally responsible building practices is evident in the convergence of recognized standards and locally adapted frameworks.

BIM's transformative role in the Architecture, Engineering, and Construction (AEC) industry is undeniable. From its inception in the 1970s to the present, BIM has evolved, overcoming challenges associated with traditional CAD tools. The major BIM software—Revit, Archicad, Vectorworks, and Microstation—serves as a crucial interface, facilitating parametric geometry modeling and offering coordinated 2D and 3D perspectives.

The multifaceted uses of BIM, from collaborative design to facility management, contribute to its indispensability in the AEC industry. Its ability to visualize, analyze, and manage building data throughout the lifecycle signifies its role as a cornerstone in modern construction practices.

In conclusion, the amalgamation of sustainable architecture, green building assessment tools, and BIM signifies a collective shift toward responsible construction practices. As the world grapples with climate change and resource constraints, this holistic approach stands as a crucial endeavor toward a sustainable and regenerative future. The evolution of BIM and the convergence of global standards underscore the industry's commitment to innovation, collaboration, and a positive global impact. Looking ahead, as technology advances, BIM is poised to play an increasingly vital role in shaping the future of the built environment. This comprehensive overview serves as a foundational literature review for

the thesis, weaving together the threads of sustainability, architecture, assessment tools, and transformative technologies.

CHAPTER 3

RESEARCH METHODOLOGY

This research aims to investigate the level of support provided by Building Information Modeling (BIM) software (Revit) for Green Building Assessment Tools (LEED & MOSTADAM). Developing a valid and reliable research methodology is a major cornerstone of this study. This chapter provides a detailed description of the research methodology adopted in the study and the rationale of the methodology.

3.1 Overview

To examine the complex relationship between Green Building Assessment Tools (GBAT) and Building Information Modeling (BIM), there is a need to use a multi-method research approach (Bryman, 2006). This is because the examined topic is complex and requires different approaches to be fully understood. By using multiple methods, researchers can check and confirm results, making the study stronger both in theory and practice (Creswell & Plano Clark, 2011).

This research utilizes several methods, including (1) extensive literature review, (2) content analysis of a sample of green building assessment tools, (3) BIM case study of a sample building, (4) data analysis and evaluation by expert panel. Employing multiple methods is a common and effective way to conduct research, when studying complex phenomena like this one, ensuring the study is well-founded and trustworthy (Tashakkori & Teddlie, 2010).

The adopted multi-method approach aims to cross-validate the results and strengthen the study theoretically and methodologically. It also ensures a practical and well-founded research framework that integrates literature review with empirical data from content analysis, case studies, and expert interview. The strategic combination of qualitative and quantitative techniques is essential for providing a holistic view of the interactions between GBAT and BIM. Qualitative methods bring depth and context through detailed analyses and practitioner interviews, while quantitative methods contribute scalable and generalizable data through simulations and statistical evaluations, enhancing the robustness and depth of the findings (Amadi, 2023).

3.2 Research Design and Methods

The research design and methods in this study are carefully crafted to investigate the application of Building Information Modeling (BIM) for two green building assessment tools (LEED and MOSTADAM) and the level of support and coverage of green building criteria of these assessment tools. The research design includes four phases: 1) Identifying green building assessment criteria, 2) BIM model development, 3) evaluating BIM performance and level of coverage, and 4) optimizing BIM capabilities. Every phase of the method includes specific research tasks and is illustrated in figure 1.

Each task is designed to ensure the thorough execution of the research methodology. This systematic workflow aims to provide comprehensive insights into sustainable construction practices, focusing on the synergies and potential gaps between GBAT and BIM. The workflow of the research methodology is illustrated in Figure 10 below in detail.

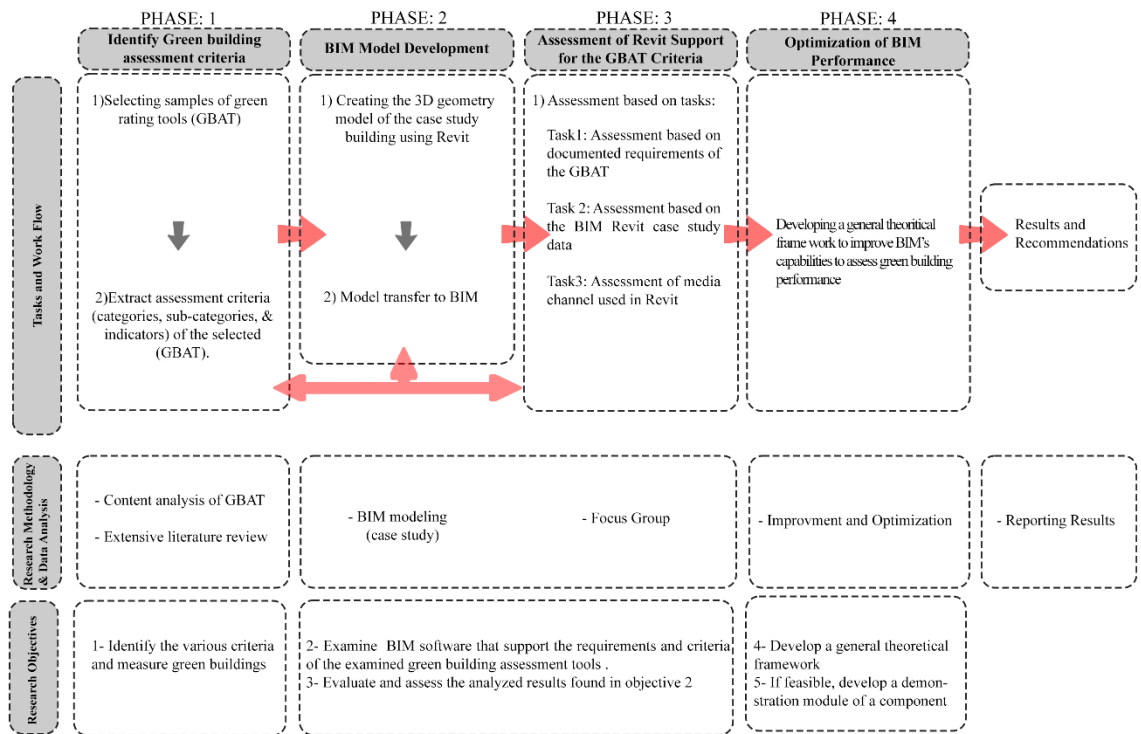


Figure 10 Workflow framework of methodology.

3.2.1 Sample of GBAT & Extraction of the GBAT Criteria

The first Phase of the research is to identify a comprehensive list of green building assessment criteria established in two GBAT as well as relevant existing literature. This is a crucial phase for subsequent phases of the research. To compile a comprehensive list of the green building criteria, the research uses a multifaceted approach combining both literature review and content analysis of a sample of Green Building Assessment Tools (GBAT). Through meticulous examination and scrutiny, samples of two relevant GBAT were selected. and extract a rich tapestry of assessment criteria, categories, sub-categories, and indicators.

I. Sample of GBAT

The initial phase of the research has identified and extracted a comprehensive list of green building assessment criteria from the two selected Green Building Assessment Tools (GBATs), specifically LEED and MOSTADAM, as well as from relevant literature. This crucial phase utilized a multifaceted approach, combining literature review and content analysis, which facilitated a thorough examination and careful selection of the GBAT samples. The analysis yielded a detailed set of assessment criteria, spanning multiple categories, sub-categories, and indicators. These findings establish a foundational framework for subsequent phases of the study, enhancing our ability to evaluate green building practices effectively.

According to a survey study conducted by (Al-Surf et al., 2021) in Saudi Arabia, LEED and Mostadam emerged as the predominant Green Building Assessment Tools (GBATs). The study revealed that LEED was more favored among respondents, while Mostadam also demonstrated strong acceptance and was often used alongside LEED. Over 44% of the respondents indicated a preference for employing both rating systems, reflecting a substantial level of awareness, and understanding of green and sustainable building principles among the participants.

LEED and MOSTADAM were selected as a sample GBATs in the study for several reasons. Firstly, LEED is globally recognized and extensively utilized within the industry, providing a comprehensive framework for evaluating sustainable building practices. Conversely, Mostadam is a regional tool specifically designed for Saudi Arabia, offering tailored criteria that address local environmental and sustainability challenges. Their

combined use ensures that the research findings will be highly relevant and broadly applicable to diverse green building initiatives within Saudi Arabia. This dual utilization underscores the importance of leveraging both systems to capture the full spectrum of sustainable building standards and practices. (Al-Mansour et al., 2021; Smith & Lee, 2023; Zhang & Liu, 2022)

The choice of LEED and MOSTADAM is strategically aligned with the study's goals to advance knowledge in the integration of green building assessment and BIM technologies. The anticipated results of this research are expected to influence industry standards and foster the development of more sustainable, efficient building projects in Saudi Arabia and potentially globally.

LEED

The selection of LEED BD+C version 4.1 for New Construction and Major Renovation for the study of a residential building is justified by its comprehensive assessment criteria tailored specifically for new residential construction and major renovation projects. This rating system is designed to address key sustainability aspects relevant to residential buildings, such as energy efficiency, water conservation, indoor environmental quality, and materials selection.

The LEED version used for this study was v4.1, prior to the updates made in July. In the updated LEED v4.1 (as of July), some adjustments were introduced to the “Optimize Energy Performance” indicator. This indicator now includes a total of 18 points, divided into two sub-indicators: Points for Percentage Improvement in Energy Performance –

Percent Cost PCI (1-9 points) and Points for Percentage Improvement in Energy Performance – Percent Greenhouse Gas Emissions PCI (1-9 points).

MOSTADAM

The selection of MOSTADAM residential D+C, the Saudi Green Building System, for the study of a residential building is justified by its tailored assessment criteria aimed at promoting sustainable practices in the Saudi Arabian context. MOSTADAM addresses key sustainability aspects relevant to residential buildings, including energy efficiency, water conservation, materials selection, and indoor environmental quality.

II. Extraction Assessment Criteria

The next phase is to extract the green building assessment criteria from the selected sample of the GBAT LEED, & MOASTADAM, to establish a comprehensive list of green building criteria in the selected GBAT sample.

LEED Extraction:

The LEED certification system is structured across various categories, each with specific indicators and associated points. The content analysis of LEED BD+C for New Construction yielded a comprehensive list of assessment criteria, organized into distinct categories and indicators. The analysis focused on extracting indicators used to assess the sustainability performance of residential buildings.

The categories included in our extraction are Location and Transportation, Sustainable Sites, Water Efficiency, Energy and Atmosphere, Materials and Resources, Indoor Environmental Quality, Innovation, and Regional Priority. Each category encompasses

specific indicators and prerequisite indicators that collectively determine the building's sustainability performance. The following table 7 provides a detailed overview of these categories, presenting the points or requirements associated with each indicator.

Table 7 Summary of key indicators in each category

Category	Indicators	Points/Requirement
Location and Transportation (LT)	LEED for Neighborhood Development Location	8-16
	Sensitive Land Protection	1
	High-Priority Site	1-2
	Surrounding Density and Diverse Uses	1-5
	Access to Quality Transit	1-5
	Bicycle Facilities	1
	Reduced Parking Footprint	1
	Green Vehicles	1
Total		32
Sustainable Sites (SS)	Construction Activity Pollution Prevention	Prerequisite
	Site Assessment	1
	Site Development - Protect or Restore Habitat	1-2
	Open Space	1
	Rainwater Management	2-3
	Heat Island Reduction	1-2
	Light Pollution Reduction	1
Total		10
Water Efficiency (WE)	Outdoor Water Use Reduction	Prerequisite
	Indoor Water Use Reduction	Prerequisite
	Outdoor Water Use Reduction	1-2
	Indoor Water Use Reduction	1-6
	Cooling Tower Water Use	1-2
	Water Metering	1
Total		11
Energy and Atmosphere (EA)	Fundamental Commissioning and Verification	Prerequisite
	Minimum Energy Performance	Prerequisite
	Building-Level Energy Metering	Prerequisite
	Fundamental Refrigerant Management	Prerequisite
	Enhanced Commissioning	2-6
	Optimize Energy Performance	1-18
	Advanced Energy Metering	1
	Demand Response	1-2
	Renewable Energy Production	1-3
	Enhanced Refrigerant Management	1
	Green Power and Carbon Offsets	1-2
Total		33
Materials and Resources (MR)	Storage and Collection of Recyclables	Prerequisite
	Building Life-Cycle Impact Reduction	2-5
	Building Product Disclosure and Optimization - Environmental Product Declarations	1-2
	Building Product Disclosure and Optimization - Material Ingredients	1-2
	Building Product Disclosure and Optimization - Sourcing of Raw Materials	1-2
	Construction and Demolition Waste Management	1-2
Total		13
	Minimum Indoor Air Quality Performance	Prerequisite
	Environmental Tobacco Smoke Control	Prerequisite

Indoor Environmental Quality (IEQ)	Enhanced Indoor Air Quality Strategies	1-2
	Low-Emitting Materials	1-3
	Construction Indoor Air Quality Management Plan	1
	Indoor Air Quality Assessment	1-2
	Thermal Comfort	1
	Interior Lighting	1-2
	Daylight	1-3
	Quality Views	1
	Acoustic Performance	1
Total		16
Overall Total		100

MOSTADAM Extraction:

The categories of MOSTADAM that were extracted are Site Sustainability, Transportation and Connectivity, Region and Culture, Energy, Water, Health and Comfort, Materials and Waste, Education and Innovation, and Policies, Management and Maintenance. Each category encompasses specific indicators that collectively determine the building's sustainability performance. The following Table 8 provides a detailed overview of these categories, presenting the points associated with each indicator.

Table 8 Summary of key indicators in each category (MOSTADAM)

Category	Indicators	Points
Site Sustainability (SS)	Sewage, Flood and Rainwater Management (Keystone)	2
	Ecological Assessment and Protection (Keystone)	2
	Construction Environmental Management	1
	Ecological Enhancement	1
	Heat Island Effect	2
	Light Pollution	1
Total		9
Transportation and Connectivity (TC)	Electric Vehicle Provisions	1
	Access to Public Transportation	2
	Access to Amenities	2
	Home	1
	Individual Sustainable Transport	1
Total		7
Region and Culture (RC)	Thriving Economy	2
	Heritage & Culture	2
	Vibrant Society	1
	Regional Focus	2
Total		7

Energy (E)	Energy Performance (Keystone)	15
	Systems Commissioning (Keystone)	1
	Envelope Commissioning	1
	Energy Metering (Keystone)	1
	Energy Efficient Appliances	1
	Renewable Energy	7
	Ozone Impact	1
Total		27
Water (W)	Indoor Water Performance (Keystone)	10
	Outdoor Water Performance (Keystone)	10
	Alternative Water Solutions	3
	Water Metering (Keystone)	1
Total		24
Health and Comfort (HC)	Outdoor Thermal Comfort (Keystone)	2
	Indoor Thermal Comfort (Keystone)	2
	Ventilation	1
	VOCs and Low-Emitting Materials	2
	Access for All	1
	Daylight and Visual Comfort	2
	Acoustics	1
	Indoor Air Quality	1
	Active Residents	1
	Outdoor Space	1
Total		14
Materials and Waste (MW)	Construction Waste Management	1
	Non-Polluting Insulation Materials	1
	Recycled Materials	2
Total		4
Education and Innovation (EI)	Innovation	2
	Mostadam Guide (Keystone)	2
Total		4
Policies, Management and Maintenance (PMM)	Residential Waste Management (Keystone)	1
	Sustainable Procurement	1
	Building Performance Monitoring	2
Total		4
Overall Total		110

LEED and MOSTADAM provide frameworks for assessing and enhancing the sustainability of residential buildings, their criteria reflect their respective operational contexts. For instance, MOSTADAM places a stronger emphasis on criteria particularly relevant to the Saudi Arabian environment, such as water conservation techniques suited to arid conditions (Al-Surf et al., 2021). This is evident in the focus on water-efficient fixtures and fittings, and water recycling and reuse systems that are crucial for sustainable building in Saudi Arabia's desert climate. Conversely, LEED offers a broader approach

suitable for diverse global contexts, with its comprehensive categories that address a wide range of environmental and sustainability issues, making it adaptable for various international settings (Amiri et al., 2019).

Every credit within the parameter and schedule groupings will undergo thorough examination and evaluation leveraging this meticulously designed BIM model. This systematic exploration aims to ascertain the model's capacity to comprehensively document and fulfill the criteria stipulated by LEED and MOSTADAM certifications.

3.2.2 Case study using BIM

Building upon the established assessment criteria identified in previous phase, the subsequent phase involves the development of customized Building Information Modeling (BIM) models tailored explicitly for assessing green buildings. This process begins by creating a detailed 3D model using REVIT as a BIM software, based on existing building documents. These models are then enriched with essential engineering data and other relevant information. The used software for creating the 3D model is Revit 2023 provided by Autodesk, a student licensed version.

To ensure the accuracy and reliability of the model, a structured validation process is implemented. Initially, the models are checked to verify that they accurately represent the actual buildings as documented. Subsequently, the simulations of building performance within the models are compared with real-world data collected from the same existing buildings.

I. Develop 3D Model Using REVIT

According to feasibility research conducted by (Gerges et al., 2017), there are various software applications of BIM used in today's market. Despite the advantages and disadvantages of each of these varied applications, Autodesk Revit is arguably the most popular BIM software tool used in the Middle East. Also, it is one of the most widely used software to develop building information models. Revit includes tools for architectural, structural, and MEP design, detailing, and engineering. This selection is based on its capability to generate intelligent building information models, which are extensively utilized by architecture, engineering, and construction professionals for efficient planning, design, construction, and project management (Autodesk, 2018). Notably, Revit facilitates the automatic generation of high-quality construction documentation, supports quantity and cost take-offs, enables 3D visualizations, ensures effective coordination across disciplines, and ensures smooth interoperability with widely used data formats such as Industry Foundation Classes (IFC).

In this phase, the focus is on generating a detailed 3D model of the case study building, which will serve as the foundation for the research. The process begins by developing the 3D geometry using Revit, a leading Building Information Modeling (BIM) software. This involves translating the two-dimensional drawings and specifications of the existing buildings into a three-dimensional digital representation. The accuracy and precision of this model are crucial, as it will be used for performance assessment and optimization later in the research. The development of the 3D geometry will be guided by the existing

structure and documents, ensuring that the model faithfully reflects the physical attributes and layout of the real building. This phase sets the stage for the subsequent analysis and evaluation of the building's performance in accordance with green building criteria.

The present study focuses on a meticulous analysis conducted at the esteemed King Fahd University of Petroleum and Minerals in Dhahran, Saudi Arabia. The research is centered on a comprehensive evaluation of a precast bachelor accommodation building, notable for its three-story structural configuration. This case study serves as a pivotal model for investigating the utilization of Building Information Modeling (BIM) in simulating the structural dynamics and environmental impacts of the building type. By employing BIM, the research aims to assess the feasibility of obtaining Leadership in Energy and Environmental Design (LEED) credits list, thereby facilitating a nuanced understanding of the building's energy efficiency and sustainability potential within the local context of Dhahran.

The case study forms a crucial component of the evaluation and assessment process, where a real-world project is analyzed using BIM tools in Revit to assess their effectiveness in achieving green building certification criteria for LEED and MOSTADAM. The selected case study provides a practical example to demonstrate how Revit supports the design, simulation, and analysis of sustainable building practices. The results from the case study are further validated by expert input, ensuring that the findings are aligned with industry standards and can be generalized for broader application in green building assessments.

Table 9 Case Study description

Item	Description
Project	Bachelor's Accommodation
Client	King Fahd University of Petroleum and Minerals
Construction End Date	7/7/2008
Location	Dhahran, Saudi Arabia
Construction Manager	Saudi Teryadh for trading and construction
Architect	Al- Hussan Engineering
Size	Total buildup area $1435m^2$ - 3-stories, $475m^2$ each floor

To ensure the efficiency of the case study approach, the following steps were established to guide its implementation:

- 1- Select the choice of building in this case (residential). The case study is a single unit three-storied building. The total floor area of three stories is $1435m^2$. The location of the building is in Dhahran city, Saudi Arabia.
- 2- Identify underlying features of BIM, LEED and Mostadam to achieve the applicability; This case study was used to verify and validate the BIM applicability to achieve LEED and Mostadam.
- 3- All credits (including prerequisites) were analyzed and interpreted into data requests.

II. Transfer Model to BIM Software

The primary objective is to integrate the 3D geometry model into a Building Information Modeling (BIM) environment, ensuring that it accurately reflects the intended building's design and characteristics. This involves creating a detailed BIM model that includes all relevant technical data necessary for green building simulation and assessment.

To achieve this, each 3D geometry parameter is carefully associated with specific energy-related data. For example, in the context of green building evaluation tools, the selection of materials plays a critical role in determining the overall sustainability of the building. Therefore, the BIM model includes detailed information about each material's properties, such as U-value, resistance, and transmittance, which are essential for accurately simulating the building's energy performance.

Additionally, the BIM model incorporates other important parameters, such as room types, HVAC systems, building orientation, and infiltration rates. These parameters are crucial for conducting comprehensive energy simulations and assessments, as they directly impact the building's overall energy efficiency and environmental impact. By integrating these elements into the BIM model, the study aims to provide a robust framework for evaluating the building's green performance and identifying areas for optimization.

A distinctive trait of a building information model is that its constituent objects possess well-defined semantic information, encompassing object type, technical specifications, materials, costs, and more (Borrmann et al., 2018). Furthermore, these objects encompass data detailing their behavior and relationships with adjacent elements. This attribute proves essential for various analyses and downstream processes, including specification writing, quantity estimation, performance simulations, and structural analyses.

All the required data needed for the 3D model to be detailed was gathered from the supported documents of the existing building. The level of details (LOD) makes what is called a BIM model. For the study up to LOD 300 is enough. LOD 300 contains all the details and parameters which includes the need to achieve the data which will be used for the green assessment. Figure 8 illustrates the LOD and describes each level.

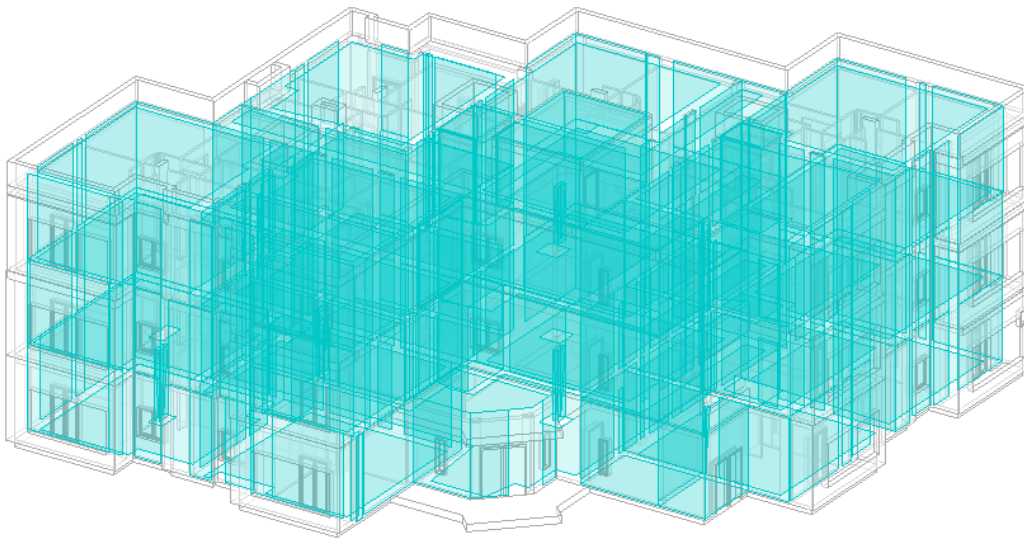
Figure 11 Level of Details (LOD)

LOD	Description
LOD 100	model elements may be represented graphically with a symbol or generic representation but are not yet geometrically depicted
LOD 200	model elements are graphically depicted as generic placeholders and systems, objects or assemblies only contain approximate sizes, shapes, orientations and locations
LOD 300	model elements are graphically represented as specific systems, objects or assemblies including exact quantities, shapes, sizes, orientations and locations
LOD 350	model elements are graphically represented as specific systems, objects or assemblies including exact quantities, shapes, sizes, orientations and locations as well as the interfaces with other building systems, the parts needed for coordination with other elements, such as supports or connects, are also modeled in this LOD
LOD 400	model elements are graphically represented as specific systems, objects or assemblies including exact quantities, shapes, sizes, orientations and locations including all relevant detailing, fabrication, assembly and installation information, an element from this LOD is modeled with enough detail and accuracy to be properly fabricated
LOD 500	model elements are field-verified representations in terms of quantity, shape, size, orientation and location, this LOD is not typically used as it does not indicate a progression to a higher level of model geometry or information

To do this, a BIM model of the intended building is created, and the relevant technical data for green building simulation and assessment is added into the model. Each 3D geometry parameter will be associated with energy data. In the material categories of green building evaluation tools, for instance, certain materials are needed to determine the category's score. As each material's U-value, resistance, and transmittance etc. parameters are predetermined. Also, parameters such as the room types, HVAC systems, building's orientation, infiltration, and more which will be shown in through the study.

To run energy simulation, an analytical energy model (Figure 12) is created where the influencing factor is passive technologies, such as, roof insulation, building orientation, window wall ratio, natural ventilation, water use reduction, water usage for irrigation & window properties.

Figure 12 Energy Analytical Model



To use BIM to provide the information required by LEED, first the LEED information needs to be added into the model. Revit and all the other BIM software allow adding new parameters to the project. To do this in Revit, designers can go to the “Manage” tab and select “Shared Parameters”; a command window will show as in the left panel of Figure 16. Then new parameters can be typed and added to a project. Before adding parameters, parameter groups can be created for ease of management.

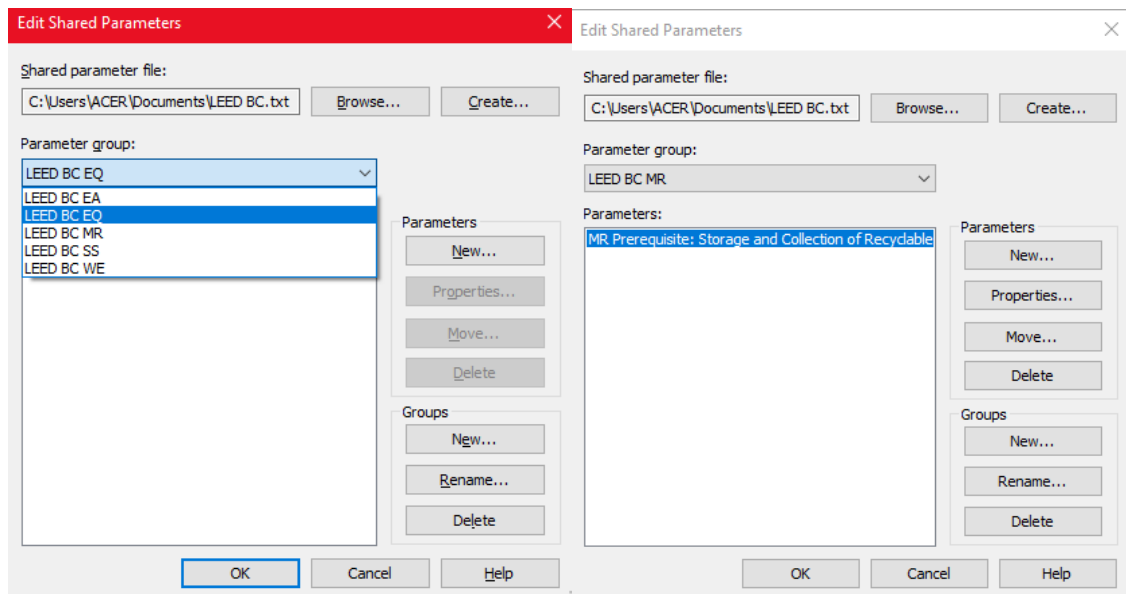


Figure 13 Revit shared parameters

Researcher now possess a set of new parameters essential for the project, requiring input for each material and component. To achieve this, researcher can select a specific component, such as a column, and utilize the "Edit Family" command to input and modify information within this component. Upon selecting "Element Properties," a command window appears, as depicted in the right panel. Within this interface, designers can seamlessly integrate the newly created parameters into the column and input values based on manufacturer specifications, mirroring the conventional LEED documentation process.

The integration of these parameters into the column is not limited to individual instances; rather, the entire column type incorporates these parameters. In Revit, material and component types are systematically organized by categories and families. Consequently, modifying the properties of a single component leads to a simultaneous alteration of all components belonging to the same family type. This streamlined approach significantly

expedites the process for designers when implementing changes to their designs. This efficient methodology is equally applicable to various component types, including beams, windows, doors, and others.

3.2.3 Assessment of Revit Support for the GBAT Criteria

The assessment phase follows a structured workflow. An Expert Panel was conducted to gather insights and validate the findings from the case study to assess their effectiveness in meeting green building assessment criteria for both LEED and MOSTADAM. Additionally

The expert panel assessment is to evaluate the capabilities of Green Building Assessment Tools (GBAT) within the Revit software environment. Specifically, it aims to determine Revit's effectiveness in achieving GBAT criteria by analyzing three key aspects: a) Assessment based on documented requirements of the (LEED/MOSTADAM) indicators, b) Assessment based on the BIM Revit case study data, c) Assessment of media channel used in Revit. This evaluation will be carried out through the Experts group meeting, with data collection facilitated by 3 tasks of each three key aspects.

3.2.3.1 Expert Panel

Expert group meeting was chosen for data collection due to their accuracy and depth in providing insights into the practical application of GBAT within Revit. The experts selected for this assessment are professionals with extensive experience in BIM, sustainability, and green building standards.

3.2.3.2 Selection Criteria for Experts

Experts are chosen based on the following criteria:

- a. A minimum of 3 years of experience with BIM software, specifically Revit.
- b. Demonstrated 2 years' experience with green building projects and familiarity with GBAT such as LEED, or MOSTADAM.
- c. Professional credentials or certifications in sustainability.

Experts were selected by searching LinkedIn for individuals who met the established selection criteria and then reaching out to qualified candidates directly.

3.2.3.3 Procedures

A two-session expert panel was conducted, one dedicated to examine LEED results and the other for Mostadam results. Pilot testing showed that it is almost impossible to assess both LEED and Mostadam results in one expert panel session because of the large number of indicators that overlap between the two systems which can cause confusion, and the long time needed to cover the addressed issues which can extend over 6 hours. The two expert panel sessions were conducted online.

The procedure used to assess the level of support of BIM for green assessment is conducted for each indicator separately. During the expert panel session, each indicator is evaluated through a process consisting of three phases: 1) the presentation phase of the indicators requirement, and case study data results 2) the discussion phases between the experts and the researcher, and 3) the feedback phase by filling the 3 tasks of each key point aspect for each indicator of the (LEED/MOSTADAM) categories.

a) The presentation phase of the indicators requirement, and case study data results:

The researcher presented to the expert members two pieces of information: 1) a summary of the requirements of the GBAT indicator, and 2) results obtained from the case study regarding support of Revit for those assessment indicators. This was done through presenting one to two slides. It takes around 1 minute for each slide.

b) The discussion phases

The members were given time to discuss the data presented and reflect on the level of support of the data generated in Revit to support the requirement of the indicator. The focus will be on the results presented however the experts are encouraged to consider their knowledge especially about issues not covered in the case study. The discussion period is around 2 minutes.

c) Feedback phase

Immediately after the discussion, experts are asked to fill in an evaluation survey which consists of three Tasks. The three tasks were provided as follows:

- **Task-1.** Revit Coverage of Assigned Points of Each Indicator in LEED/MOSTADAM. Based on the presentation provided on each LEED/MOSTADAM green building indicator and its objectives and requirements, please rate the following two aspects using the form below:

1. On a 7-point scale in the form below, please rate the level of which Revit is able to achieve the requirements of the specified LEED/MOSTADAM indicators.

2. In the last column of the form below, please indicate the number of points Revit is able to assess/achieve out of the ‘possible points’ for the specified LEED/MOSTADAM indicator. *Note: you can use a fraction in your answer for the achievable points (for example, achievable points can be 0.5 points, 1.5 points, 2.75 points, etc.).*

- **Task-2.** Level of Appropriateness of The Support of Revit case study for Each LEED/MOSTADAM Indicator.

Based on the presentation provided regarding the results of the case study, please do the following:

- 1) On a 7-point scale, please rate the level of which Revit is able to achieve the requirements of the specified LEED/MOSTADAM indicator based on the data of case study presented.
- 2) In the last column of the form below, please indicate the number of points that Revit is able to achieve out of the ‘possible points’ for the specified LEED/MOSTADAM indicator based on the data of case study presented. *Note: you can use a fraction in your answer for the achievable points (for example, achievable points can be 0.5 points, 1.5 points, 2.75 points, etc.).*

- **Task-3.** Best Media Used to support/achieve the requirement of each indicator in LEED/MOSTADAM.

Based on the provided information in the previous TASKS (*i.e. the indicator requirements and case study results*), please do the following:

In the form below, for each media/channel type in Revit, please rank the ability/importance of each media/channel type to achieving/assessing the objectives and requirement of the corresponding indicator using a scale from 1 to 10. (*A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator objectives/requirements while 1 indicates that the media/channel is least in importance*).

To review the forms of the three tasks for each LEED/MOSTADAM, they are provided in Appendix A1.

3.2.3.4 Analysis

In assessing Revit's support for GBAT indicators, the data collection process utilized both a 7-point Likert scale and a 10-point scale to gauge expert evaluations. To achieve a unified understanding of support levels across both scales, the data required conversion to establish consistent thresholds for "high," "moderate," and "low" support levels.

Conversion Process Between the 7-Point and 10-Point Scales:

To map the 7-point scale scores to the 10-point scale accurately, each point on the 7-point scale was proportionally translated to its 10-point equivalent using the following formula(Colman et al., 1997):

$$\text{10-point scale equivalent} = \left(\frac{\text{7-point value} - 1}{6} \right) \times 9 + 1$$

This conversion established equivalents for key thresholds as follows:

Figure X: Ranking Conversion between 10-Point and 7-Point Scales

Scale	Ranking Conversion										
10 points scale	1.0	2.0	3.0	4.0	5.0	6.0	7.0	7.7	8.0	9.0	10.0
7 points scale	1.0	1.7	2.3	3.0	3.7	4.3	5.0	5.5	5.7	6.3	7.0

Measuring Consensus

According to (Al-Qawasmi, 2021; von der Gracht, 2012) , consensus strength in the expert evaluations was determined based on the Interquartile Range (IQR) for each scale. For responses measured on the 7-point Likert scale, an **IQR of ≤ 1** indicates strong consensus among experts, whereas an **IQR above 1** reflects a lack of consensus. For the 10-point scale, an **IQR of ≤ 2** similarly denotes strong consensus, while an **IQR greater than 2** suggests no consensus among experts.

Accordingly, the study has adopted the following metrics to measure consensus/agreement among expert panels:

- **Highly Supported Indicator:** An indicator with an $IQR \leq 1$ and a mean of ≥ 5.5 (for the 7-point Likert scale) or an $IQR \leq 2$ and a mean of ≥ 7.7 (for the 10-point scale).
- **Moderately Supported Indicator:** An indicator with ($IQR \leq 1$ for the 7-point scale and ≤ 2 for the 10-point scale), but the mean falls between 3 and 5.5 (7-point scale) or between 4 and 7.7 (10-point scale).
- **Lowly Supported Indicator:** an indicator with a mean ≤ 3 on the 7-point scale or ≤ 4 on the 10-point scale and an $IQR \leq 1$ (7-point) or ≤ 2 (10-point) are considered lowly supported with consensus.

Figure 14 Level of agreement /consensus among the experts regarding level of support of Revit (LEED/MOSTADAM) indicators.

Data based on Q2 (7-point Likert)		Level of support	Data based on Q1 (achievable point out of 10)		Level of support
Mean	IQR		Mean	IQR	
≥ 5.5	$IQR \leq 1$	High Support with consensus	≥ 7.7	$IQR \leq 2$	High Support with consensus
≥ 5.5	$IQR > 1$	High Support without consensus	≥ 7.7	$IQR > 2$	High Support without consensus
$3 < \text{mean} < 5.5$	$IQR \leq 1$	Moderate Support with consensus	$4 < \text{mean} < 7.7$	$IQR \leq 2$	Moderate Support with consensus
$3 < \text{mean} < 5.5$	$IQR > 1$	Moderate Support without consensus	$4 < \text{mean} < 7.7$	$IQR > 2$	Moderate Support without consensus
≤ 3	$IQR \leq 1$	Low Support with consensus	≤ 4	$IQR \leq 2$	Low Support with consensus
≤ 3	$IQR > 1$	Low Support without consensus	≤ 4	$IQR > 2$	Low Support without consensus

Figure 15 displays the aggregated level of agreement among experts regarding Revit's support for LEED and MOSTADAM indicators, based on two main metrics: Q1 (7-point Likert scale) and Q2 (10-point achievable scale). By cross-referencing these scales, the figure provides insight into the consistency of expert evaluations, determining whether Revit's support is high, moderate, or low, and whether it is with or without consensus:

- **High Support with Agreement:** When both Q1 and Q2 indicate "High support with consensus (HC)," experts agree that Revit's support is strong, covering a high percentage of achievable points. This outcome signals a high confidence level in Revit's capabilities. When either Q1 or Q2 lacks consensus (HN), the classification changes to **High Support without Agreement**, reflecting some divergence in expert opinions.
- **Moderate Support with Agreement:** Indicators with a moderate consensus in both Q1 and Q2 are classified as Moderately with Agreement. This level of support indicates that experts recognize moderate functionality within Revit for these

indicators, though the support may not be as comprehensive. When Q1 or Q2 lacks consensus, it is classified as **Moderately without Agreement**.

- **Low Support with Agreement:** When both Q1 and Q2 indicate "Low support with consensus," it is classified as Low with Agreement, underscoring limited support from Revit for these indicators, as agreed upon by experts. If either Q1 or Q2 is categorized as "Low without consensus," the classification shifts to **Low without Agreement**.
- **Inconsistent Support:** When there is a discrepancy between Q1 and Q2 levels, the support is marked as "Inconsistent." For example, if Q1 is "High support with consensus" and Q2 is "Moderate with consensus," the outcome is **Inconsistent with Agreement**. Inconsistent classifications highlight where Revit's support is perceived differently across metrics, suggesting varying levels of effectiveness or reliability.

Figure 15 Aggregated level of agreement /consensus among the experts regarding level of support of Revit for LEED/MOSTADAM indicators

Consensus on level of support based on Q1 (7-point Likert)	Consensus on level of support based on Q2 (achievable point out of 10)	Aggregated Consensus on level of support based on Q1 & Q2
High support with consensus (HC)	High support with consensus (HC)	high with agreement
High support with consensus (HC)	High Support without consensus (HN)	high without agreement
High Support without consensus (HN)	High support with consensus (HC)	high without agreement
High Support without consensus (HN)	High Support without consensus (HN)	high without agreement
High support with consensus (HC)	moderate with consensus (MC)	Inconsistent with agreement
High Support without consensus (HN)	moderate with consensus (MC)	Inconsistent without agreement
High support with consensus (HC)	moderate without consensus (MN)	Inconsistent without agreement
High Support without consensus (HN)	moderate without consensus (MN)	Inconsistent without agreement
High support with consensus (HC)	Low with consensus (LC)	Inconsistent with agreement
High Support without consensus (HN)	Low with consensus (LC)	Inconsistent without agreement
High support with consensus (HC)	Low without consensus (LN)	Inconsistent without agreement
High Support without consensus (HN)	Low without consensus (LN)	Inconsistent without agreement

moderate with consensus (MC)	moderate with consensus (MC)	Moderately with agreement
moderate with consensus (MC)	moderate without consensus (MN)	Moderately without agreement
moderate without consensus (MN)	moderate without consensus (MN)	Moderately without agreement
moderate without consensus (MN)	moderate with consensus (MC)	Moderately without agreement
moderate with consensus (MC)	High support with consensus (HC)	Inconsistent with agreement
moderate with consensus (MC)	High Support without consensus (HN)	Inconsistent without agreement
moderate without consensus (MN)	High Support without consensus (HN)	Inconsistent without agreement
moderate without consensus (MN)	High support with consensus (HC)	Inconsistent without agreement
moderate with consensus (MC)	Low with consensus (LC)	Inconsistent with agreement
moderate with consensus (MC)	Low without consensus (LN)	Inconsistent without agreement
moderate without consensus (MN)	Low with consensus (LC)	Inconsistent without agreement
moderate without consensus (MN)	Low without consensus (LN)	Inconsistent without agreement
Low with consensus (LC)	Low with consensus (LC)	Low with agreement
Low with consensus (LC)	Low without consensus (LN)	Low without agreement
Low without consensus (LN)	Low with consensus (LC)	Low without agreement
Low without consensus (LN)	Low without consensus (LN)	Low without agreement
Low with consensus (LC)	High support with consensus (HC)	Inconsistent with agreement
Low without consensus (LN)	High support without consensus (HN)	Inconsistent without agreement
Low with consensus (LC)	High support without consensus (HN)	Inconsistent without agreement
Low without consensus (LN)	High support with consensus (HC)	Inconsistent without agreement
Low with consensus (LC)	Moderate support with consensus (MC)	Inconsistent with agreement
Low without consensus (LN)	Moderate support without consensus (MN)	Inconsistent without agreement
Low with consensus (LC)	Moderate support without consensus (MN)	Inconsistent without agreement
Low without consensus (LN)	Moderate support with consensus (MC)	Inconsistent without agreement

3.2.4 Optimization of BIM Performance

The optimization of BIM performance for green building assessment, guided by a synthesis of insights gleaned from preceding phases. Here, we embark on the development of a robust theoretical framework informed by empirical findings, aimed at delineating the optimal parameters for leveraging BIM in green building assessment. Additionally, contingent upon feasibility, we endeavor to actualize this theoretical framework through the creation of a demonstration module showcasing its practical application. This phase embodies the overarching research objective of developing a holistic theoretical framework and, if viable, a prototype module, thus furnishing a roadmap for harnessing BIM's transformative capabilities in green building assessment. The used software for coding is Microsoft visual studio 2022. The coding language used is C# to access the Revit API to create customized plugins for the theoretical framework section.

CHAPTER 4

DATA ANALYSIS & RESULTS

4.1 Introduction

This chapter presents the data analysis and results of this study that aims to assess the support of Revit, as a BIM tool/package, for the indicators of LEED and MOSTADAM, as two green building assessment tools. This chapter presents the results regarding three tasks of assessment: T1- assessment of Revit support based on the documented requirements (DR) of the indicators, T2- assessment of Revit Support based on Case study (CS), and T3- Assessment of the support of Revit Media channels.

4.2 Results of Assessment of Revit support for LEED indicators

The study has conducted two sessions for the expert panel. Session-1 was conducted on 26 September 2024 and dedicated to assess the level of support of Revit for LEED. Session-2 was conducted on 30 September 2024 and dedicated to assess the level of support of Revit for MOSTADAM indicators. Each session is consisted of 3 tasks. Task-1 (assessment of Revit support based on the documented requirements “DR” of the indicators), Task-2 (assessment of Revit Support based on Case study “CS” of the indicators), and Task-3 (Assessment of the support of Revit Media channels for the indicators). In this section the results and analysis of **session-1** will be presented. Following up for session-2 will be presented in section 4.2.

4.2.1 Assessment of Revit Support for LEED LT Indicators

The assessment of Revit support for LT indicators are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements “DR” of the indicators), T2: (assessment of Revit Support based on Case study “CS” of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.2.1.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-1 of the expert panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each LEED indicator: Q1) “indicate the number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by LEED”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified LEED indicator using a 7-point Likert scale”. Appendix A2-T1 presents the detailed responses of each expert in the expert panel for each question in task-1: T1-Q1 and T1-Q2. Table 10 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Location and Transportation (LT) category using the two measurements (Q1 and Q2). While Figure 16 provides a graphical representation (radar chart) of the data in Table 10. These two measurements capture the experts’ assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each LEED LT indicators.

Table 10 Experts assessment of the level of support of Revit for LEED indicators in the LT category based on the documented requirements (DR) of LEED indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of LT category	Indicator Type	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
			Mean of achievable points (out of max possible points)	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
LEED for neighborhood development location	Cr	16	0.5	0.3	1.5
Sensitive land protection	Cr	1	0.2	2.0	2.0
High-priority site	Cr	2	0.0	0.0	1.0
Surrounding density and diverse uses	Cr	5	1.6	3.2	1.8
Access to quality transit	Cr	5	1.3	2.6	2.5
Bicycle facilities	Cr	1	1.0	10.0	6.3
Reduced parking footprint	Cr	1	1.0	10.0	6.8
Green vehicles	Cr	1	1.0	10.0	7.0

(Legend: Cr: Credit , Pr: Prerequisite)

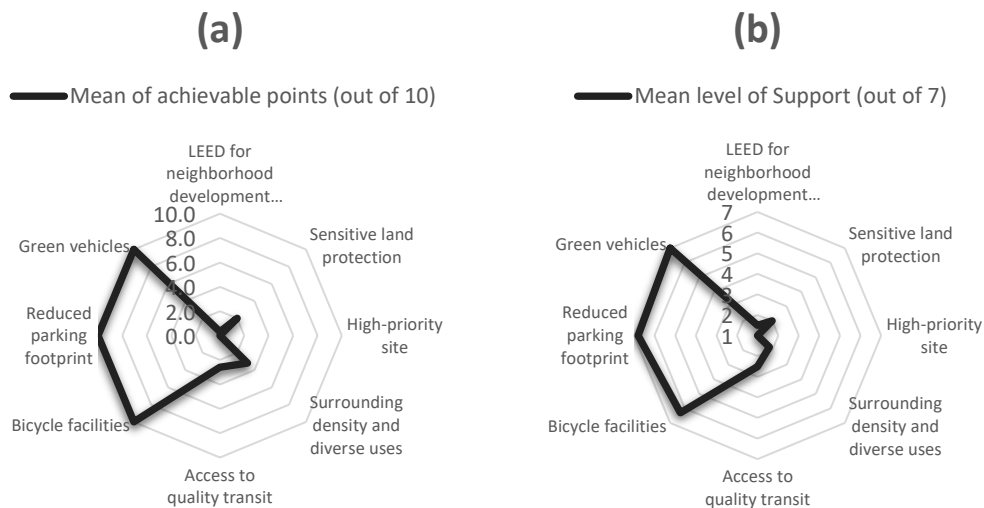


Figure 16 Radar Chart of Expert's assessment of the level of support of Revit for LEED indicators in the LT category based on the documented requirements (DR) of LEED indicators using two measurements (Q1 and Q2)

(a) Mean achievable points-Q1 (out of 10) (b) Mean level of Revit support for the indicator-Q2 (out of 7)

The results presented in Table 10 and Figure 16(a) regarding Q1 (the mean achievable points for each indicator in the LT category based on the documented requirements) show that Revit provides limited support for most LEED indicators in the Location and Transportation (LT) category. Specifically, the indicators "LEED for Neighborhood Development Location," "Sensitive Land Protection," and "High-Priority Site" have very low mean achievable points, with Revit scoring 0.5, 0.2, and 0.0 points out of the maximum possible, respectively. As Figure 16(a) illustrates, these indicators fall significantly short of their maximum potential, suggesting that Revit's tools may not adequately support more complex site selection and sensitive land considerations required by LEED. This limited support highlights areas where Revit's current functionality could be expanded or enhanced to better address comprehensive site analysis needs.

However, as also shown in Figure 16(a), Revit demonstrates relatively higher support for indicators such as "Bicycle Facilities," "Reduced Parking Footprint," and "Green Vehicles," with each of these indicators achieving close to the maximum possible points in Q1. For instance, "Bicycle Facilities" scored a mean of 1.0 out of 1.0, and "Green Vehicles" also reached a high score, indicating that Revit provides solid support for certain transportation and infrastructure indicators within the LT category. This pattern in Figure 16(a) highlights Revit's strength in supporting straightforward infrastructure requirements, which are less complex than those involving detailed environmental and contextual analysis.

Regarding Q2 (mean level of support out of 7), the results indicate that Revit's support varies significantly across the LEED LT indicators, as shown in Figure 16(b). Indicators

related to basic transportation infrastructure, such as "Green Vehicles" and "Reduced Parking Footprint," scored relatively high, with mean support levels of 7.0 and 6.8, respectively. Figure 16(b) visually reinforces these high scores, suggesting that Revit offers strong capabilities for meeting specific transportation requirements in the LT category, providing architects and designers with the necessary tools to meet LEED criteria in these areas.

On the other hand, indicators involving more complex site analysis and contextual factors, such as "LEED for Neighborhood Development Location," "Sensitive Land Protection," and "High-Priority Site," have lower mean support levels. For instance, "LEED for Neighborhood Development Location" scored only 1.5 out of 7, while "High-Priority Site" scored 1.0, as depicted in Figure 16(b). These low scores highlight Revit's limited ability to address comprehensive site selection requirements effectively. The overall pattern from both charts suggests that while Revit is well-suited to handle certain straightforward transportation and infrastructure criteria, it may require enhancements or supplementary tools to fully support LEED requirements related to complex site selection and land sensitivity.

4.2.1.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study “CS”

During task-2 of session-1 of the expert panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each LEED indicator based on the results of the case study presented to them (CS): Q1) “indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the data of case study presented”, and Q2) “on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the LEED indicator based on the data of case study presented”. Appendix A2-T2 presents the detailed responses of each expert in the expert panel for each question in this task. Table 11 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Location and Transportation (LT) category using the two measurements (Q1 and Q2). While Figure 17 provides a graphical representation radar chart of the data in Table 11. These two measurements capture the experts’ assessment of Revit's ability to meet/support LEED requirements for each indicator based on the results of the case study.

Table 11 Experts assessment of the level of support of Revit for LEED indicators in the LT category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of LT category	Indicator Type	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale Mean level of Support (out of 7)
			Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (out of 10)	
LEED for neighborhood development location	<i>Cr</i>	<i>16</i>	1.5	0.9	1.0
Sensitive land protection	<i>Cr</i>	<i>1</i>	0.2	2.0	1.5
High-priority site	<i>Cr</i>	<i>2</i>	0.0	0.0	1.0
Surrounding density and diverse uses	<i>Cr</i>	<i>5</i>	1.9	3.8	2.3

Access to quality transit	<i>Cr</i>	5	1.0	2.0	2.5
Bicycle facilities	<i>Cr</i>	1	0.9	9.0	6.8
Reduced parking footprint	<i>Cr</i>	1	1.0	10.0	7.0
Green vehicles	<i>Cr</i>	1	1.0	10.0	7.0

(Legend: *Cr* : Credit , *Pr*: Prerequisite)

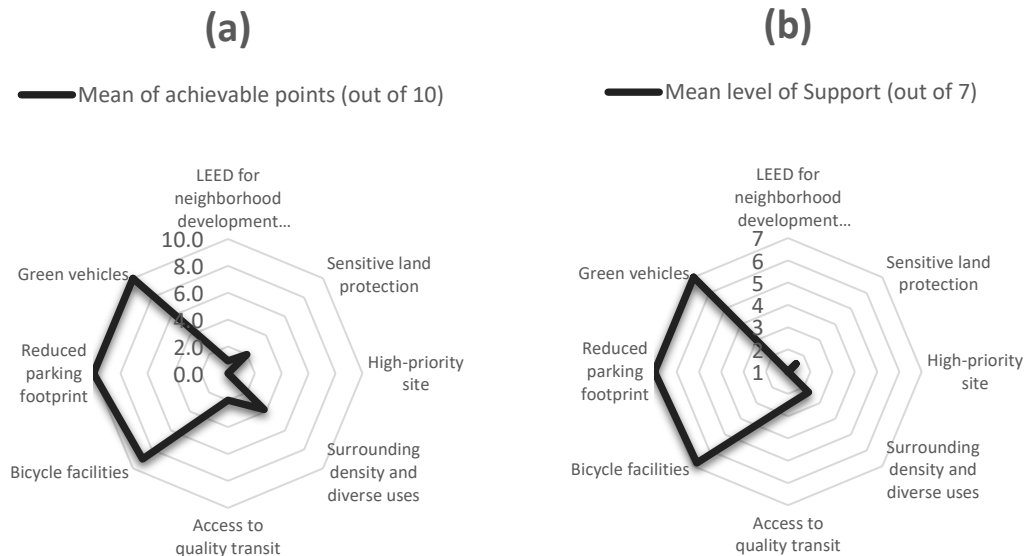


Figure 17 Radar Chart of expert's assessment of the level of support of Revit for LEED indicators in the LT category based on based on the case study (CS) results using two measurements (Q1 and Q2)

(a) Mean Achievable points- **Q1** (out of 10) **(b)** Mean level of Revit support - **Q2** (out of 7)

The results presented in Table 11 and Figure 17(a) regarding Q1 (the mean achievable points for each indicator in the LT category based on the case study results) show that Revit provides limited support for most LEED indicators in the Location and Transportation (LT) category. Specifically, the indicators "LEED for Neighborhood Development Location," "Sensitive Land Protection," and "High-Priority Site" have very low mean achievable points, with Revit scoring 1.5, 0.2, and 0.0 points out of the maximum possible, respectively. As illustrated in Figure 17(a), these indicators fall significantly short of their maximum potential, suggesting that Revit's tools may not adequately support complex site

selection and sensitive land considerations as required by LEED in real-world scenarios. This limited support highlights areas where Revit's functionality could be enhanced to address comprehensive site analysis requirements more effectively.

However, as also shown in Figure 17(a), Revit demonstrates relatively higher support for indicators such as "Bicycle Facilities," "Reduced Parking Footprint," and "Green Vehicles," with each of these indicators achieving close to the maximum possible points in Q1. For example, "Bicycle Facilities" scored a mean of 0.9 out of 1.0, and both "Reduced Parking Footprint" and "Green Vehicles" scored 1.0 out of 1.0. This indicates that Revit provides solid support for specific transportation and infrastructure indicators within the LT category, as it excels in supporting straightforward infrastructure requirements.

Regarding Q2 (mean level of support out of 7), the results show that Revit's support varies significantly across the LEED LT indicators, as seen in Figure 17(b). Indicators related to basic transportation infrastructure, such as "Green Vehicles" and "Reduced Parking Footprint," scored relatively high, with mean support levels of 7.0 each. Figure 17(b) visually reinforces these high scores, suggesting that Revit offers strong capabilities for meeting specific transportation-related requirements in the LT category, providing practical tools for architects and designers to fulfill LEED criteria in these areas.

On the other hand, indicators involving more complex site analysis and contextual factors, such as "LEED for Neighborhood Development Location," "Sensitive Land Protection," and "High-Priority Site," have lower mean support levels. For instance, "LEED for Neighborhood Development Location" scored only 1.0 out of 7, and "High-Priority Site" scored 1.0 as well, as depicted in Figure 17(b). These low scores highlight Revit's limited

ability to address comprehensive site selection requirements effectively. The overall pattern from both charts suggests that while Revit is well-suited to handle certain straightforward transportation and infrastructure criteria, it may require further enhancements or supplementary tools to fully support LEED requirements related to complex site selection and land sensitivity in practical case study applications.

4.2.1.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-1 of the expert panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each LEED indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked “to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each LEED indicator using a scale from 1 to 10”. A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 12 provides a summary of the experts’ assessment of Revit of Mean ranking level for the support of each Media Type for LEED LT indicators in the LT category. While Figure 18 provides a graphical representation (radar chart) of the data in Table 12.

Table 12 Mean ranking level for the support of each Media Type for LEED LT indicators in the LT category.

INDICATOR	Indicator Type	Mean Ranking of the support of Revit media channel for LEED (out of 10)			
		TD	M	S	DI
LEED for neighborhood development location	Cr	6.0	2.7	0.0	2.0
Sensitive land protection	Cr	6.3	4.0	0.0	1.7
High-priority site	Cr	8.0	4.7	0.0	0.0
Surrounding density and diverse uses	Cr	7.7	5.0	0.0	4.3
Access to quality transit	Cr	6.3	8.3	0.0	4.3
Bicycle facilities	Cr	5.0	8.0	0.0	4.0
Reduced parking footprint	Cr	2.7	8.0	1.0	1.0
Green vehicles	Cr	3.7	4.7	0.0	1.0

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration).

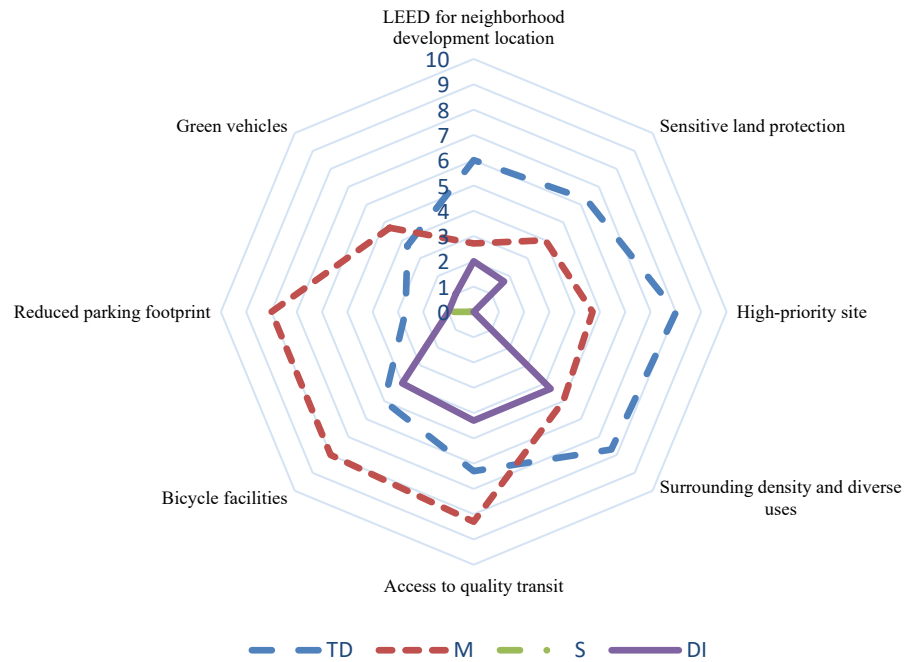


Figure 18 Radar Chart for expert's assessment of Revit Media Channel Support for LEED Indicators in the LT

(TD: text documentation, M: modeling, S: simulation, and DI: data integration).

According to the results in Table 12 and Figure 18, TD (Text Documentation) plays a substantial role in supporting several LT (Location and Transportation) indicators. For example, indicators such as *High-Priority Site* (8.0), *Surrounding Density and Diverse*

Uses (7.7), and *Sensitive Land Protection (6.3)* show high support from TD, highlighting the value of comprehensive documentation for validating site selection and planning considerations in Revit. This underscores Revit's strength in managing compliance reporting for location-sensitive credits. However, TD plays a secondary role in indicators like *Reduced Parking Footprint (2.7)* and *Green Vehicles (3.7)*, where modeling and data integration are more effective.

M (Modeling) shows high levels of support for design-centric LT indicators, especially for *Access to Quality Transit (8.3)*, *Bicycle Facilities (8.0)*, and *Reduced Parking Footprint (8.0)*. Revit's 3D modeling capabilities are essential in visualizing these elements and creating accurate layouts that meet LEED requirements. The results indicate that modeling is highly effective for transportation-related credits, allowing for spatial and design analysis that supports sustainability in urban planning. Lower support in indicators like *LEED for Neighborhood Development Location (2.7)* suggests that modeling plays a minor role in credits requiring broader documentation and strategic planning.

S (Simulation) plays a limited role in the LT category, with low to no support across most indicators (0.0 for most), aside from minimal support in *Reduced Parking Footprint (1.0)*. This suggests that LT indicators do not typically require dynamic performance analysis, and thus simulation tools in Revit are less applicable in this category.

DI (Data Integration) provides moderate support for indicators that benefit from external data input, such as *Surrounding Density and Diverse Uses (4.3)*, *Access to Quality Transit (4.3)*, and *Bicycle Facilities (4.0)*. This highlights the role of data integration in enhancing Revit's ability to incorporate external geographic, demographic, or transport-related data

for these indicators. However, for indicators such as *High-Priority Site (0.0)* and *Reduced Parking Footprint (1.0)*, DI plays a minimal role, as Revit's internal tools and documentation may be sufficient for achieving compliance.

4.2.1.4 Assessment of Revit Support for LEED LT Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for LEED LT indicators based on both Task-1 of expert panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study "CS"). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of LEED indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a 'fraction of 10') were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 13 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements "DR") and task-2 (T2: data based on case study "CS").

Table 13 Aggregate assessment of the Experts for the level of support of Revit for LEED LT indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

INDICATORS of LT category	Indicator Type	Level of Support based on T1-Q1 & T2-Q1		Level of Support based on T1-Q2 & T2-Q2	
		Mean (out of 10)	IQR	Mean (out of 7)	IQR
LEED for neighborhood development location	<i>Cr</i>	0.6	1.3	1.3	0.3
Sensitive land protection	<i>Cr</i>	2.1	1.0	1.8	1.0
High-priority site	<i>Cr</i>	0.0	0.0	1.0	0.0
Surrounding density and diverse uses	<i>Cr</i>	3.5	2.5	2.0	1.3
Access to quality transit	<i>Cr</i>	2.3	0.5	2.5	1.0
Bicycle facilities	<i>Cr</i>	9.6	0.3	6.5	1.0
Reduced parking footprint	<i>Cr</i>	10.0	0.0	6.9	0.0
Green vehicles	<i>Cr</i>	10.0	0.0	7.0	0.0

(Legend: *Cr* : Credit , *Pr*: Prerequisite)

To be able to identify aggregated level of support of Revit for the LT indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (**Q2**) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where mean ≤ 3 . Then also for the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where mean ≤ 4 .

Data based on Q2 (7-point Likert)		Level of support	Data based on Q1 (achievable point out of 10)		Level of support
Mean	IQR		Mean	IQR	
≥ 5.5	$\text{IQR} \leq 1$	High Support with consensus	≥ 7.7	$\text{IQR} \leq 2$	High Support with consensus
≥ 5.5	$\text{IQR} > 1$	High Support without consensus	≥ 7.7	$\text{IQR} > 2$	High Support without consensus
$3 < \text{mean} < 5.5$	$\text{IQR} \leq 1$	Moderate Support with consensus	$4 < \text{mean} < 7.7$	$\text{IQR} \leq 2$	Moderate Support with consensus
$3 < \text{mean} < 5.5$	$\text{IQR} > 1$	Moderate Support without consensus	$4 < \text{mean} < 7.7$	$\text{IQR} > 2$	Moderate Support without consensus
≤ 3	$\text{IQR} \leq 1$	Low Support with consensus	≤ 4	$\text{IQR} \leq 2$	Low Support with consensus

≤ 3	$IQR > 1$	Low Support without consensus	≤ 4	$IQR > 2$	Low Support without consensus
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Figure 19 level of agreement /consensus among the experts regarding level of support of Revit for indicators.

Then, the researcher examined the level of agreement /(i.e consensus) among the members of expert panel on the level of support of Revit for the LT indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 13 for **Q1** (mean achievable points out of 10) provide a detailed view of Revit's support level across the various LEED LT indicators. The aggregated data from both Task-1 and Task-2 reveal that Revit demonstrates high support for transportation-related indicators, particularly "Bicycle Facilities," "Reduced Parking Footprint," and "Green Vehicles." These indicators achieved mean scores of 9.6, 10.0, and 10.0, respectively, placing them firmly in the high support category with minimal variability, as shown by their low interquartile ranges (IQRs) of 0.3 or 0.0. These high scores indicate strong consensus among experts regarding Revit's capability to support these straightforward infrastructure-focused requirements. In contrast, indicators that involve complex site selection and land sensitivity considerations, such as "LEED for Neighborhood Development Location," "Sensitive Land Protection," and "High-Priority Site," received much lower mean scores. For instance, "LEED for Neighborhood Development Location" scored only 0.6, and "High-Priority Site" scored 0.0, placing them in the low support category. This suggests that Revit may lack the tools necessary to meet the requirements for more intricate site-related indicators in the LEED LT category.

For **Q2** (mean level of support out of 7), the results show that Revit's support varies significantly across the LEED LT indicators, with transportation-focused indicators again performing better. "Green Vehicles" and "Reduced Parking Footprint" achieved high mean support levels of 7.0 and 6.9, respectively, with no variability (IQR = 0.0), reflecting unanimous agreement among experts that Revit is effective in supporting these indicators. "Bicycle Facilities" also scored highly, with a mean of 6.5, though with a slightly higher IQR of 1.0. On the other hand, indicators that demand complex site analysis and environmental sensitivity, such as "LEED for Neighborhood Development Location" and "High-Priority Site," scored much lower, with means of 1.3 and 1.0, respectively, and similarly low IQRs. These low scores place them in the low support category, suggesting limited functionality within Revit for these particular requirements. The moderate scores for indicators like "Surrounding Density and Diverse Uses" (mean of 2.0) and "Access to Quality Transit" (mean of 2.5) further indicate that while Revit provides some level of support, it may not be sufficient to fully meet the LEED requirements for these indicators.

Table 14 Aggregated level of support of Revit for LEED LT indicators based on the results of Task-1 and Task2.

INDICATORS of LT category	Type	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
		Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
LEED for neighborhood development location	<i>Cr</i>	0.6	1.3	LC	1.3	0.3	LC	LC
Sensitive land protection	<i>Cr</i>	2.1	1.0	LC	1.8	1.0	LC	LC
High-priority site	<i>Cr</i>	0.0	0.0	LC	1.0	0.0	LC	LC
Surrounding density and diverse uses	<i>Cr</i>	3.5	2.5	LN	2.0	1.3	LN	LN
Access to quality transit	<i>Cr</i>	2.3	0.5	LC	2.5	1.0	LC	LC
Bicycle facilities	<i>Cr</i>	9.6	0.3	HC	6.5	1.0	HC	HC
Reduced parking footprint	<i>Cr</i>	10.0	0.0	HC	6.9	0.0	HC	HC
Green vehicles	<i>Cr</i>	10.0	0.0	HC	7.0	0.0	HC	HC

(HC: High with consensus, MC: Moderate with consensus, LC: low with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1** & **Q2**, an aggregated level of support is presented in Table 14. The measurement used to measure the aggregated level of support was mentioned in Figure 14 :(*Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators*) in Section 3.2.3.4 in the Methodology chapter 3.

According to the results of the aggregated level of support presented in Table 14, the indicator LEED for Neighborhood Development Location is classified as "Low with consensus" (LC). With low mean scores of 0.6 in Q1 and 1.3 in Q2, and moderate interquartile ranges (IQRs) of 1.3 and 0.3 respectively, experts agree that Revit provides minimal support for this indicator, highlighting limitations in addressing complex site selection requirements. Similarly, Sensitive Land Protection also has an aggregated level of support classified as "Low with consensus" (LC), with mean scores of 2.1 (Q1) and 1.8 (Q2) and IQRs of 1.0 for both metrics. This consensus suggests that Revit's capabilities are insufficient for meeting sensitive land protection requirements as specified by LEED.

The indicator High-Priority Site also falls under "Low with consensus" (LC), with mean scores of 0.0 in Q1 and 1.0 in Q2, and no variability in expert responses (IQR of 0.0 for both). This strong agreement reflects that Revit offers very limited to no support for high-priority site criteria, indicating a significant gap in functionality. In contrast, Surrounding Density and Diverse Uses is classified as "Low with no consensus" (LN), with mean scores of 3.5 in Q1 and 2.0 in Q2, and higher IQRs of 2.5 and 1.3, respectively. This variability reflects differing expert opinions, suggesting that while support is generally perceived as low, there is a lack of consensus on Revit's adequacy in handling surrounding density and diverse use considerations.

Access to Quality Transit is another indicator classified as "Low with consensus" (LC). With mean scores of 2.3 in Q1 and 2.5 in Q2, and IQRs of 0.5 and 1.0, respectively, experts agree on Revit's minimal support for transit access requirements, indicating a potential need for Revit to expand its functionalities to address these transportation-related criteria. On the other hand, Bicycle Facilities is classified as "High with consensus" (HC), with Revit scoring 9.6 in Q1 and 6.5 in Q2, both with low IQRs of 0.3 and 1.0. This high level of support, combined with strong expert agreement, demonstrates Revit's effectiveness in meeting LEED requirements for bicycle facilities within the LT category.

Reduced Parking Footprint and Green Vehicles are also rated "High with consensus" (HC), with Revit achieving perfect scores of 10.0 in Q1 and nearly perfect scores of 6.9 and 7.0 in Q2, respectively, with no variability (IQR of 0.0 for both metrics). This unanimous expert agreement indicates that Revit is highly capable of supporting the requirements for these transportation-focused indicators, making it an effective tool for meeting these specific LEED LT criteria.

4.2.2 Assessment of Revit Support for LEED SS Indicators

The assessment of Revit support for SS indicators are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements “DR” of the indicators), T2: (assessment of Revit Support based on Case study “CS” of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.2.2.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-1 of the expert panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each LEED indicator: Q1) “indicate the number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by LEED”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified LEED indicator using a 7-point Likert scale”. Appendix A2-T1 presents the detailed responses of each expert in the expert panel for each question in task-1: T1-Q1 and T1-Q2. Table 15 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Sustainable Sites (SS) category using the two measurements (Q1 and Q2). While Figure 20 provides a graphical representation (radar chart) of the data in Table 15. These two measurements capture the experts’ assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each LEED SS indicators.

Table 15 Achievable points and Level of coverage of the indicators in the SS category in LEED as assessed by experts (Assessment based on documented requirements of the indicators)

Indicators of SS category	Indicator Type	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
			Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (out of 10)	Mean level of Support
Construction activity pollution prevention	<i>Pr</i>	<i>10</i>	0.0	0.0	1.3
Site assessment	<i>Cr</i>	<i>1</i>	0.3	3.0	1.5
Site development—protect or restore habitat	<i>Cr</i>	<i>2</i>	0.1	0.5	1.3
Open space	<i>Cr</i>	<i>1</i>	1.0	10.0	6.8

Rainwater management	Cr	3	2.4	8.0	6.3
Heat island reduction	Cr	2	2.0	10.0	6.5
Light pollution reduction	Cr	1	1.0	10.0	6.5

(Legend: Mean Level of Support: Out Of 7 , Cr : Credit , Pr: Prerequisite)

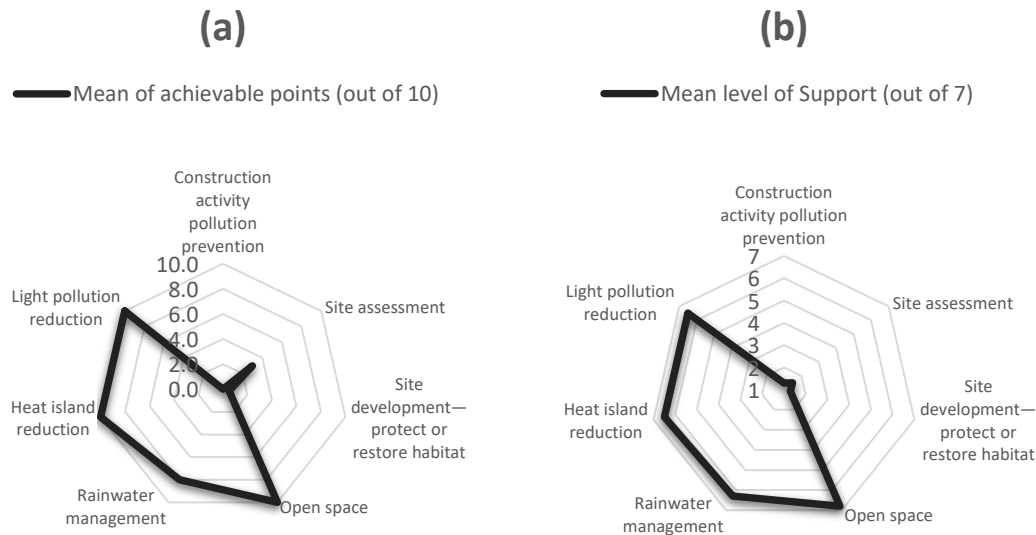


Figure 20 Radar Chart of Expert's assessment of the level of support of Revit for LEED indicators in the SS category based on the documented requirements (DR) of LEED indicators using two measurements (Q1 and Q2)

(a) Mean achievable points-Q1 (out of 10) (b) Mean level of Revit support for the indicator-Q2 (out of 7)

The results presented in Table 15 and Figure 20(a) regarding Q1 (the mean achievable points for each indicator in the SS category based on documented requirements) suggest that Revit provides limited support for several LEED indicators within the Sustainable Sites (SS) category. Specifically, the indicators "Construction Activity Pollution Prevention," "Site Development—Protect or Restore Habitat," and "Site Assessment" demonstrate very low mean achievable points, with scores of 0.0, 0.1, and 0.3 out of their respective maximum possible points. As illustrated in Figure 20(a), these indicators fall substantially short of their full potential, indicating that Revit's tools may not sufficiently

address detailed site protection and assessment requirements outlined by LEED. This limited support emphasizes areas where Revit's capabilities could be expanded to better support comprehensive environmental site management and conservation efforts.

However, Figure 20(a) also shows that Revit performs comparatively well on certain SS indicators, such as "Open Space," "Rainwater Management," and "Heat Island Reduction," each of which achieves higher mean scores. For instance, "Open Space" scored a mean of 1.0 out of 1.0 achievable points, and "Rainwater Management" scored 2.4 out of 3.0, suggesting that Revit provides relatively robust support for these infrastructure and environmental quality indicators. This trend in Figure 20(a) underscores Revit's capabilities in managing requirements tied to physical infrastructure and water conservation, which may be less complex than those involving specific environmental impact assessments or restoration efforts.

Regarding Q2 (mean level of support out of 7), as depicted in Figure 20(b), Revit's support across SS indicators displays a broad range. Indicators related to physical site development, such as "Open Space," "Heat Island Reduction," and "Light Pollution Reduction," scored relatively high on the support scale, with means of 6.8, 6.5, and 6.5, respectively. These high scores in Figure 20(b) suggest that Revit is well-equipped to assist in meeting certain environmental and infrastructure criteria in the SS category, thus providing users with effective tools for addressing LEED requirements in these areas.

In contrast, indicators requiring more detailed environmental analysis, such as "Construction Activity Pollution Prevention" and "Site Development—Protect or Restore Habitat," exhibit lower mean support levels, scoring only 1.3 each. These low scores, as

shown in Figure 20(b), highlight Revit's limitations in supporting rigorous environmental protection and habitat conservation practices. The overall pattern from both figures indicates that, while Revit excels in meeting straightforward infrastructure-related SS requirements, it may require additional features or complementary tools to fully address LEED's more complex site assessment and pollution prevention criteria.

4.2.2.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study "CS"

During task-2 of session-1 of the expert panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each LEED indicator based on the results of the case study presented to them (CS): Q1) "indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the data of case study presented", and Q2) "on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the LEED indicator based on the data of case study presented". Appendix A2-T2 presents the detailed responses of each expert in expert panel for each question in this task. Table 16 provides a summary of the experts' assessment of Revit support/coverage for each indicator in the Sustainable Sites (SS) category using the two measurements (Q1 and Q2). While Figure 21 provides a graphical representation (radar diagram?? Check) of the data in Table 16. These two measurements capture the experts' assessment of Revit's ability to meet/support LEED requirements for each indicator based on the results of the case study.

Table 16 Achievable points and Level of coverage of the indicators in the ss category in LEED as assessed by experts (Assessment based on the case study data)

Indicators of SS category	Indicator Type	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
			Mean of achievable points (out of max possible points)	Mean of achievable points (out of 10)	Mean level of Support
Construction activity pollution prevention	<i>Pr</i>	10	0.0	0.0	1.3
Site assessment	<i>Cr</i>	1	0.2	2.0	1.5
Site development—protect or restore habitat	<i>Cr</i>	2	0.2	1.0	1.5
Open space	<i>Cr</i>	1	1.0	10.0	6.8
Rainwater management	<i>Cr</i>	3	2.1	7.0	5.0
Heat island reduction	<i>Cr</i>	2	2.0	10.0	6.5
Light pollution reduction	<i>Cr</i>	1	1.0	10.0	6.5

(Legend: Mean Level of Support: Out Of 7 , Cr : Credit , Pr: Prerequisite)

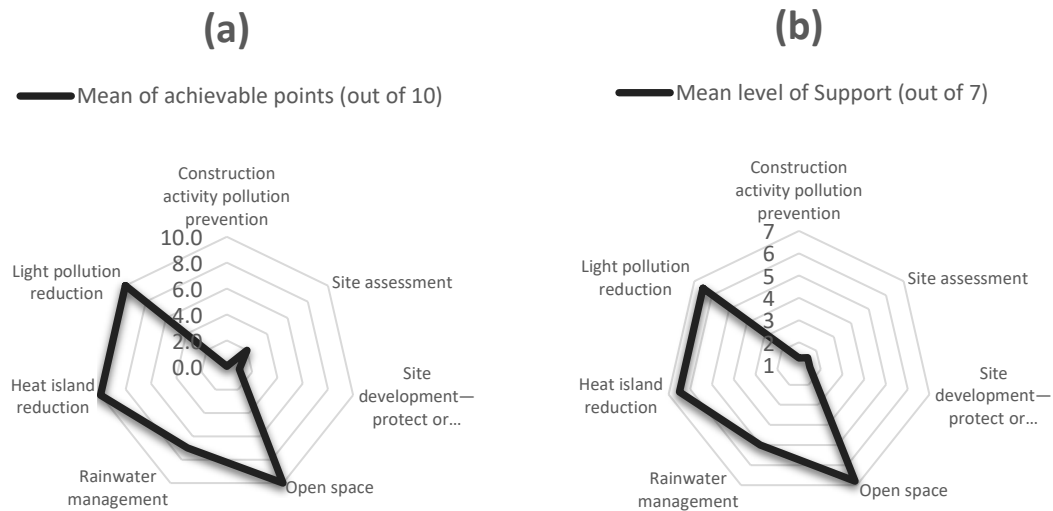


Figure 21 Radar Chart of expert's assessment of the level of support of Revit for LEED indicators in the SS category based on the case study (CS) results using two measurements (Q1 and Q2)

(a) Mean Achievable points- **Q1** (out of 10) **(b)** Mean level of Revit support - **Q2** (out of 7)

The analysis of Table 16 and Figure 21(a) regarding **Q1** (the mean achievable points for each indicator in the SS category based on case study data) indicates that Revit offers limited support for many LEED indicators within the Sustainable Sites (SS) category. In particular, indicators such as "Construction Activity Pollution Prevention," "Site Assessment," and "Site Development—Protect or Restore Habitat" show very low mean achievable points, with scores of 0.0, 0.2, and 0.2 out of the maximum possible, respectively. Figure 21(a) clearly illustrates this shortfall, suggesting that Revit's tools may be insufficient for handling the complex environmental and protective measures required by LEED for these indicators. This limited support identifies areas where Revit's functionalities could be expanded to address more comprehensive environmental management and conservation efforts.

Conversely, Figure 21(a) shows that Revit performs relatively well on certain SS indicators, particularly "Open Space," "Heat Island Reduction," and "Light Pollution Reduction," each achieving close to their maximum possible points. For instance, "Open Space" scored a perfect mean of 1.0 out of 1.0, while "Heat Island Reduction" and "Light Pollution Reduction" both achieved high scores of 2.0 out of 2.0 and 1.0 out of 1.0, respectively. This pattern in Figure 21(a) reflects Revit's strength in addressing straightforward infrastructure-related criteria, where the requirements align more closely with its existing capabilities.

As for **Q2** (mean level of support out of 7), Figure 21(b) highlights a significant variation in Revit's support across SS indicators. Indicators focused on specific physical site development criteria, such as "Open Space," "Heat Island Reduction," and "Light Pollution Reduction," achieved relatively high support ratings, with means of 6.8, 6.5, and 6.5,

respectively. These high scores, as shown in Figure 21(b), indicate that Revit is well-suited to support certain infrastructure requirements in the SS category, providing architects and designers with effective tools for meeting these LEED standards.

In contrast, indicators requiring more detailed site analysis, such as "Construction Activity Pollution Prevention" and "Site Development—Protect or Restore Habitat," display lower mean support levels, with scores of only 1.3 and 1.5, respectively. These low ratings in Figure 21(b) reinforce the limitations in Revit's capacity to meet complex site management and environmental protection requirements. Taken together, both figures suggest that while Revit is competent in handling infrastructure-related SS indicators, it may need additional tools or plugins to comprehensively support LEED's stringent site and environmental protection criteria.

4.2.2.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-1 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each LEED indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked “to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each LEED indicator using a scale from 1 to 10”. A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance Table 17 provides a summary of the experts’ assessment of Revit of Mean ranking level for the support of each Media Type for LEED

SS indicators in the SS category. While Figure 22 provides a graphical representation (radar chart) of the data in Table 17.

Table 17 Mean ranking level for the support of each Media Type for LEED SS indicator in SS category.

INDICATOR	Type	Mean Ranking of the support of Revit media channel for LEED			
		TD	M	S	DI
Construction activity pollution prevention	<i>Pr</i>	5.3	2.7	0	2
Site assessment	<i>Cr</i>	6	4.3	1.7	1.7
Site development—protect or restore habitat	<i>Cr</i>	5	5.3	2	1.3
Open space	<i>Cr</i>	5.7	8.7	4.3	1.3
Rainwater management	<i>Cr</i>	4.3	5.3	5.7	7
Heat island reduction	<i>Cr</i>	5.7	9	8.3	3.3
Light pollution reduction	<i>Cr</i>	3.3	5	5	1.7

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration).

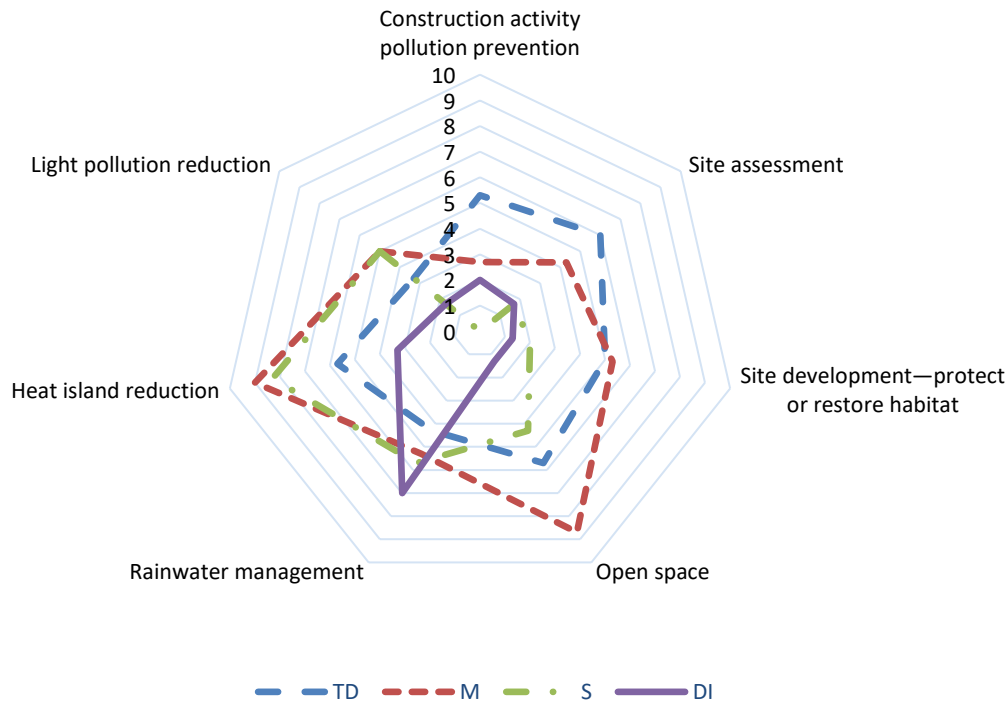


Figure 22 Radar Chart for expert's assessment of Revit Media Channel Support for LEED Indicators in the SS (TD: text documentation, M: modeling, S: simulation, and DI: data integration).

According to the results of Table 17 & Figure 22, it shows that TD (Text Documentation) plays a prominent role in several SS indicators, as seen in Table 17 and Figure 22. For indicators such as *Construction Activity Pollution Prevention (5.3)*, *Site Assessment (6.0)*, and *Site Development—Protect or Restore Habitat (5.0)*, TD shows moderate to strong support. This reflects its importance in offering descriptive documentation and validation for these credits, highlighting Revit’s strengths in managing text-based compliance reporting. However, TD’s role is secondary for indicators like *Rainwater Management (4.3)* and *Light Pollution Reduction (3.3)*, suggesting the need for more complex design approaches for these credits.

M (Modeling) demonstrates high support for indicators like *Open Space (8.7)* and *Heat Island Reduction (9.0)*, where 3D modeling is crucial for visualizing and validating these sustainable design elements. Revit’s modeling capabilities are especially effective for environmental design and analysis, as evidenced by its strong support for *Rainwater Management (5.3)* and *Light Pollution Reduction (5.0)*. These results underscore Revit’s ability to achieve sustainable site planning objectives through detailed modeling, especially for visual and spatial analysis.

S (Simulation) shows a moderate to significant role in supporting indicators such as *Heat Island Reduction (8.3)*, *Rainwater Management (5.7)*, and *Light Pollution Reduction (5.0)*. Revit’s simulation tools provide dynamic performance evaluations essential for credits requiring environmental and energy analysis. The data indicate that while simulation is less critical for simpler credits like *Site Assessment* and *Site Development—Protect or Restore Habitat*, it is critical for indicators requiring performance-based analysis, such as heat island mitigation and light pollution management.

DI (Data Integration) is particularly critical for the *Heat Island Reduction* indicator, achieving a score of 7.0, which signifies the need to integrate external datasets (environmental and geographic) into Revit models for accurate performance. DI also supports *Rainwater Management (1.3)* and *Site Assessment (1.7)*, enhancing sustainability outcomes through external tool integration. However, for indicators like *Open Space (1.3)* and *Site Development—Protect or Restore Habitat (1.3)*, DI's role is limited, as Revit's built-in tools often suffice.

4.2.2.4 Assessment of Revit Support for LEED SS Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for LEED SS indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study “CS”). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of LEED indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a ‘fraction of 10’) were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 18 shows the aggregated metrics from the two

tasks: Task-1 (T1: data based on documented requirements “DR”) and task-2 (T2: data based on case study “CS”).

Table 18 Aggregate assessment of the Experts for the level of support of Revit for LEED SS indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

INDICATORS of SS category	Indicator Type	Level of Support based on T1-Q1 & T2-Q1		Level of Support based on T1-Q2 & T2-Q2	
		Mean (out of 10)	IQR	Mean (out of 7)	IQR
Construction activity pollution prevention	<i>Pr</i>	0.0	0.0	1.3	0.3
Site assessment	<i>Cr</i>	2.4	1.0	1.5	1.0
Site development—protect or restore habitat	<i>Cr</i>	0.6	1.1	1.4	1.0
Open space	<i>Cr</i>	9.8	0.0	6.8	0.3
Rainwater management	<i>Cr</i>	7.5	5.0	5.6	2.3
Heat island reduction	<i>Cr</i>	10.0	0.0	6.5	1.0
Light pollution reduction	<i>Cr</i>	9.9	0.0	6.5	1.0

(Legend: *Cr*: Credit , *Pr*: Prerequisite)

To be able to identify aggregated level of support of Revit for the SS indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (**Q2**) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where mean ≤ 3 . Then also for the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where mean ≤ 4 .

Data based on Q2 (7-point Likert)		Level of support	Data based on Q1 (achievable point out of 10)		Level of support
Mean	IQR		Mean	IQR	
≥ 5.5	$\text{IQR} \leq 1$	High Support with consensus	≥ 7.7	$\text{IQR} \leq 2$	High Support with consensus
≥ 5.5	$\text{IQR} > 1$	High Support without consensus	≥ 7.7	$\text{IQR} > 2$	High Support without consensus
$3 < \text{mean} < 5.5$	$\text{IQR} \leq 1$	Moderate Support with consensus	$4 < \text{mean} < 7.7$	$\text{IQR} \leq 2$	Moderate Support with consensus

$3 < \text{mean} < 5.5$	$\text{IQR} > 1$	Moderate Support without consensus	$4 < \text{mean} < 7.7$	$\text{IQR} > 2$	Moderate Support without consensus
≤ 3	$\text{IQR} \leq 1$	Low Support with consensus	≤ 4	$\text{IQR} \leq 2$	Low Support with consensus
≤ 3	$\text{IQR} > 1$	Low Support without consensus	≤ 4	$\text{IQR} > 2$	Low Support without consensus

Figure 23 level of agreement /consensus among the experts regarding level of support of Revit for indicators.

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the LT indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 18 for **Q1** (mean achievable points out of 10) provide a detailed view of Revit's support level across the various LEED SS indicators. The aggregated data from both Task-1 and Task-2 reveal that Revit demonstrates high support for environmental management-related indicators, particularly "Open Space," "Heat Island Reduction," and "Light Pollution Reduction." These indicators achieved mean scores of 9.8, 10.0, and 9.9, respectively, placing them firmly in the high support category with minimal variability, as shown by their low interquartile ranges (IQRs) of 0.0 or 0.3. These high scores indicate strong consensus among experts regarding Revit's capability to support these straightforward infrastructure-focused requirements within the SS category.

In contrast, indicators that involve complex site assessment and habitat preservation considerations, such as "Construction Activity Pollution Prevention," "Site Assessment," and "Site Development—Protect or Restore Habitat," received much lower mean scores. For instance, "Construction Activity Pollution Prevention" scored only 0.0, and "Site

Development—Protect or Restore Habitat" scored 0.6, placing them in the low support category. This suggests that Revit may lack the tools necessary to meet the requirements for more intricate site-related indicators in the LEED SS category.

For **Q2** (mean level of support out of 7), the results show that Revit's support varies significantly across the LEED SS indicators, with environmental management-focused indicators again performing better. "Light Pollution Reduction" and "Heat Island Reduction" achieved high mean support levels of 6.5 each, with no variability (IQR = 1.0), reflecting unanimous agreement among experts that Revit is effective in supporting these indicators. "Open Space" also scored highly, with a mean of 6.8 and a slightly lower IQR of 0.3.

On the other hand, indicators that demand complex site management and environmental sensitivity, such as "Construction Activity Pollution Prevention" and "Site Development—Protect or Restore Habitat," scored much lower, with means of 1.3 and 1.4, respectively, and similarly low IQRs. These low scores place them in the low support category, suggesting limited functionality within Revit for these requirements. The moderate scores for indicators like "Rainwater Management" (Mean of 5.6) further indicate that while Revit provides some level of support, it may not be sufficient to fully meet the LEED requirements for these indicators.

Table 19 Aggregated level of support of Revit for LEED SS indicators based on the results of Task-1 and Task2.

Indicators of SS category	Type	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
		Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Construction activity pollution prevention	<i>Pr</i>	0.0	0.0	LC	1.3	0.3	LC	LC

Site assessment	<i>Cr</i>	2.4	1.0	LC	1.5	1.0	LC	LC
Site development—protect or restore habitat	<i>Cr</i>	0.6	1.1	LC	1.4	1.0	LC	LC
Open space	<i>Cr</i>	9.8	0.0	HC	6.8	0.3	HC	HC
Rainwater management	<i>Cr</i>	7.5	5.0	MN	5.6	2.3	HN	Inconsistent without agreement
Heat island reduction	<i>Cr</i>	10.0	0.0	HC	6.5	1.0	HC	HC
Light pollution reduction	<i>Cr</i>	9.9	0.0	HC	6.5	1.0	HC	HC

(HC: High with consensus, MC: Moderate with consensus, LC: Moderate with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1 & Q2**, an aggregated level of support is presented in Table 19. The measurement used to measure the aggregated level of support was mentioned in Figure 14 :(*Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators*) in Section 3.2.3.4 in the Methodology chapter 3.

According to the results of the aggregated level of support presented in Table 19, the indicator "Construction Activity Pollution Prevention" is classified as "Low with Consensus" (LC). With low mean scores of 0.0 in Q1 and 1.3 in Q2, and interquartile ranges (IQRs) of 0.0 and 0.3, respectively, experts agree that Revit provides minimal support for this prerequisite, underscoring limitations in addressing pollution prevention requirements during construction activities.

Similarly, "Site Assessment" also has an aggregated level of support classified as "Low with Consensus" (LC), with mean scores of 2.4 in Q1 and 1.5 in Q2, and IQRs of 1.0 for both. This consensus indicates that Revit's capabilities are insufficient to fully meet the requirements for a comprehensive site assessment as specified by LEED.

The indicator "Site Development—Protect or Restore Habitat" falls under "Low with Consensus" (LC) as well, with mean scores of 0.6 in Q1 and 1.4 in Q2, and IQRs of 1.1

and 1.0, respectively. This consensus reflects that Revit provides limited support for habitat protection and restoration, signifying a notable gap in functionality for this indicator.

In contrast, the indicator "Open Space" is classified as "High with Consensus" (HC), with Revit achieving mean scores of 9.8 in Q1 and 6.8 in Q2, with low IQRs of 0.0 and 0.3. This high level of support, combined with strong expert agreement, demonstrates Revit's effectiveness in supporting open space requirements within the SS category.

"Rainwater Management" is rated as "Moderate to High with No Consensus" (MN/HN), with mean scores of 7.5 in Q1 and 5.6 in Q2, but high IQRs of 5.0 and 2.3, reflecting a lack of expert agreement. These results suggest that while Revit provides a moderate to high level of support for rainwater management, expert opinions on its adequacy vary significantly.

The indicators "Heat Island Reduction" and "Light Pollution Reduction" are both rated as "High with Consensus" (HC). Revit achieved near-perfect mean scores of 10.0 and 9.9 in Q1, respectively, and 6.5 in Q2 for both, with IQRs of 0.0 and 1.0, respectively. This unanimous agreement among experts highlights Revit's strong support for these environmental impact indicators, indicating its high capability in meeting these specific LEED SS criteria.

4.2.3 Assessment of Revit Support for LEED WE Indicators

The assessment of Revit support for WE indicators are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements “DR” of the indicators), T2: (assessment of Revit Support based on Case study “CS” of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.2.3.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-1 of the Expert Panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each LEED indicator: Q1) “indicate the number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by LEED”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified LEED indicator using a 7-point Likert scale”. Appendix A2-T1 presents the detailed responses of each expert in the Expert Panel for each question in task-1: T1-Q1 and T1-Q2. Table 20 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in Water Efficiency (WE) category using the two measurements (Q1 and Q2). While Figure 24 provides a graphical representation (radar chart) of the data in Table 20. These two measurements capture the experts’ assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each LEED WE indicators.

Table 20 Experts assessment of the level of support of Revit for LEED indicators in the WE category based on the documented requirements (DR) of LEED indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of WE category	Indicator Type	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale Mean level of Support
			Mean of achievable points (out of max possible points)	Mean of achievable points (out of 10)	
Outdoor water use reduction	<i>Pr</i>	10	7.0	7.0	5.3
Indoor water use reduction	<i>Pr</i>	10	7.0	7.0	5.3
Cooling tower water use	<i>Cr</i>	2	0.3	1.5	1.3
Water metering	<i>Cr</i>	1	0.9	9.0	6.0

(Legend: Mean Level of Support: Out Of 7 , Cr : Credit , Pr: Prerequisite)

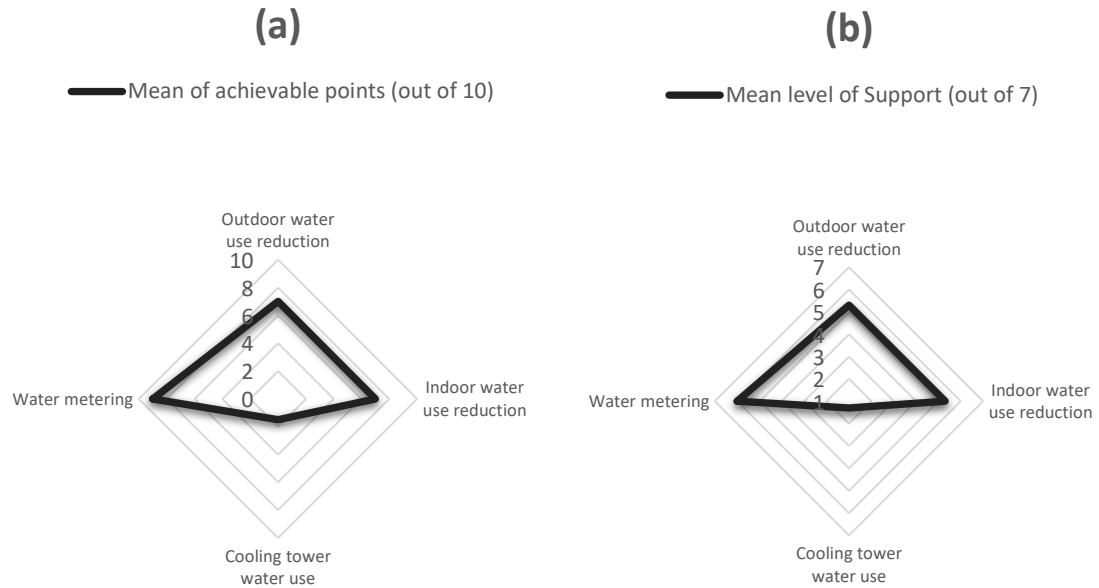


Figure 24 Radar Chart of Expert's assessment of the level of support of Revit for LEED indicators in the WE category based on the documented requirements (DR) of LEED indicators using two measurements (Q1 and Q2)

(a) Mean achievable points-Q1 (out of 10) (b) Mean level of Revit support for the indicator-Q2 (out of 7)

The analysis of Table 20 and Figure 24(a) regarding **Q1** (the mean achievable points for each indicator in the WE category based on documented requirements) indicates that Revit provides a varying degree of support across LEED Water Efficiency (WE) indicators. Specifically, indicators like "Outdoor Water Use Reduction" and "Indoor Water Use Reduction" show relatively high mean achievable points, with both scoring 7.0 out of the maximum possible 10 points. As shown in Figure 24(a), these indicators achieve significant portions of their potential points, suggesting that Revit's tools are well-aligned with LEED requirements for water use reduction, allowing architects and designers to address water efficiency goals effectively.

Conversely, Figure 24(a) reveals that other indicators, such as "Cooling Tower Water Use" and "Water Metering," score lower in terms of achievable points. For instance, "Cooling Tower Water Use" achieves a mean of only 0.3 points out of 2.0, indicating limited support for this indicator. This disparity suggests that Revit's existing functionality may not fully support more complex or specialized water management requirements as specified by LEED.

When examining **Q2** (mean level of support on a 7-point scale), Figure 24(b) highlights the range of Revit's support levels across WE indicators. Indicators like "Outdoor Water Use Reduction" and "Indoor Water Use Reduction" display relatively high support levels, each scoring 5.3 out of 7, as illustrated in Figure 24(b). This pattern suggests that Revit offers substantial support for fundamental water reduction initiatives, providing effective tools for meeting LEED standards in these areas.

In contrast, "Cooling Tower Water Use" and "Water Metering" show more limited support, with mean levels of 1.3 and 6.0, respectively. The low support level for "Cooling Tower Water Use," as depicted in Figure 24(b), emphasizes Revit's limited capabilities in addressing specific water management systems, while the higher support for "Water Metering" reflects moderate effectiveness for simpler metering requirements. The results from both figures suggest that Revit performs well in facilitating basic water use reduction criteria within the WE category but may benefit from additional tools or features to meet more specialized LEED water management and metering needs.

4.2.3.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study “CS”

During task-2 of session-1 of the Expert Panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each LEED indicator based on the results of the case study presented to them (CS): Q1) “indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the data of case study presented”, and Q2) “on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the LEED indicator based on the data of case study presented”. Appendix A2-T2 presents the detailed responses of each expert in the Expert Panel for each question in this task. Table 21 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Water Efficiency (WE) category using the two measurements (Q1 and Q2). While Figure 25 provides a graphical representation radar chart of the data in Table 21. These two measurements capture the

experts' assessment of Revit's ability to meet/support LEED requirements for each indicator based on the results of the case study.

Table 21 Experts assessment of the level of support of Revit for LEED indicators in the WE category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of WE category	Indicator Type	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale Mean level of Support
			Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (out of 10)	
Outdoor water use reduction	<i>Pr</i>	<i>10</i>	7.0	7.0	6.0
Indoor water use reduction	<i>Pr</i>	<i>10</i>	6.8	6.8	6.0
Cooling tower water use	<i>Cr</i>	<i>2</i>	0.2	1.0	1.5
Water metering	<i>Cr</i>	<i>1</i>	0.9	9.0	5.8

(Legend: Mean Level of Support: Out Of 7, Cr : Credit, Pr: Prerequisite)

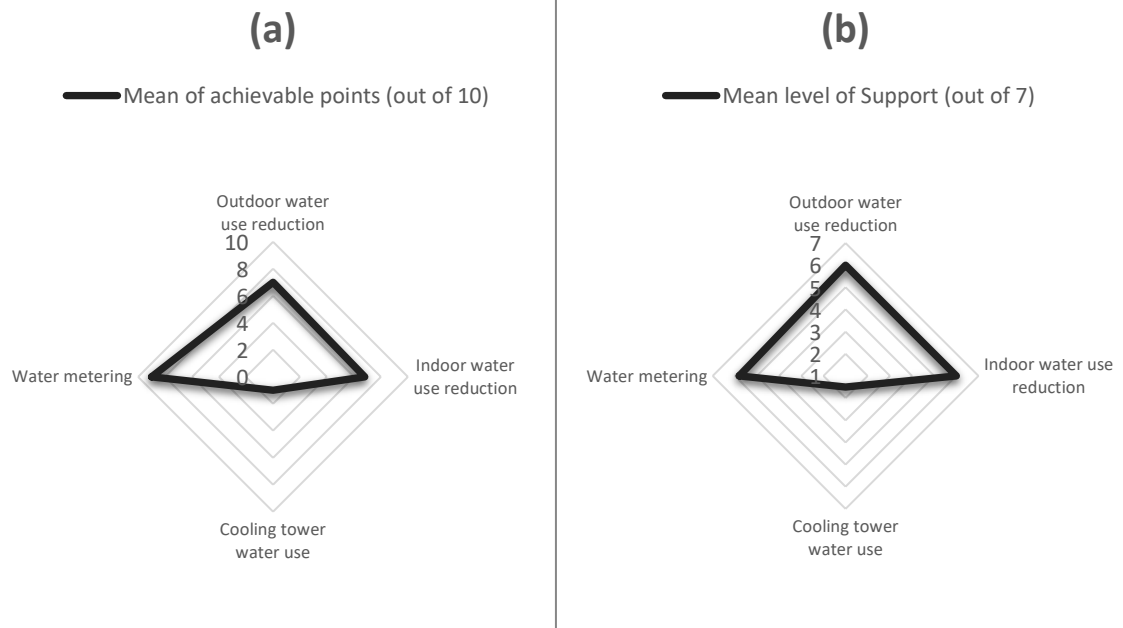


Figure 25 Radar Chart of expert's assessment of the level of support of Revit for LEED indicators in the WE category based on the case study (CS) results using two measurements (Q1 and Q2)

(a) Mean Achievable points- Q1 (out of 10) (b) Mean level of Revit support - Q2 (out of 7)

Based on the analysis presented in Table 21 and Figure 25(a) for **Q1** (the mean achievable points for each indicator in the WE category based on case study results), Revit shows varying levels of support for the Water Efficiency (WE) indicators in LEED. Indicators such as "Outdoor Water Use Reduction" and "Indoor Water Use Reduction" exhibit relatively high mean achievable points, with scores of 7.0 and 6.8 out of the maximum possible 10 points, respectively. As illustrated in Figure 25(a), these indicators reach substantial portions of their potential, indicating that Revit's tools align well with the requirements for basic water reduction measures, facilitating architects and designers in meeting essential LEED water efficiency criteria.

In contrast, Figure 25(a) highlights lower scores for indicators like "Cooling Tower Water Use" and "Water Metering," which achieve mean points of 0.2 and 0.9 out of their respective maximums. These lower scores suggest that Revit may lack sufficient functionality to fully address specific and complex water management requirements, especially for cooling tower systems.

Examining **Q2** (mean level of support on a 7-point scale), Figure 25(b) further underscores the variability in Revit's support for WE indicators. "Outdoor Water Use Reduction" and "Indoor Water Use Reduction" stand out with higher support levels, each achieving a score of 6.0 out of 7, as shown in Figure 25(b). This pattern suggests that Revit provides strong support for basic water reduction practices within the WE category, allowing users to effectively engage with foundational LEED water efficiency goals.

On the other hand, indicators such as "Cooling Tower Water Use" and "Water Metering" exhibit lower support levels, scoring 1.5 and 5.8, respectively. The low rating for "Cooling Tower Water Use" in Figure 25(b) highlights Revit's limitations in addressing more specific water system requirements, while the moderately high score for "Water Metering" indicates that Revit is reasonably capable of supporting simpler metering needs. Overall, the results from both figures suggest that while Revit is well-suited to facilitate basic water reduction initiatives, it may benefit from enhancements to fully address specialized water management requirements for LEED compliance in the WE category.

4.2.3.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-1 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each LEED indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked “to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each LEED indicator using a scale from 1 to 10”. A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 22 provides a summary of the experts’ assessment of Revit of Mean ranking level for the support of each Media Type for LEED WE indicators in the WE category. While Figure 26 provides a graphical representation (radar chart) of the data in Table 22.

Table 22 Mean ranking level for the support of each Media Type for LEED WE indicator in WE category.

INDICATOR	Type	Mean Ranking of the support of Revit media channel for LEED			
		TD	M	S	DI
Outdoor water use reduction	Pr	4	5.3	5.3	5
Indoor water use reduction	Pr	4	5.3	5.3	5
Cooling tower water use	Cr	4.3	3.7	6	4.3
Water metering	Cr	3.7	2.3	4.3	4

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration).

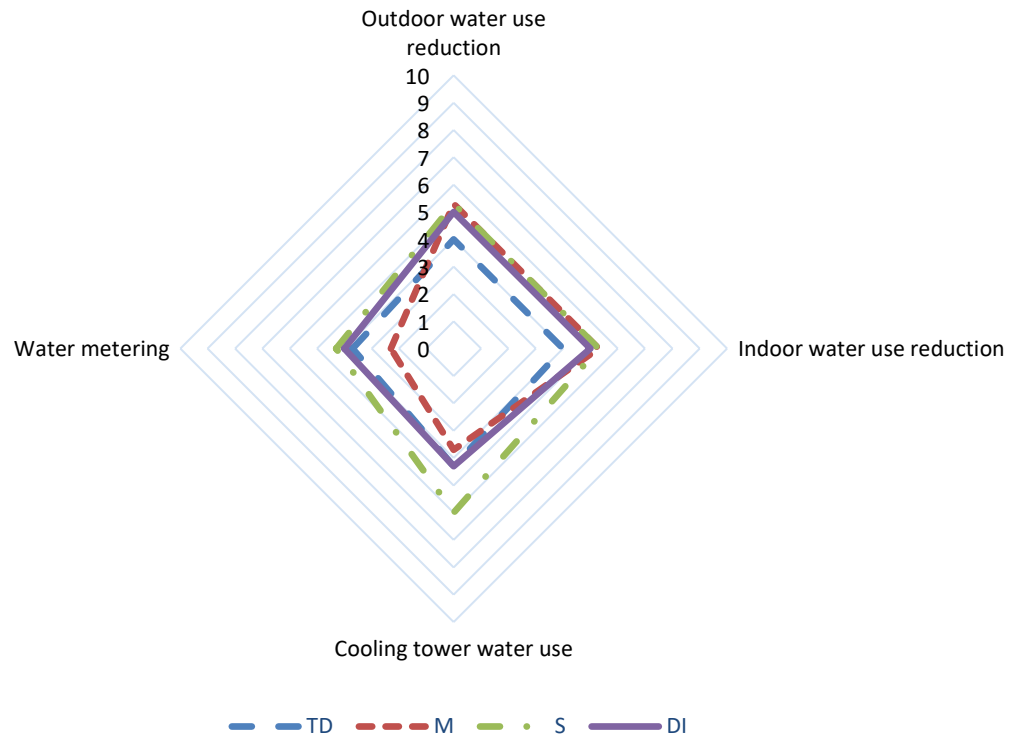


Figure 26 Radar Chart for expert's assessment of Revit Media Channel Support for LEED Indicators in the WE (TD: text documentation, M: modeling, S: simulation, and DI: data integration).

According to the results of Table 22 and Figure 26, TD (Text Documentation) plays a supportive role across several WE indicators. For instance, indicators like *Cooling Tower Water Use* (4.3) and *Outdoor Water Use Reduction* (4.0) show moderate support through

TD, reflecting its importance in providing descriptive documentation and compliance validation for these credits. This highlights Revit's strength in handling text-based reporting for water efficiency. However, TD's role is more limited for indicators such as *Water Metering (3.7)*, indicating that more complex data integration or modeling methods may be required for comprehensive analysis.

M (Modeling) demonstrates moderate to high support for water efficiency indicators such as *Outdoor Water Use Reduction (5.3)* and *Indoor Water Use Reduction (5.3)*, where 3D modeling is instrumental in visualizing and simulating water-efficient designs. Revit's modeling capabilities are effective in representing both outdoor and indoor water-saving measures, showing its strengths in sustainable water planning. However, for indicators like *Water Metering (2.3)*, modeling support is less pronounced, suggesting that additional media types may be needed to accurately capture metering requirements.

S (Simulation) shows significant support, particularly for *Cooling Tower Water Use (6.0)* and *Outdoor Water Use Reduction (5.3)*. Revit's simulation tools enable performance evaluations that are crucial for water efficiency credits involving operational analysis. The data from Table 22 and Figure 26 illustrate that while simulation is less critical for simpler credits, such as *Water Metering (4.3)*, it is essential for those requiring detailed performance-based analysis, such as cooling tower water usage and outdoor water reduction.

DI (Data Integration) is essential for *Cooling Tower Water Use (4.3)* and *Outdoor Water Use Reduction (5.0)*, where external data, such as climate and usage metrics, is incorporated into Revit models for precise assessments. DI also supports *Indoor Water Use*

Reduction (5.0), underscoring the role of external data integration in achieving these water efficiency objectives. However, DI's impact is more limited for *Water Metering (4.0)*, as Revit's internal tools can often handle basic metering requirements without extensive external input.

4.2.3.4 Assessment of Revit Support for LEED WE Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for LEED WE indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study "CS"). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of LEED indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a 'fraction of 10') were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 23 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements "DR") and task-2 (T2: data based on case study "CS").

Table 23 Aggregate assessment of the Experts for the level of support of Revit for LEED WE indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

INDICATORs of WE category	Indicator Type	Level of Support based on T1-Q1 & T2-Q1		Level of Support based on T1-Q2 & T2-Q2	
		Mean (out of 10)	IQR	Mean (out of 7)	IQR
Outdoor water use reduction	<i>Pr</i>	7.0	1.3	5.8	0.5
Indoor water use reduction	<i>Pr</i>	6.9	2.0	5.8	0.5
Cooling tower water use	<i>Cr</i>	1.2	1.3	1.4	0.3
Water metering	<i>Cr</i>	8.6	1.3	6.0	1.0

(Legend: *Cr* : Credit , *Pr*: Prerequisite)

To be able to identify aggregated level of support of Revit for the WE indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (**Q2**) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where $\text{mean} \leq 3$. Then also for the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where $\text{mean} \leq 4$.

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the LT indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 23 for **Q1** (mean achievable points out of 10) provide a detailed view of Revit's support level across the various LEED WE indicators. The aggregated data from both Task-1 and Task-2 reveal that Revit demonstrates high support for certain water efficiency indicators, particularly "Water Metering," which achieved a mean score of 8.6, placing it in the high support category with minimal variability, as shown by an interquartile range (IQR) of 1.3. This high score

indicates a strong consensus among experts regarding Revit's capability to support water metering requirements.

In contrast, indicators that involve more specific water use considerations, such as "Cooling Tower Water Use," received much lower mean scores. For example, "Cooling Tower Water Use" scored only 1.2, placing it in the low support category. This suggests that Revit may lack the necessary tools to fully address cooling tower water efficiency requirements within the LEED WE category.

For **Q2** (mean level of support out of 7), the results show that Revit's support varies across the LEED WE indicators, with basic water management-focused indicators again performing better. Both "Outdoor Water Use Reduction" and "Indoor Water Use Reduction" achieved moderate mean support levels of 5.8, with minimal variability (IQR = 0.5), reflecting a consensus among experts that Revit provides moderate support for these indicators. "Water Metering" also scored relatively high, with a mean of 6.0 and an IQR of 1.0, indicating strong expert agreement on Revit's effectiveness in meeting water metering requirements.

On the other hand, indicators that demand more complex water use management, such as "Cooling Tower Water Use," scored significantly lower, with a mean of 1.4 and a low IQR of 0.3, placing it in the low support category. These scores suggest limited functionality within Revit for addressing specific cooling water requirements. The moderate scores for "Outdoor Water Use Reduction" and "Indoor Water Use Reduction" indicate that while Revit provides some level of support for water conservation in these areas, it may not be sufficient to fully meet the LEED requirements for these indicators.

Table 24 Aggregated level of support of Revit for LEED WE indicators based on the results of Task-1 and Task2.

INDICATORS of WE category	Type	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
		Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Outdoor water use reduction	<i>Pr</i>	7.0	1.3	MC	5.8	0.5	HC	Inconsistent with agreement
Indoor water use reduction	<i>Pr</i>	6.9	2.0	MC	5.8	0.5	HC	Inconsistent with agreement
Cooling tower water use	<i>Cr</i>	1.2	1.3	LC	1.4	0.3	LC	LC
Water metering	<i>Cr</i>	8.6	1.3	HC	6.0	1.0	HC	HC

(HC: High with consensus, MC: Moderate with consensus, LC: Moderate with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1** & **Q2**, an aggregated level of support is presented in Table 24. The measurement used to measure the aggregated level of support was mentioned in Figure 14 :(*Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators*) in Section 3.2.3.4 in the Methodology chapter 3.

According to the results of the aggregated level of support presented in Table 24, the indicator "Outdoor Water Use Reduction" is classified as "Moderate with Consensus" (MC). With mean scores of 7.0 in Q1 and 5.8 in Q2, and interquartile ranges (IQRs) of 1.3 and 0.5, respectively, experts agree that Revit provides a moderate level of support for this indicator. This suggests that while Revit can address some aspects of outdoor water conservation, there may still be limitations in fully aligning with LEED requirements, resulting in Inconsistent with agreement.

Similarly, "Indoor Water Use Reduction" also has an aggregated level of support classified as "Moderate with Consensus" (MC), with mean scores of 6.9 in Q1 and 5.8 in Q2, and IQRs of 2.0 and 0.5, respectively. This classification reflects that Revit offers moderate support for indoor water reduction efforts, indicating it can assist in certain aspects of water

efficiency, but may not fully satisfy LEED standards, leading to Inconsistent with agreement in expert consensus.

The indicator "Cooling Tower Water Use" falls under "Low with Consensus" (LC), with mean scores of 1.2 in Q1 and 1.4 in Q2, both with IQRs of 1.3 and 0.3, respectively. This strong agreement highlights Revit's limited functionality for cooling tower water efficiency, indicating a significant gap in its capability for this indicator within the WE category.

In contrast, "Water Metering" is classified as "High with Consensus" (HC), with Revit achieving mean scores of 8.6 in Q1 and 6.0 in Q2, and IQRs of 1.3 and 1.0, respectively. This high level of support, combined with strong expert consensus, underscores Revit's effectiveness in supporting water metering requirements, marking it as a valuable tool for tracking and managing water usage in line with LEED standards.

4.2.4 Assessment of Revit Support for LEED EA Indicators

The assessment of Revit support for EA indicators are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements "DR" of the indicators), T2: (assessment of Revit Support based on Case study "CS" of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.2.4.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-1 of the Expert Panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each LEED indicator: Q1) “indicate the number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by LEED”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified LEED indicator using a 7-point Likert scale”. Appendix A2-T1 presents the detailed responses of each expert in the Expert Panel for each question in task-1: T1-Q1 and T1-Q2. Table 25 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in Energy & Atmosphere (EA) category using the two measurements (Q1 and Q2). While Figure 27 provides a graphical representation (radar chart) of the data in Table 25. These two measurements capture the experts’ assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each LEED EA indicators.

Table 25 Experts assessment of the level of support of Revit for LEED indicators in the EA category based on the documented requirements (DR) of LEED indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of EA category	Indicator Type	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
			Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (<i>out of 10</i>)	Mean level of Support
Fundamental commissioning and verification	<i>Pr</i>	<i>10</i>	0.0	0.0	1.0
Minimum energy performance	<i>Pr</i>	<i>10</i>	9.5	9.5	6.8
Building-level energy metering	<i>Pr</i>	<i>10</i>	9.0	9.0	5.8
Fundamental refrigerant management	<i>Pr</i>	<i>10</i>	6.0	6.0	4.5

Enhanced commissioning	Cr	6	0.4	0.7	1.3
Optimize Energy Performance	Cr	18	18.0	10.0	7.0
Advanced energy metering	Cr	1	0.9	9.0	6.3
Demand response	Cr	2	0.1	0.5	1.8
Renewable energy production	Cr	3	2.8	9.3	6.8
Enhanced refrigerant management	Cr	1	0.7	7.0	5.0
Green power and carbon offsets	Cr	2	0.3	1.5	1.3

(Legend: Mean Level of Support: Out Of 7 , Cr : Credit , Pr: Prerequisite)

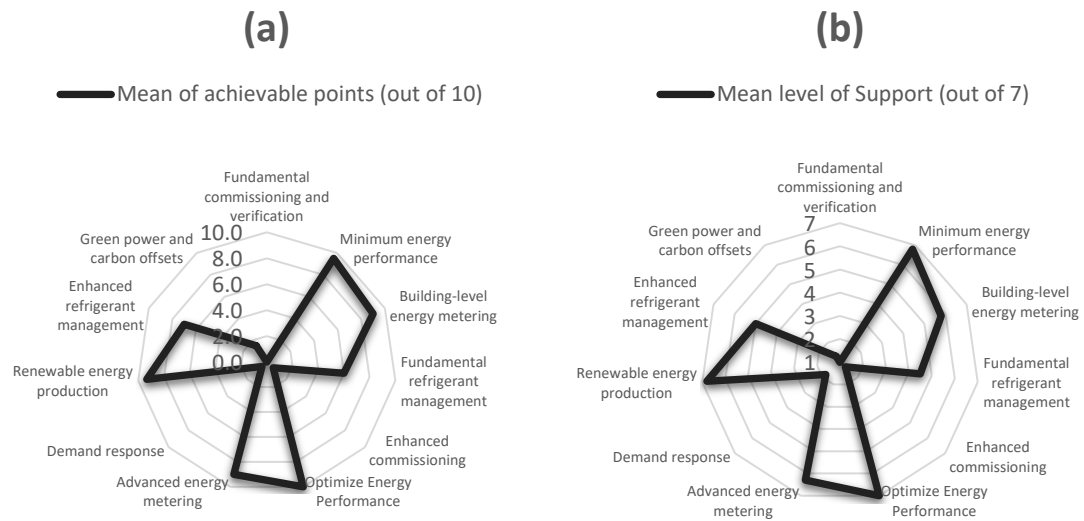


Figure 27 Radar Chart of Expert's assessment of the level of support of Revit for LEED indicators in the EA category based on the documented requirements (DR) of LEED indicators using two measurements (Q1 and Q2)

(a) Mean achievable points-Q1 (out of 10) (b) Mean level of Revit support for the indicator-Q2 (out of 7)

The analysis of Table 25 and Figure 27(a) regarding Q1 (the mean achievable points for each indicator in the EA category based on documented requirements) shows a significant range in Revit's support for the Energy and Atmosphere (EA) indicators within LEED. Indicators like "Minimum Energy Performance" and "Optimize Energy Performance" demonstrate high mean achievable points, scoring 9.5 out of 10 and a full 18 out of 18,

respectively. As depicted in Figure 27(a), these high scores indicate that Revit is highly capable of supporting essential energy performance requirements, providing architects and designers with tools that align well with LEED standards for energy efficiency.

On the other hand, indicators such as "Fundamental Commissioning and Verification," "Enhanced Commissioning," and "Demand Response" show considerably lower scores, with mean achievable points of 0.0, 0.4, and 0.1, respectively. This discrepancy, as shown in Figure 27(a), suggests that Revit's tools are less equipped to handle complex commissioning and demand response requirements, highlighting potential areas for improvement in supporting these aspects of LEED compliance.

Figure 27(b) provides insights into Q2 (mean level of support on a 7-point scale), which further illustrates the diversity in Revit's support for EA indicators. Indicators related to energy metering, such as "Building-Level Energy Metering" and "Advanced Energy Metering," show relatively high levels of support, scoring 5.8 and 6.3, respectively. This trend, as seen in Figure 27(b), underscores Revit's strong support for basic energy monitoring and metering, facilitating compliance with LEED's EA criteria in these areas.

In contrast, indicators that involve specialized environmental and energy strategies, such as "Enhanced Commissioning" and "Green Power and Carbon Offsets," score much lower, with support levels of 1.3 and 1.3, respectively. The low scores, particularly for "Fundamental Commissioning and Verification" and "Demand Response," reinforce Revit's limited functionality in supporting advanced commissioning and demand response requirements.

4.2.4.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study “CS”

During task-2 of session-1 of the Expert Panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each LEED indicator based on the results of the case study presented to them (CS): Q1) “indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the data of case study presented”, and Q2) “on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the LEED indicator based on the data of case study presented”. Appendix A2-T2 presents the detailed responses of each expert in the Expert Panel for each question in this task. Table 26 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Energy & Atmosphere (EA) category using the two measurements (Q1 and Q2). While Figure 28 provides a graphical representation radar chart of the data in Table 26. These two measurements capture the experts’ assessment of Revit's ability to meet/support LEED requirements for each indicator based on the results of the case study.

Table 26 Experts assessment of the level of support of Revit for LEED indicators in the EA category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of EA category	Indicator Type	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale Mean level of Support
			Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (out of 10)	
Fundamental commissioning and verification	<i>Pr</i>	10	0.0	0.0	1.0
Minimum energy performance	<i>Pr</i>	10	9.3	9.3	7.0
Building-level energy metering	<i>Pr</i>	10	7.5	7.5	5.8
Fundamental refrigerant management	<i>Pr</i>	10	8.3	8.3	6.3

Enhanced commissioning	Cr	6	0.3	0.5	1.0
Optimize Energy Performance	Cr	18	18.0	10.0	7.0
Advanced energy metering	Cr	1	0.9	9.0	5.0
Demand response	Cr	2	0.4	2.0	2.3
Renewable energy production	Cr	3	3.0	10.0	7.0
Enhanced refrigerant management	Cr	1	1.0	10.0	6.8
Green power and carbon offsets	Cr	2	0.3	1.5	1.0

(Legend: Mean Level of Support: Out Of 7 , Cr : Credit , Pr: Prerequisite)

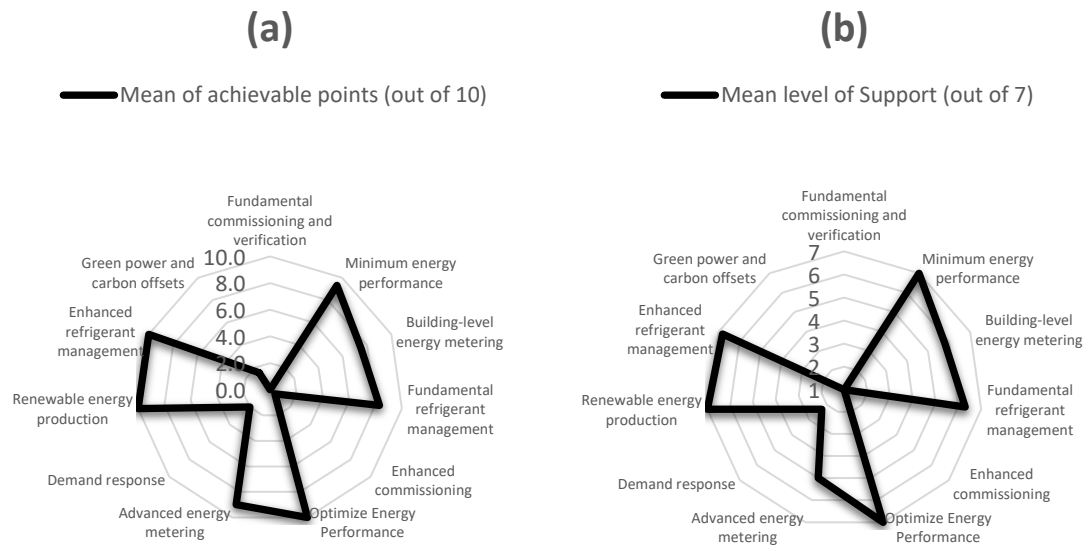


Figure 28 Radar Chart of expert's assessment of the level of support of Revit for LEED indicators in the EA category based on based on the case study (CS) results using two measurements (Q1 and Q2)

(a) Mean Achievable points- Q1 (out of 10) (b) Mean level of Revit support - Q2 (out of 7)

The analysis of Table 26 and Figure 28(a) regarding Q1 (the mean achievable points for each indicator in the EA category based on case study results) reveals that Revit provides substantial support for several LEED Energy and Atmosphere (EA) indicators. Indicators such as "Minimum Energy Performance," "Optimize Energy Performance," and

"Renewable Energy Production" show high mean achievable points, scoring 9.3 out of 10, a full 18 out of 18, and 3.0 out of 3.0, respectively. As shown in Figure 28(a), these scores suggest that Revit is well-suited to address core energy performance and renewable energy requirements, offering users tools aligned with these aspects of LEED compliance.

In contrast, indicators like "Fundamental Commissioning and Verification," "Enhanced Commissioning," and "Green Power and Carbon Offsets" exhibit notably lower scores, with mean achievable points of 0.0, 0.3, and 0.3, respectively. This disparity, illustrated in Figure 28(a), indicates that Revit's tools may lack adequate functionality for supporting complex commissioning tasks and renewable energy offsets, pointing to areas where additional features could enhance Revit's LEED capabilities.

Figure 28(b), which examines **Q2** (mean level of support on a 7-point scale), further highlights the variability in Revit's support for EA indicators. Indicators with a focus on core energy metrics, such as "Minimum Energy Performance" and "Optimize Energy Performance," receive high support ratings of 7.0, reflecting Revit's effectiveness in facilitating these fundamental energy efficiency requirements in the EA category.

On the other hand, indicators like "Enhanced Commissioning" and "Green Power and Carbon Offsets" display low support ratings, scoring 1.0 each. The low level of support for "Fundamental Commissioning and Verification" (1.0) and "Demand Response" (2.3) further underscores Revit's limitations in meeting more specialized energy management and commissioning requirements within LEED standards.

4.2.4.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-1 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each LEED indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked “to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each LEED indicator using a scale from 1 to 10”. A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 27 provides a summary of the experts’ assessment of Revit of Mean ranking level for the support of each Media Type for LEED EA indicators in the EA category. While Figure 29 provides a graphical representation (radar chart) of the data in Table 27.

Table 27 Mean ranking level for the support of each Media Type for LEED EA indicators in the EA category.

INDICATOR	Type	Mean Ranking of the support of Revit media channel for LEED			
		TD	M	S	DI
Fundamental commissioning and verification	Pr	4.7	2	2	4.3
Minimum energy performance	Pr	5.7	9	9	6.7
Building-level energy metering	Pr	4	4.7	5.3	6.3
Fundamental refrigerant management	Pr	5	5	2.3	4
Enhanced commissioning	Cr	5.3	2.3	2.3	4.7
Optimize Energy Performance	Cr	6.3	9.3	9.7	8.7
Advanced energy metering	Cr	3.7	4.7	4.7	4.7
Demand response	Cr	5	4	2.3	3.7
Renewable energy production	Cr	6.3	9.3	9.3	8.7
Enhanced refrigerant management	Cr	4.3	4.3	2	4
Green power and carbon offsets	Cr	5.3	2	0	4

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration).

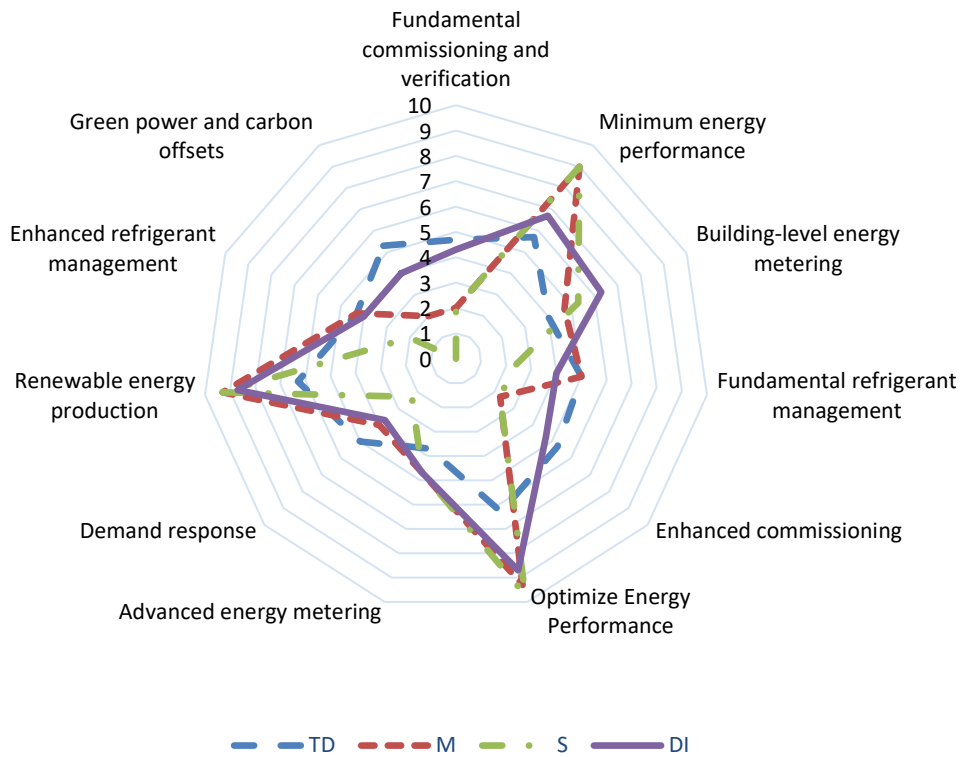


Figure 29 Radar Chart for expert's assessment of Revit Media Channel Support for LEED Indicators in the SS (TD: text documentation, M: modeling, S: simulation, and DI: data integration).

According to the results in Table 27 and Figure 29, TD (Text Documentation) plays a supportive role in several EA (Energy and Atmosphere) indicators. For indicators such as *Optimize Energy Performance* (6.3), *Renewable Energy Production* (6.3), and *Enhanced Commissioning* (5.3), TD shows moderate to strong support. This reflects the importance of descriptive documentation and compliance reporting in Revit to address these energy-focused credits. However, TD's role is secondary in indicators like *Building-Level Energy Metering* (4.0) and *Green Power and Carbon Offsets* (5.3), indicating that more sophisticated modeling or simulation approaches may be required for complex energy performance evaluations.

M (Modeling) demonstrates high levels of support for energy-related indicators, particularly for *Optimize Energy Performance (9.3)* and *Renewable Energy Production (9.3)*, where 3D modeling is crucial for visualizing and validating energy-efficient design elements. Revit's modeling tools also show strong support for *Minimum Energy Performance (9.0)*, emphasizing its capabilities in capturing design requirements for enhanced energy performance. However, modeling provides moderate support in areas such as *Building-Level Energy Metering (4.7)*, where additional integration with simulation tools is beneficial for accurate performance tracking.

S (Simulation) plays a significant role in supporting complex energy indicators, including *Optimize Energy Performance (9.7)*, *Renewable Energy Production (9.3)*, and *Minimum Energy Performance (9.0)*. These indicators benefit greatly from Revit's simulation tools, which provide essential performance evaluations for energy efficiency and production. While simulation is less critical for simpler credits like *Fundamental Refrigerant Management (2.3)* and *Demand Response (2.3)*, it is indispensable for credits that require comprehensive performance-based analysis.

DI (Data Integration) is essential for energy indicators that require external data for detailed analysis. For example, *Optimize Energy Performance (8.7)*, *Renewable Energy Production (8.7)*, and *Minimum Energy Performance (6.7)* all demonstrate strong support from DI, indicating the value of incorporating external datasets, such as energy usage and environmental factors, into Revit models. Data Integration also plays a moderate role in *Building-Level Energy Metering (6.3)* and *Advanced Energy Metering (4.7)*, where the inclusion of external data sources enhances tracking accuracy and compliance.

4.2.4.4 Assessment of Revit Support for LEED EA Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for LEED EA indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study “CS”). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of LEED indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a ‘fraction of 10’) were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 28 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements “DR”) and task-2 (T2: data based on case study “CS”).

Table 28 Aggregate assessment of the Experts for the level of support of Revit for LEED EA indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

Indicators of EA category	Type	Level of Support based on T1-Q1 & T2-Q1		Level of Support based on T1-Q2 & T2-Q2	
		Mean (out of 10)	IQR	Mean (out of 7)	IQR
Fundamental commissioning and verification	<i>Pr</i>	0.0	0.0	1.0	0.0
Minimum energy performance	<i>Pr</i>	9.4	1.0	6.9	0.0
Building-level energy metering	<i>Pr</i>	8.3	1.5	5.8	1.0
Fundamental refrigerant management	<i>Pr</i>	7.1	4.5	5.4	2.5
Enhanced commissioning	<i>Cr</i>	0.6	1.0	1.1	0.0
Optimize Energy Performance	<i>Cr</i>	10.0	0.0	7.0	0.0
Advanced energy metering	<i>Cr</i>	9.0	1.3	5.6	2.3

Demand response	<i>Cr</i>	1.2	2.6	2.0	2.0
Renewable energy production	<i>Cr</i>	9.6	0.0	6.9	0.0
Enhanced refrigerant management	<i>Cr</i>	8.2	2.8	5.9	1.8
Green power and carbon offsets	<i>Cr</i>	1.4	1.9	1.1	0.0

(Legend: *Cr* : Credit , *Pr*: Prerequisite)

To be able to identify aggregated level of support of Revit for the EA indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (**Q2**) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where $\text{mean} \leq 3$. Then also for the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where $\text{mean} \leq 4$.

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the LT indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 28 for **Q1** (mean achievable points out of 10) provide a detailed view of Revit's support level across the various LEED EA indicators. The aggregated data from both Task-1 and Task-2 reveal that Revit demonstrates high support for energy efficiency-related indicators, particularly "Optimize Energy Performance," "Renewable Energy Production," and "Minimum Energy Performance." These indicators achieved mean scores of 10.0, 9.6, and 9.4, respectively, placing them firmly in the high support category with minimal variability, as shown by their low interquartile ranges (IQRs) of 0.0 and 1.0. These high scores indicate strong consensus among experts regarding Revit's capability to support these core energy-focused requirements.

In contrast, indicators that involve more specialized criteria, such as "Fundamental Commissioning and Verification" and "Enhanced Commissioning," received much lower mean scores. For instance, "Fundamental Commissioning and Verification" scored only 0.0 in Q1 and 1.0 in Q2, placing it in the low support category. This suggests that Revit may lack the necessary tools to fully meet the commissioning requirements specified by LEED for these indicators.

For **Q2** (mean level of support out of 7), the results show that Revit's support varies across the LEED EA indicators, with energy efficiency indicators again performing better. "Optimize Energy Performance" and "Minimum Energy Performance" achieved high mean support levels of 7.0 and 6.9, respectively, with no variability (IQR = 0.0), reflecting unanimous agreement among experts that Revit is effective in supporting these indicators. "Renewable Energy Production" also scored highly, with a mean of 6.9 and an IQR of 0.0, reinforcing the strong consensus on Revit's effectiveness in supporting renewable energy objectives.

On the other hand, indicators that demand more complex energy management and specialized systems, such as "Fundamental Refrigerant Management" and "Demand Response," scored significantly lower, with means of 5.4 and 2.0, respectively, and higher IQRs. These scores place them in the moderate to low support categories, suggesting limited functionality within Revit for addressing these particular energy requirements. The moderate scores for indicators like "Building-Level Energy Metering" (mean of 5.8) further indicate that while Revit provides some level of support, it may not be sufficient to fully meet the LEED requirements for these indicators.

Table 29 Aggregated level of support of Revit for LEED EA indicators based on the results of Task-1 and Task2.

INDICATORS of EA category	Type	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
		Mean of (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Fundamental commissioning and verification	<i>Pr</i>	0.0	0.0	LC	1.0	0.0	LC	LC
Minimum energy performance	<i>Pr</i>	9.4	1.0	HC	6.9	0.0	HC	HC
Building-level energy metering	<i>Pr</i>	8.3	1.5	HC	5.8	1.0	HC	HC
Fundamental refrigerant management	<i>Pr</i>	7.1	4.5	MN	5.4	2.5	MN	MN
Enhanced commissioning	<i>Cr</i>	0.6	1.0	LC	1.1	0.0	LC	LC
Optimize Energy Performance	<i>Cr</i>	10.0	0.0	HC	7.0	0.0	HC	HC
Advanced energy metering	<i>Cr</i>	9.0	1.3	HC	5.6	2.3	HN	HN
Demand response	<i>Cr</i>	1.2	2.6	LN	2.0	2.0	LN	LN
Renewable energy production	<i>Cr</i>	9.6	0.0	HC	6.9	0.0	HC	HC
Enhanced refrigerant management	<i>Cr</i>	8.2	2.8	HN	5.9	1.8	HN	HN
Green power and carbon offsets	<i>Cr</i>	1.4	1.9	LC	1.1	0.0	LC	LC

(HC: High with consensus, MC: Moderate with consensus, LC: Moderate with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1** & **Q2**, an aggregated level of support is presented in Table 29. The measurement used to measure the aggregated level of support was mentioned in Figure 14 :*(Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators)* in Section 3.2.3.4 in the Methodology chapter 3.

According to the results of the aggregated level of support presented in Table 29, the indicator "Fundamental Commissioning and Verification" is classified as "Low with Consensus" (LC). With mean scores of 0.0 in Q1 and 1.0 in Q2, and no variability in interquartile ranges (IQRs of 0.0 for both), experts agree that Revit provides minimal support for this indicator, highlighting limitations in addressing fundamental commissioning requirements. Similarly, "Enhanced Commissioning" also has an aggregated level of support classified as "Low with Consensus" (LC), with mean scores of 0.6 in Q1 and 1.1 in Q2, and an IQR of 1.0 and 0.0, respectively. This consensus suggests

that Revit's capabilities are insufficient for meeting enhanced commissioning requirements as specified by LEED.

The indicator "Green Power and Carbon Offsets" also falls under "Low with Consensus" (LC), with mean scores of 1.4 in Q1 and 1.1 in Q2, and an IQR of 1.9 and 0.0, respectively. This strong agreement reflects that Revit offers very limited support for renewable energy credits associated with carbon offsets, indicating a significant gap in functionality. In contrast, "Fundamental Refrigerant Management" is classified as "Moderate with No Consensus" (MN), with mean scores of 7.1 in Q1 and 5.4 in Q2, and higher IQRs of 4.5 and 2.5, respectively. This variability reflects differing expert opinions, suggesting that while support is generally perceived as moderate, there is a lack of consensus on Revit's adequacy in managing refrigerants effectively.

"Advanced Energy Metering" is another indicator classified as "High with No Consensus" (HN). With mean scores of 9.0 in Q1 and 5.6 in Q2, and IQRs of 1.3 and 2.3, respectively, experts recognize Revit's high support level for this criterion but display divided opinions, indicating potential areas where Revit's functionalities could be enhanced to better align with expert expectations.

On the other hand, "Optimize Energy Performance" and "Renewable Energy Production" are classified as "High with Consensus" (HC), with Revit achieving perfect scores of 10.0 and 9.6 in Q1 and nearly perfect scores of 7.0 and 6.9 in Q2, respectively, with no variability (IQR of 0.0 for both metrics). This unanimous expert agreement indicates that Revit is highly capable of supporting the requirements for these energy-focused indicators, making it an effective tool for meeting these specific LEED EA criteria.

4.2.5 Assessment of Revit Support for LEED MR Indicators

The assessment of Revit support for MR indicators are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements “DR” of the indicators), T2: (assessment of Revit Support based on Case study “CS” of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.2.5.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-1 of the Expert Panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each LEED indicator: Q1) “indicate the number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by LEED”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified LEED indicator using a 7-point Likert scale”. Appendix A2-T1 presents the detailed responses of each expert in the Expert Panel for each question in task-1: T1-Q1 and T1-Q2. Table 30 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Material & Resources (MR) category using the two measurements (Q1 and Q2). While Figure 30 provides a graphical representation (radar chart) of the data in Table 30. These two measurements capture the experts’ assessment of Revit’s ability to meet/support the documented requirements (DR) and objectives of each LEED MR indicators.

Table 30 Experts assessment of the level of support of Revit for LEED indicators in the MR category based on the documented requirements (DR) of LEED indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of MR category	Indicator Type	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
			Mean of achievable points (out of max possible points)	Mean of achievable points (out of 10)	Mean level of Support
Storage and collection of recyclables	<i>Pr</i>	10	3.8	3.8	3.0
Construction and demolition waste management	<i>Pr</i>	10	1.8	1.8	2.8
Building life-cycle impact reduction	<i>Cr</i>	2	1.1	5.5	4.5
environmental product declarations	<i>Cr</i>	2	0.7	3.5	2.8
material ingredients	<i>Cr</i>	2	0.5	2.5	2.3
sourcing of raw materials	<i>Cr</i>	2	0.5	2.5	2.3

(Legend: Mean Level of Support: Out Of 7, Cr : Credit, Pr: Prequisite)

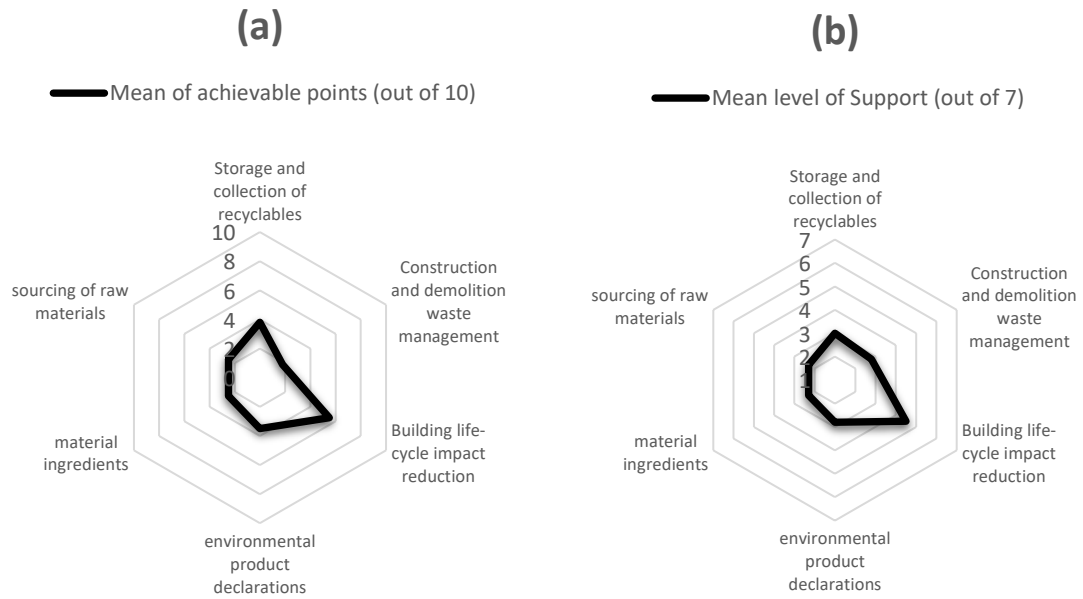


Figure 30 Radar Chart of Expert's assessment of the level of support of Revit for LEED indicators in the MR category based on the documented requirements (DR) of LEED indicators using two measurements (Q1 and Q2)

(a) Mean achievable points-Q1 (out of 10) (b) Mean level of Revit support for the indicator-Q2 (out of 7)

The analysis of Table 30 and Figure 30(a) for **Q1** (the mean achievable points for each indicator in the MR category based on documented requirements) reveals that Revit offers limited support for several LEED Materials and Resources (MR) indicators. Indicators such as "Storage and Collection of Recyclables" and "Building Life-Cycle Impact Reduction" show relatively higher mean achievable points, with scores of 3.8 out of 10 and 1.1 out of 2, respectively. As illustrated in Figure 30(a), these indicators achieve a portion of their potential points, suggesting that Revit provides some capacity to address basic material and resource management requirements within LEED.

In contrast, indicators like "Construction and Demolition Waste Management," "Environmental Product Declarations," and "Sourcing of Raw Materials" have lower mean achievable points, scoring 1.8, 0.7, and 0.5, respectively. This trend, shown in Figure 30(a), suggests that Revit's capabilities may not fully align with the comprehensive tracking and reporting needs for materials and resource use in construction, as outlined by LEED.

Figure 30(b) examines **Q2** (mean level of support on a 7-point scale), further underscoring the variability in Revit's support across MR indicators. Indicators such as "Storage and Collection of Recyclables" and "Building Life-Cycle Impact Reduction" receive relatively higher support ratings, with scores of 3.0 and 4.5, respectively, indicating that Revit provides moderate support for basic recyclable storage and life-cycle assessment, which are foundational components in the MR category.

On the other hand, indicators that require detailed materials tracking, such as "Environmental Product Declarations" and "Sourcing of Raw Materials," score lower on the support scale, with both receiving scores around 2.8 or lower. These low ratings,

particularly for "Material Ingredients" (2.3) and "Sourcing of Raw Materials" (2.3), indicate that Revit may not have the necessary tools to fully address complex material composition and sourcing documentation needs.

4.2.5.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study “CS”

During task-2 of session-1 of the Expert Panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each LEED indicator based on the results of the case study presented to them (CS): Q1) “indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the data of case study presented”, and Q2) “on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the LEED indicator based on the data of case study presented”. Appendix A2-T2 presents the detailed responses of each expert in the Expert Panel for each question in this task. Table 31 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Material & Resources (MR) category using the two measurements (Q1 and Q2). While Figure 32 provides a graphical representation radar chart of the data in Table 31. These two measurements capture the experts’ assessment of Revit’s ability to meet/support LEED requirements for each indicator based on the results of the case study.

Table 31 Experts assessment of the level of support of Revit for LEED indicators in the MR category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of MR category	Indicator Type	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale Mean level of Support
			Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (<i>out of 10</i>)	
Storage and collection of recyclables	<i>Pr</i>	10	2.9	2.9	3.0
Construction and demolition waste management	<i>Pr</i>	10	2.3	2.3	3.0
Building life-cycle impact reduction	<i>Cr</i>	2	1.2	6	4.8
environmental product declarations	<i>Cr</i>	2	0.6	3	1.5
material ingredients	<i>Cr</i>	2	0.5	2.5	1.5
sourcing of raw materials	<i>Cr</i>	2	0.5	2.5	1.8

(Legend: Mean Level of Support: Out Of 7, Cr : Credit, Pr: Prerequisite)

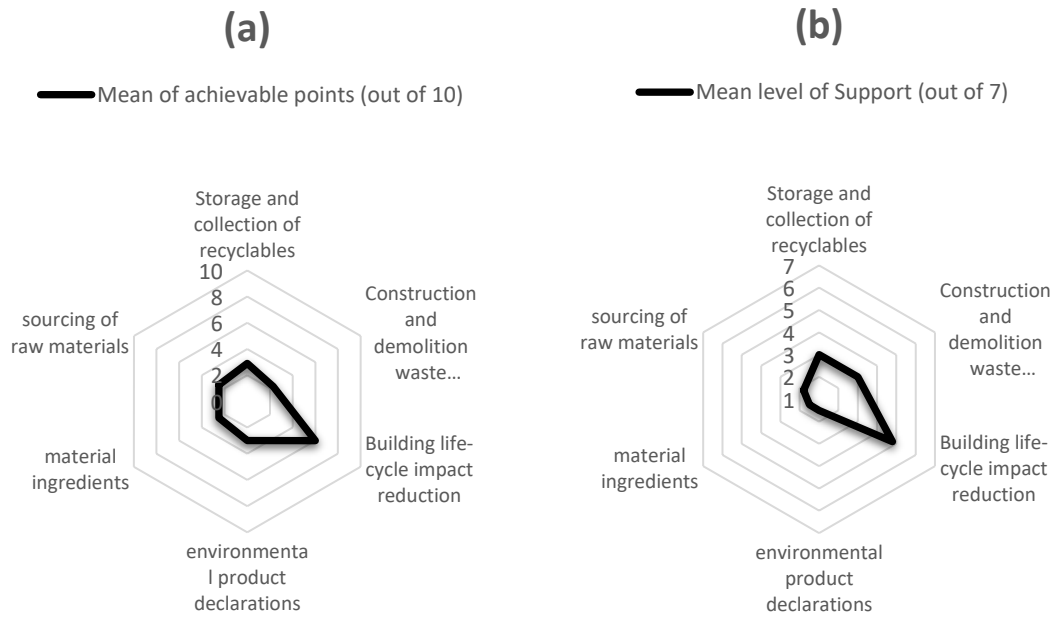


Figure 31 Radar Chart of expert's assessment of the level of support of Revit for LEED indicators in the MR category based on based on the case study (CS) results using two measurements (Q1 and Q2)

(a) Mean Achievable points- Q1 (out of 10) (b) Mean level of Revit support - Q2 (out of 7)

The analysis of Table 31 and Figure 31(a) for **Q1** (the mean achievable points for each indicator in the MR category based on case study results) indicates a range of support provided by Revit for LEED Materials and Resources (MR) indicators. Notably, indicators such as "Storage and Collection of Recyclables" and "Building Life-Cycle Impact Reduction" show relatively higher mean achievable points, with scores of 2.9 out of 10 and 1.2 out of 2, respectively. As depicted in Figure 31(a), these scores suggest that Revit offers some degree of functionality for supporting recyclable storage and conducting life-cycle impact assessments, which are essential in meeting basic LEED MR requirements.

In contrast, indicators like "Environmental Product Declarations," "Material Ingredients," and "Sourcing of Raw Materials" have lower mean achievable points, scoring 0.6, 0.5, and 0.5, respectively. This trend, illustrated in Figure 31(a), suggests that Revit may not have sufficient features to fully address the detailed documentation and reporting needs required for comprehensive material and resource tracking as specified by LEED.

Figure 31(b) further illustrates **Q2** (mean level of support on a 7-point scale), highlighting Revit's variability in supporting different MR indicators. Indicators like "Storage and Collection of Recyclables" and "Building Life-Cycle Impact Reduction" receive relatively higher support ratings, with scores of 3.0 and 4.8, respectively. These scores reflect moderate support for basic storage and life-cycle assessments, which aligns with some of the foundational requirements of the MR category.

However, indicators that involve in-depth materials analysis and documentation, such as "Environmental Product Declarations" and "Material Ingredients," show lower support levels, scoring only 1.5 each. The low ratings for "Material Ingredients" (1.5) and

"Sourcing of Raw Materials" (1.8) indicate that Revit may require additional tools or plugins to meet LEED's detailed materials tracking and sourcing documentation criteria fully.

4.2.5.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-1 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each LEED indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked "to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each LEED indicator using a scale from 1 to 10". A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 32 provides a summary of the experts' assessment of Revit of Mean ranking level for the support of each Media Type for LEED MR indicators in the MR category. While Figure 32 provides a graphical representation (radar chart) of the data in Table 32.

Table 32 Mean ranking level for the support of each Media Type for LEED MR indicator in MR Category.

INDICATOR	Type	Mean Ranking of the support of Revit media channel for LEED			
		TD	M	S	DI
Storage and collection of recyclables	<i>Pr</i>	7	1.7	2.3	3.3
Construction and demolition waste management	<i>Pr</i>	6.3	1.7	0	4
Building life-cycle impact reduction	<i>Cr</i>	6.3	6.3	7	3.7
Building product disclosure and optimization—environmental product declarations	<i>Cr</i>	6	0	0	3.3
Building product disclosure and optimization – material ingredients	<i>Cr</i>	6	0	0	3.3
Building product disclosure and optimization – sourcing of raw materials	<i>Cr</i>	6	0	0	3.3

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration).

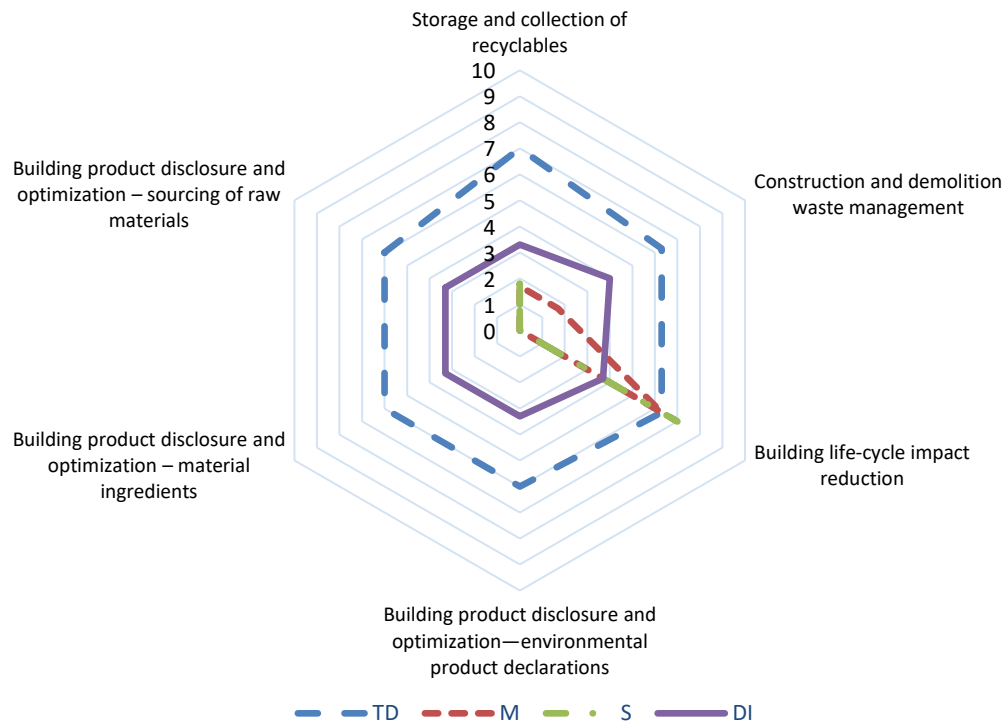


Figure 32 Radar Chart for expert's assessment of Revit Media Channel Support for LEED Indicators in the MR
(TD: text documentation, M: modeling, S: simulation, and DI: data integration).

According to the results in Table 32 and Figure 32, TD (Text Documentation) plays a significant role in supporting various MR (Materials and Resources) indicators. For indicators such as *Storage and Collection of Recyclables* (7.0), *Construction and Demolition Waste Management* (6.3), and *Building Life-Cycle Impact Reduction* (6.3), TD shows moderate to strong support. This reflects its importance in providing descriptive project documentation, compliance records, and sustainability validation within Revit. However, for indicators that focus on detailed material analysis, such as *Building Product Disclosure and Optimization* credits (6.0 for Environmental Product Declarations, Material Ingredients, and Sourcing of Raw Materials), TD provides general support but may require additional data integration or simulation for comprehensive assessments.

M (Modeling) provides limited support in the MR category, as indicated by low scores across most indicators. Modeling shows minimal support in credits such as *Storage and Collection of Recyclables (1.7)* and *Construction and Demolition Waste Management (1.7)*, reflecting that material-focused credits often do not require extensive 3D modeling. This suggests that Revit's modeling tools are less critical for MR indicators compared to text documentation or data integration.

S (Simulation) has a limited role across the MR indicators, as seen by consistently low scores (0 for many indicators). Simulation support is most evident in *Building Life-Cycle Impact Reduction (7.0)*, where performance-based evaluations can benefit from Revit's simulation tools to assess long-term impacts on materials and resource efficiency. For most MR credits, simulation is less applicable, highlighting the fact that MR indicators typically do not require in-depth simulation.

DI (Data Integration) shows moderate support in indicators requiring external data or verification, such as *Storage and Collection of Recyclables (3.3)*, *Construction and Demolition Waste Management (4.0)*, and *Building Life-Cycle Impact Reduction (3.7)*. These results reflect the role of integrating external data sources in Revit to enhance sustainability assessments for certain MR credits. For indicators like *Building Product Disclosure and Optimization (3.3 for Environmental Product Declarations, Material Ingredients, and Sourcing of Raw Materials)*, DI supports sustainability objectives by enabling the inclusion of third-party product information, contributing to comprehensive material resource evaluation.

4.2.5.4 Assessment of Revit Support for LEED MR Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for LEED MR indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study “CS”). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of LEED indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a ‘fraction of 10’) were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 33 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements “DR”) and task-2 (T2: data based on case study “CS”).

To be able to identify aggregated level of support of Revit for the MR indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (**Q2**) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where mean ≤ 3 . Then also for the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where mean ≤ 4 .

Table 33 Aggregate assessment of the Experts for the level of support of Revit for LEED MR indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS)

Indicators of MR category	Indicator Type	Level of Support based on T1-Q1 & T2-Q1		Level of Support based on T1-Q2 & T2-Q2	
		Mean (out of 10)	IQR	Mean (out of 7)	IQR
Storage and collection of recyclables	<i>Pr</i>	3.3	2.6	3.0	2.0
Construction and demolition waste management	<i>Pr</i>	2.0	2.5	2.9	2.0
Building life-cycle impact reduction	<i>Cr</i>	5.8	1.5	4.6	1.0
environmental product declarations	<i>Cr</i>	3.1	3.8	2.1	0.5
material ingredients	<i>Cr</i>	2.5	5.0	1.9	1.3
sourcing of raw materials	<i>Cr</i>	2.5	5.0	2.0	2.0

(Legend: *Cr* : Credit , *Pr*: Prerequisite)

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the LT indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 33 for **Q1** (mean achievable points out of 10) provide a detailed view of Revit's support level across the various LEED MR indicators. The aggregated data from both Task-1 and Task-2 reveal that Revit demonstrates low support for material resource management indicators, particularly "Storage and Collection of Recyclables" and "Construction and Demolition Waste Management." These indicators achieved mean scores of 3.3 and 2.0, respectively, placing them firmly in the low support category with considerable variability, as shown by their high interquartile ranges (IQRs) of 2.6 and 2.5. These low scores indicate a lack of consensus among experts regarding Revit's ability to effectively support these waste and recycling-focused requirements.

In contrast, indicators that address broader environmental impacts, such as "Building Life-Cycle Impact Reduction," received moderate support. For instance, "Building Life-Cycle Impact Reduction" scored 5.8 in Q1 and 4.6 in Q2, placing it in the moderate support category with relatively low IQRs of 1.5 and 1.0, respectively. This consensus suggests that Revit provides a consistent, though limited, level of functionality for life-cycle impact considerations in material resource management.

For **Q2** (mean level of support out of 7), the results show that Revit's support varies across the LEED MR indicators. "Building Life-Cycle Impact Reduction" achieved a moderate mean support level of 4.6, with minimal variability (IQR = 1.0), reflecting general agreement among experts that Revit offers some support for this indicator. On the other hand, indicators that demand specific documentation of material characteristics, such as "Environmental Product Declarations" and "Material Ingredients," scored much lower, with means of 2.1 and 1.9, respectively, and higher IQRs. These low scores place them in the low support category, suggesting limited functionality within Revit for these documentation-related requirements. The low scores for indicators like "Sourcing of Raw Materials" (mean of 2.5) further indicate that while Revit provides a minimal level of support, it may not be sufficient to fully meet the LEED requirements for these material sourcing indicators.

Lastly to measure the consensus from the two questions **Q1 & Q2**, an aggregated level of support is presented in Table 34. The measurement used to measure the aggregated level of support was mentioned in Figure 14 :*(Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators)* in Section 3.2.3.4 in the Methodology chapter 3.

Table 34 Aggregated level of support of Revit for LEED MR indicators based on the results of Task-1 and Task2.

Indicators of MR category	Type	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
		Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Storage and collection of recyclables	<i>Pr</i>	3.3	2.6	LN	3.0	2.0	LN	LN
Construction and demolition waste management	<i>Pr</i>	2.0	2.5	LN	2.9	2.0	LN	LN
Building life-cycle impact reduction	<i>Cr</i>	5.8	1.5	MC	4.6	1.0	MC	MC
environmental product declarations	<i>Cr</i>	3.1	3.8	LN	2.1	0.5	LC	LN
material ingredients	<i>Cr</i>	2.5	5.0	LN	1.9	1.3	LN	LN
sourcing of raw materials	<i>Cr</i>	2.5	5.0	LN	2.0	2.0	LN	LN

(HC: High with consensus, MC: Moderate with consensus, LC: Moderate with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

According to the results of the aggregated level of support presented in Table 34, the indicator "Storage and Collection of Recyclables" is classified as "Low with No Consensus" (LN). With mean scores of 3.3 in Q1 and 3.0 in Q2, and high interquartile ranges (IQRs) of 2.6 and 2.0, respectively, experts demonstrate varying opinions on Revit's ability to support this prerequisite, indicating limitations in addressing requirements for recycling management effectively.

Similarly, "Construction and Demolition Waste Management" also has an aggregated level of support classified as "Low with No Consensus" (LN), with mean scores of 2.0 in Q1 and 2.9 in Q2, and IQRs of 2.5 and 2.0, respectively. This lack of consensus suggests that while Revit provides some functionality, its capability to support construction waste management remains limited and inconsistent.

The indicator "Building Life-Cycle Impact Reduction" is classified as "Moderate with Consensus" (MC), with mean scores of 5.8 in Q1 and 4.6 in Q2, and lower IQRs of 1.5 and 1.0, respectively. This consensus reflects a moderate level of support, indicating that Revit

is able to meet some of the LEED requirements for life-cycle impact considerations, though it may still fall short in fully addressing them.

"Environmental Product Declarations" is categorized as "Low with No Consensus" (LN), with mean scores of 3.1 in Q1 and 2.1 in Q2, and IQRs of 3.8 and 0.5, respectively. This variability in expert responses suggests differing perspectives on Revit's effectiveness in supporting environmental product declarations, highlighting limitations in Revit's capabilities for documenting material impacts.

The indicators "Material Ingredients" and "Sourcing of Raw Materials" are also classified as "Low with No Consensus" (LN). With mean scores of 2.5 in Q1 for both indicators and similarly low scores of 1.9 and 2.0 in Q2, paired with high IQRs of 5.0 and 2.0, respectively, these scores reflect broad expert disagreement and limited support from Revit in addressing material ingredient transparency and sustainable sourcing requirements as specified by LEED.

4.2.6 Assessment of Revit Support for LEED IEQ Indicators

The assessment of Revit support for IEQ indicators are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements "DR" of the indicators), T2: (assessment of Revit Support based on Case study "CS" of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.2.6.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-1 of the Expert Panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each LEED indicator: Q1) “indicate the number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by LEED”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified LEED indicator using a 7-point Likert scale”. Appendix A2-T1 presents the detailed responses of each expert in the Expert Panel for each question in task-1: T1-Q1 and T1-Q2. Table 35 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Indoor Environmental Quality (IEQ) category using the two measurements (Q1 and Q2). While Figure 33 provides a graphical representation (radar chart) of the data in Table 35. These two measurements capture the experts’ assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each LEED IEQ indicators.

Table 35 Experts assessment of the level of support of Revit for LEED indicators in the IEQ category based on the documented requirements (DR) of LEED indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of IEQ category	Indicator Type	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale Mean level of Support
			Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (out of 10)	
Minimum indoor air quality performance	<i>Pr</i>	10	8.5	10.0	6.3
Environmental tobacco smoke control	<i>Pr</i>	10	6.0	10.0	4.8
Enhanced indoor air quality strategies	<i>Cr</i>	2	0.1	0.5	1.3
Low-emitting materials	<i>Cr</i>	3	1.6	5.3	4.3

Construction indoor air quality management plan	Cr	1	0.1	1.0	1.0
Indoor air quality assessment	Cr	2	1.0	5.0	2.5
Thermal comfort	Cr	1	1.0	10.0	6.8
Interior lighting	Cr	2	1.9	9.5	6.5
Daylight	Cr	3	2.8	9.3	6.8
Quality views	Cr	1	1.0	10.0	6.5
Acoustic performance	Cr	1	0.9	9.0	6.5

(Legend: Mean Level of Support: Out Of 7 , Cr : Credit , Pr: Prerequisite)

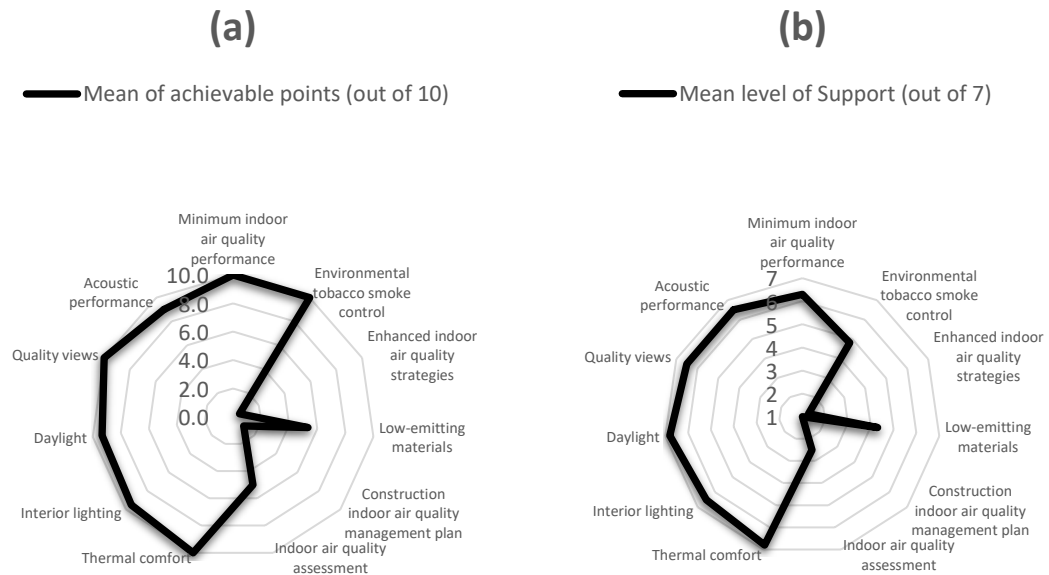


Figure 33 Radar Chart of Expert's assessment of the level of support of Revit for LEED indicators in the IEQ category based on the documented requirements (DR) of LEED indicators using two measurements (Q1 and Q2)

(a) Mean achievable points-Q1 (out of 10) (b) Mean level of Revit support for the indicator-Q2 (out of 7)

The analysis of Table 35 and Figure 33(a) for **Q1** (the mean achievable points for each indicator in the Indoor Environmental Quality (IEQ) category based on documented requirements) shows that Revit provides substantial support for several LEED IEQ indicators. Indicators like "Minimum Indoor Air Quality Performance," "Thermal Comfort," and "Daylight" exhibit high mean achievable points, scoring 8.5 out of 10, 1.0 out of 1.0, and 2.8 out of 3.0, respectively. These high scores, as shown in Figure 33(a), suggest that Revit aligns well with core indoor air quality and comfort requirements, offering effective tools for ensuring these basic LEED IEQ standards.

In contrast, indicators like "Enhanced Indoor Air Quality Strategies" and "Construction Indoor Air Quality Management Plan" show notably lower mean achievable points, with scores of 0.1 each. This trend, highlighted in Figure 33(a), indicates that Revit's tools may not fully support the comprehensive measures and strategies required for enhanced indoor air quality management, pointing to areas for potential improvement.

Figure 33(b) provides insights into **Q2** (mean level of support on a 7-point scale), further reflecting Revit's variability in supporting different IEQ indicators. Indicators such as "Thermal Comfort," "Daylight," and "Quality Views" score high, with mean levels of support of 6.8, 6.8, and 6.5, respectively, as shown in Figure 33(b). These scores indicate that Revit provides strong support for indicators focused on comfort and environmental quality, aiding users in meeting key IEQ goals.

Conversely, indicators requiring specific air quality strategies, such as "Enhanced Indoor Air Quality Strategies" and "Construction Indoor Air Quality Management Plan," show lower support levels, with scores of 1.3 and 1.0, respectively. The lower scores for "Indoor

Air Quality Assessment" (2.5) and "Environmental Tobacco Smoke Control" (4.8) further highlight Revit's limited capacity to handle comprehensive air quality measures, reinforcing the need for additional features to fully address these criteria.

4.2.6.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study "CS"

During task-2 of session-1 of the Expert Panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each LEED indicator based on the results of the case study presented to them (CS): Q1) "indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the data of case study presented", and Q2) "on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the LEED indicator based on the data of case study presented". Appendix A2-T2 presents the detailed responses of each expert in the Expert Panel for each question in this task. Table 36 provides a summary of the experts' assessment of Revit support/coverage for each indicator in the Indoor Environmental Quality (IEQ) category using the two measurements (Q1 and Q2). While Figure 34 provides a graphical representation radar chart of the data in Table 36. These two measurements capture the experts' assessment of Revit's ability to meet/support LEED requirements for each indicator based on the results of the case study.

Table 36 Experts assessment of the level of support of Revit for LEED indicators in the IEQ category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of IEQ category	Indicator Type	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale Mean level of Support
			Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (out of 10)	
Minimum indoor air quality performance	<i>Pr</i>	<i>10</i>	9.0	9.0	6.5
Environmental tobacco smoke control	<i>Pr</i>	<i>10</i>	7.5	7.5	5.5
Enhanced indoor air quality strategies	<i>Cr</i>	<i>2</i>	0.0	0.0	1.0
Low-emitting materials	<i>Cr</i>	<i>3</i>	1.6	5.3	4.3
Construction indoor air quality management plan	<i>Cr</i>	<i>1</i>	0.1	1.0	1.0
Indoor air quality assessment	<i>Cr</i>	<i>2</i>	0.8	4.0	3.0
Thermal comfort	<i>Cr</i>	<i>1</i>	1.0	10.0	7.0
Interior lighting	<i>Cr</i>	<i>2</i>	2.0	10.0	6.8
Daylight	<i>Cr</i>	<i>3</i>	3.0	10.0	6.8
Quality views	<i>Cr</i>	<i>1</i>	0.9	9.0	6.8
Acoustic performance	<i>Cr</i>	<i>1</i>	1.0	10.0	6.3

(Legend: Mean Level of Support: Out Of 7 , Cr : Credit , Pr: Prerequisite)

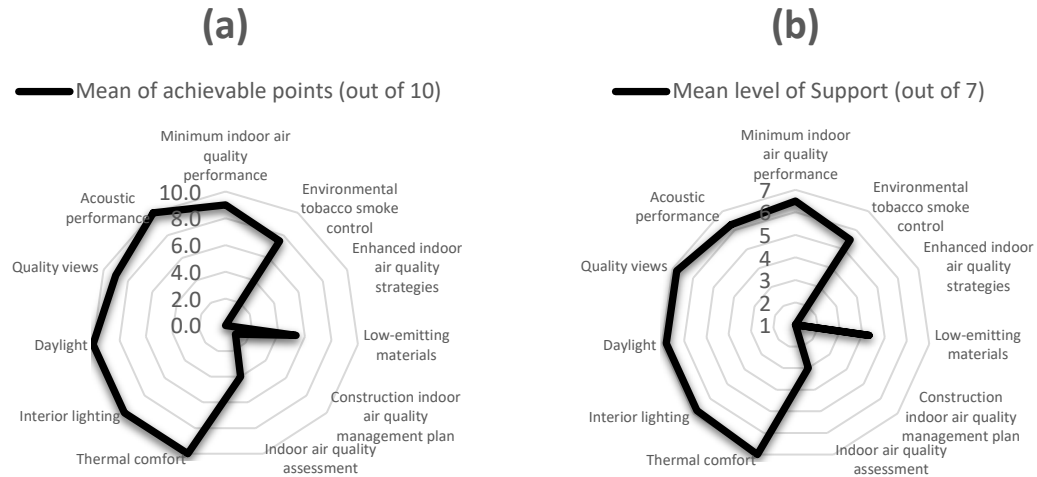


Figure 34 Radar Chart of expert's assessment of the level of support of Revit for LEED indicators in the IEQ category based on based on the case study (CS) results using two measurements (Q1 and Q2)

(a) Mean Achievable points- Q1 (out of 10) (b) Mean level of Revit support - Q2 (out of 7)

The analysis of Table 36 and Figure 34(a) for Q1 (the mean achievable points for each indicator in the Indoor Environmental Quality (IEQ) category based on case study results) demonstrates that Revit provides strong support for several LEED IEQ indicators. Indicators like "Minimum Indoor Air Quality Performance," "Thermal Comfort," and "Daylight" show high mean achievable points, scoring 9.0 out of 10, 1.0 out of 1.0, and 3.0 out of 3.0, respectively. As depicted in Figure 34(a), these high scores indicate that Revit's tools align effectively with core indoor environmental quality requirements, helping users meet essential LEED IEQ standards for air quality, thermal comfort, and natural lighting.

In contrast, some indicators, such as "Enhanced Indoor Air Quality Strategies" and "Construction Indoor Air Quality Management Plan," show notably lower mean achievable points, scoring 0.0 and 0.1, respectively. This trend, shown in Figure 34(a), suggests that

Revit's functionality may not fully address the detailed strategies required for enhanced indoor air quality management and construction-phase air quality planning.

Figure 34(b) offers insights into **Q2** (mean level of support on a 7-point scale), which further highlights Revit's variability in supporting different IEQ indicators. Indicators focused on thermal comfort and lighting, including "Thermal Comfort," "Interior Lighting," and "Daylight," receive high support levels, scoring 7.0, 6.8, and 6.8, respectively, as illustrated in Figure 34(b). These scores suggest that Revit is well-suited to support indicators related to occupant comfort and environmental quality, providing users with valuable tools for these LEED criteria.

On the other hand, indicators requiring specialized air quality strategies, such as "Enhanced Indoor Air Quality Strategies" and "Construction Indoor Air Quality Management Plan," show low support ratings, with scores of 1.0 each. The lower support scores for "Indoor Air Quality Assessment" (3.0) and "Environmental Tobacco Smoke Control" (5.5) further reinforce the limitations in Revit's ability to handle comprehensive indoor air quality and control measures.

4.2.6.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-1 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each LEED indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked "to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each LEED indicator

using a scale from 1 to 10”. A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 37 provides a summary of the experts’ assessment of Revit of Mean ranking level for the support of each Media Type for LEED IEQ indicators in the IEQ category. While Figure 35 provides a graphical representation (radar chart) of the data in Table 37.

Table 37 Mean ranking level for the support of each Media Type for LEED IEQ indicator in IEQ category.

INDICATOR	Type	Mean Ranking of the support of Revit media channel for LEED			
		TD	M	S	DI
Minimum indoor air quality performance	<i>Pr</i>	4.7	7	8	3.7
Environmental tobacco smoke control	<i>Pr</i>	4.3	2.7	4.3	4
Enhanced indoor air quality strategies	<i>Cr</i>	5	1.7	4.7	1.7
Low-emitting materials	<i>Cr</i>	6.7	0	0	4.3
Construction indoor air quality management plan	<i>Cr</i>	4.3	0	0	2.7
Indoor air quality assessment	<i>Cr</i>	4	1.7	5	1.3
Thermal comfort	<i>Cr</i>	5	5	7	3.7
Interior lighting	<i>Cr</i>	5.7	7.7	8	4.3
Daylight	<i>Cr</i>	3	5.7	5.7	2.3
Quality views	<i>Cr</i>	2.7	5	8	1.7
Acoustic performance	<i>Cr</i>	4	5.3	6.7	3

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration).

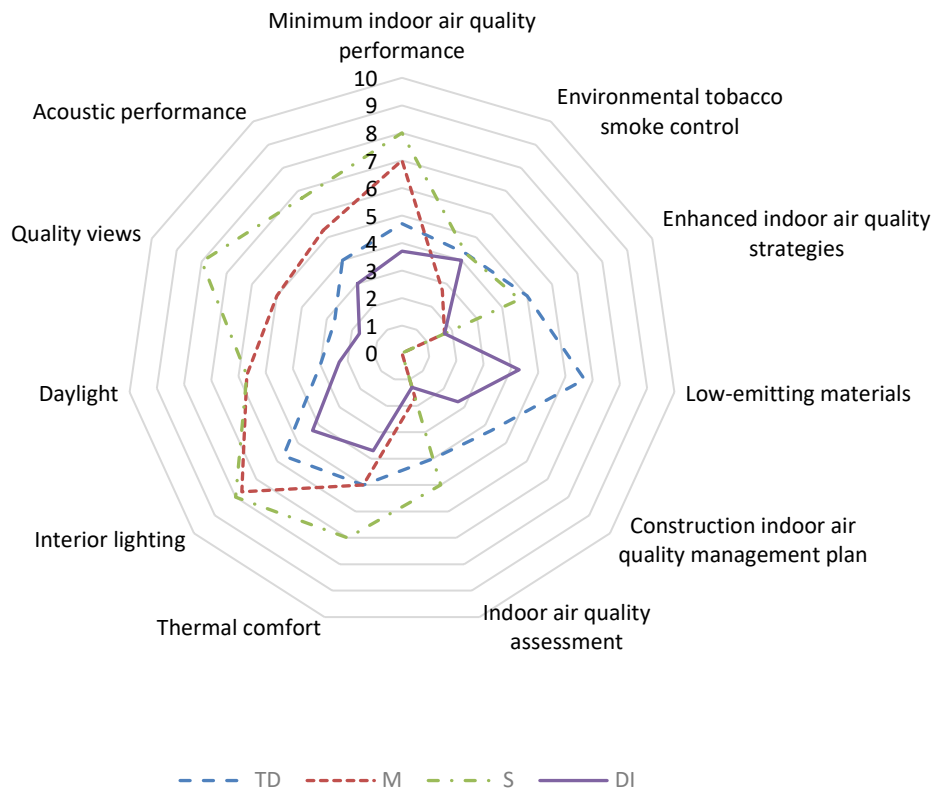


Figure 35 Radar Chart for expert's assessment of Revit Media Channel Support for LEED Indicators in the IEQ (TD: text documentation, M: modeling, S: simulation, and DI: data integration).

According to the results in Table 37 and Figure 35, TD (Text Documentation) plays a supportive role across several IEQ (Indoor Environmental Quality) indicators. For instance, indicators like *Low-Emitting Materials* (6.7), *Enhanced Indoor Air Quality Strategies* (5.0), and *Interior Lighting* (5.7) show moderate support from TD. This reflects the role of detailed documentation in Revit for compliance reporting and validating strategies aimed at enhancing indoor environmental quality. However, TD's role is secondary in more complex indicators, such as *Quality Views* (2.7) and *Daylight* (3.0), where more advanced modeling and simulation methods are required to achieve optimal design.

M (Modeling) demonstrates high support for visually-oriented and spatially complex IEQ indicators. Indicators like *Interior Lighting (7.7)* and *Minimum Indoor Air Quality Performance (7.0)* benefit from Revit's 3D modeling capabilities, which enable accurate visualization and layout planning. Modeling also shows moderate support for *Thermal Comfort (5.0)* and *Quality Views (5.0)*, underscoring Revit's role in creating detailed models to support visual and environmental design objectives in IEQ. Lower scores in indicators such as *Construction Indoor Air Quality Management Plan (0)* reflect that these credits rely less on modeling and more on documentation and planning.

S (Simulation) plays a critical role in indicators requiring performance-based evaluations, such as *Minimum Indoor Air Quality Performance (8.0)*, *Interior Lighting (8.0)*, and *Quality Views (8.0)*. Revit's simulation tools are essential for dynamic assessments, particularly for indicators focused on environmental performance and occupant comfort. The data in Table 37 and Figure 35 suggest that simulation is especially valuable for indicators involving air quality and lighting, although it is less applicable for documentation-heavy indicators, such as *Construction Indoor Air Quality Management Plan (0)*.

DI (Data Integration) shows moderate support for several IEQ indicators where external data can enhance design accuracy. Indicators like *Interior Lighting (4.3)*, *Low-Emitting Materials (4.3)*, and *Thermal Comfort (3.7)* benefit from data integration in Revit to incorporate material specifications, lighting standards, and environmental data. Data Integration plays a lesser role for simpler indicators like *Indoor Air Quality Assessment (1.3)* and *Daylight (2.3)*, where Revit's built-in tools are typically sufficient without extensive external data.

4.2.6.4 Assessment of Revit Support for LEED IEQ Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for LEED IEQ indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study “CS”). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of LEED indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a ‘fraction of 10’) were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 38 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements “DR”) and task-2 (T2: data based on case study “CS”).

Table 38 Aggregate assessment of the Experts for the level of support of Revit for LEED IEQ indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

Indicators of IEQ category	Indicator Type	Level of Support based on T1-Q1 & T2-Q1		Level of Support based on T1-Q2 & T2-Q2	
		Mean (out of 10)	IQR	Mean (out of 7)	IQR
Minimum indoor air quality performance	<i>Pr</i>	8.75	2.0	6.4	1.0
Environmental tobacco smoke control	<i>Pr</i>	6.75	2.3	5.1	1.3
Enhanced indoor air quality strategies	<i>Cr</i>	0.13	0.0	1.1	0.0
Low-emitting materials	<i>Cr</i>	5.44	2.4	4.3	0.3
Construction indoor air quality management plan	<i>Cr</i>	0.94	1.4	1.0	0.0

Indoor air quality assessment	<i>Cr</i>	4.56	0.3	2.8	1.0
Thermal comfort	<i>Cr</i>	10.00	0.0	6.9	0.0
Interior lighting	<i>Cr</i>	9.56	0.3	6.6	1.0
Daylight	<i>Cr</i>	9.50	0.2	6.8	0.3
Quality views	<i>Cr</i>	9.63	0.0	6.6	1.0
Acoustic performance	<i>Cr</i>	9.38	0.5	6.4	1.0

(Legend: *Cr* : Credit , *Pr*: Prerequisite)

To be able to identify aggregated level of support of Revit for the IEQ indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (**Q2**) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where mean ≤ 3 . Then also for the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where mean ≤ 4 .

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the LT indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 38 for **Q1** (mean achievable points out of 10) provide a detailed view of Revit's support level across the various LEED IEQ indicators. The aggregated data from both Task-1 and Task-2 reveal that Revit demonstrates high support for indoor environmental quality indicators, particularly "Thermal Comfort," "Daylight," and "Quality Views." These indicators achieved mean scores of 10.0, 9.5, and 9.63, respectively, placing them firmly in the high support category with minimal variability, as shown by their low interquartile ranges (IQRs) of 0.0, 0.2, and

0.0. These high scores indicate strong consensus among experts regarding Revit's capability to support these essential comfort-focused requirements.

In contrast, indicators that involve more complex air quality management and material emissions considerations, such as "Enhanced Indoor Air Quality Strategies" and "Construction Indoor Air Quality Management Plan," received much lower mean scores. For example, "Enhanced Indoor Air Quality Strategies" scored only 0.13, and "Construction Indoor Air Quality Management Plan" scored 0.94, placing them in the low support category. This suggests that Revit may lack the tools necessary to fully address these advanced indoor air quality measures within the LEED IEQ category.

For **Q2** (mean level of support out of 7), the results show that Revit's support varies significantly across the LEED IEQ indicators, with comfort-focused indicators again performing better. "Thermal Comfort" and "Daylight" achieved high mean support levels of 6.9 and 6.8, respectively, with no variability (IQR = 0.0 for "Thermal Comfort" and 0.3 for "Daylight"), reflecting unanimous agreement among experts that Revit is effective in supporting these indicators. "Interior Lighting" also scored highly, with a mean of 6.6 and an IQR of 1.0.

On the other hand, indicators that demand more specialized air quality and emissions control, such as "Environmental Tobacco Smoke Control" and "Low-Emitting Materials," scored moderately, with means of 5.1 and 4.3, respectively, and slightly higher IQRs. These moderate scores indicate that while Revit provides some level of support, it may not be sufficient to fully meet the LEED requirements for these air quality and emissions indicators. The low scores for indicators like "Indoor Air Quality Assessment" (mean of

4.56) further indicate that while Revit offers partial functionality, additional improvements would be needed to align fully with LEED IEQ standards.

Table 39 Aggregated level of support of Revit for LEED IEQ indicators based on the results of Task-1 and Task2.

Indicators of IEQ category	Type	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
		Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Minimum indoor air quality performance	<i>Pr</i>	8.8	2.0	HC	6.4	1.0	HC	HC
Environmental tobacco smoke control	<i>Pr</i>	6.8	2.3	MN	5.1	1.3	MN	MN
Enhanced indoor air quality strategies	<i>Cr</i>	0.1	0.0	LC	1.1	0.0	LC	LC
Low-emitting materials	<i>Cr</i>	5.1	2.4	MN	4.3	0.3	MC	MN
Construction indoor air quality management plan	<i>Cr</i>	0.9	1.4	LC	1.0	0.0	LC	LC
Indoor air quality assessment	<i>Cr</i>	4.6	0.3	MC	2.8	1.0	LC	Inconsistent with agreement
Thermal comfort	<i>Cr</i>	10.0	0.0	HC	6.9	0.0	HC	HC
Interior lighting	<i>Cr</i>	9.6	0.3	HC	6.6	1.0	HC	HC
Daylight	<i>Cr</i>	9.5	0.2	HC	6.8	0.3	HC	HC
Quality views	<i>Cr</i>	9.6	0.0	HC	6.6	1.0	HC	HC
Acoustic performance	<i>Cr</i>	9.4	0.5	HC	6.4	1.0	HC	HC

(HC: High with consensus, MC: Moderate with consensus, LC: Moderate with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1 & Q2**, an aggregated level of support is presented in Table 39. The measurement used to measure the aggregated level of support was mentioned in Figure 14 : (Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators) in Section 3.2.3.4 in the Methodology chapter 3.

According to the results of the aggregated level of support presented in Table 39, the indicator "Minimum Indoor Air Quality Performance" is classified as "High with consensus" (HC). With mean scores of 8.8 in Q1 and 6.4 in Q2, and interquartile ranges (IQRs) of 2.0 and 1.0, respectively, experts agree that Revit provides substantial support for this prerequisite, effectively addressing indoor air quality standards.

Similarly, "Thermal Comfort" also has an aggregated level of support classified as "High with consensus" (HC), with mean scores of 10.0 in Q1 and 6.9 in Q2, and no variability (IQR of 0.0 for both metrics). This strong agreement reflects Revit's comprehensive support for thermal comfort criteria, underscoring its capability in meeting this essential indoor environmental quality requirement.

The indicator "Enhanced Indoor Air Quality Strategies" falls under "Low with consensus" (LC), with mean scores of 0.1 in Q1 and 1.1 in Q2, both with no variability (IQR of 0.0). This unanimous agreement highlights Revit's limited functionality in supporting advanced air quality measures, indicating a significant gap for this credit.

Indicators such as "Daylight" and "Quality Views" are also classified as "High with consensus" (HC). With mean scores of 9.5 and 9.6 in Q1, and nearly perfect scores of 6.8 and 6.6 in Q2, respectively, both with low IQRs (0.2 and 0.0), experts show strong consensus that Revit is highly effective in supporting these visual and lighting-related indicators within the LEED IEQ category.

On the other hand, indicators related to material emissions control, such as "Low-Emitting Materials," are classified as "Moderate with No Consensus" (MN). With mean scores of 5.1 in Q1 and 4.3 in Q2, and IQRs of 2.4 and 0.3, respectively, experts have varying opinions on Revit's adequacy for this indicator, indicating moderate support but without complete consensus.

The "Indoor Air Quality Assessment" indicator, which shows a mean of 4.6 in Q1 (classified as Moderate with consensus) but a lower mean of 2.8 in Q2 (classified as Low

with consensus), is designated as Inconsistent with agreement, reflecting a discrepancy in Revit's support level as perceived across these two metrics.

4.2.7 Assessment of Revit Support for LEED IP Indicators

The assessment of Revit support for IP indicators are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements “DR” of the indicators), T2: (assessment of Revit Support based on Case study “CS” of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.2.7.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-1 of the Expert Panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each LEED indicator: Q1) “indicate the number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by LEED”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified LEED indicator using a 7-point Likert scale”. Appendix A2-T1 presents the detailed responses of each expert in the Expert Panel for each question in task-1: T1-Q1 and T1-Q2. Table 40 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Integrative Process (IP) category using the two measurements (Q1 and Q2). These two

measurements capture the experts' assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each LEED IP indicators.

Table 40 Experts assessment of the level of support of Revit for LEED indicators in the IP category based on the documented requirements (DR) of LEED indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of IP category	Indicator Type	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
			Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (out of 10)	Mean level of Support
Integrative Process	<i>Cr</i>	<i>1</i>	1.0	10.0	6.0

(Legend: Mean Level of Support: Out Of 7 , Cr : Credit , Pr: Prerequisite)

The analysis of Table 40 for **Q1** (the mean achievable points for the Integrative Process (IP) category based on documented requirements) indicates that Revit offers robust support for this LEED indicator. The "Integrative Process" indicator achieves a full score of 1.0 out of 1.0 in mean achievable points, suggesting that Revit's tools are well-aligned with the LEED requirements for supporting an integrative design approach.

Regarding **Q2** (mean level of support on a 7-point scale), Revit shows a high support level of 6.0, reinforcing its capability to facilitate an integrative process that brings together various disciplines to achieve sustainability goals. This high level of support reflects Revit's strength in enabling collaborative design practices, providing architects and designers with effective tools that align well with LEED's integrative process objectives.

4.2.7.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study “CS”

During task-2 of session-1 of the Expert Panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each LEED indicator based on the results of the case study presented to them (CS): Q1) “indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the data of case study presented”, and Q2) “on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the LEED indicator based on the data of case study presented”. Appendix A2-T2 presents the detailed responses of each expert in the Expert Panel for each question in this task. Table 41 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Integrative Process (IP) category using the two measurements (Q1 and Q2). These two measurements capture the experts’ assessment of Revit’s ability to meet/support LEED requirements for each indicator based on the results of the case study.

Table 41 Experts assessment of the level of support of Revit for LEED indicators in the IP category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of IP category	Indicator Type	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale Mean level of Support
			Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (out of 10)	
Integrative Process	Cr	1	1.0	10.0	6.5

(Legend: Mean Level of Support: Out Of 7 , Cr : Credit , Pr: Prerequisite)

The analysis of Table 41 for **Q1** (the mean achievable points for the Integrative Process (IP) category based on case study results) demonstrates that Revit provides excellent

support for this LEED indicator. The "Integrative Process" indicator achieves a full score of 1.0 out of 1.0 in mean achievable points, indicating that Revit's functionality aligns closely with the requirements for promoting an integrative design approach as outlined by LEED.

In terms of **Q2** (mean level of support on a 7-point scale), Revit achieves a high support level of 6.5, further underscoring its effectiveness in facilitating an integrative process. This high score reflects Revit's capability to support collaborative design practices that bring together multiple disciplines to meet sustainability objectives effectively.

4.2.7.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-1 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each LEED indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked "to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each LEED indicator using a scale from 1 to 10". A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 42 provides a summary of the experts' assessment of Revit of Mean ranking level for the support of each Media Type for LEED IP indicators in the IP category.

Table 42 Mean ranking level for the support of each Media Type Support for LEED IP indicator .

INDICATOR	Mean Ranking of the support of Revit media channel for LEED			
	TD	M	S	DI
Integrative Process	5.7	4	2.3	8.7

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration).

Table 42 provides a detailed analysis of the media types used in Revit to support the Integrative Process indicator in the LEED IP category. The media types evaluated in the table are Text Documentation (TD), Modeling (M), Simulation (S), and Data Integration (DI). Each media type is ranked out of 10 based on its contribution to supporting the respective indicator.

TD (Text Documentation) plays a significant role in supporting the Integrative Process indicator, with a score of 5.7. This highlights the importance of documenting the integrative design process in detail, where textual descriptions of interdisciplinary collaboration and project goals are crucial for achieving this credit. TD provides the narrative and justifications needed to explain the methods and strategies used in the integrative process, making it a vital component for this indicator.

M (Modeling) plays a moderate role in the Integrative Process indicator, scoring 4.0. This reflects the usefulness of 3D models in visualizing how different systems, designs, and strategies are integrated into the project. Modeling helps stakeholders understand spatial relationships, energy flows, and the overall impact of design decisions, supporting collaborative efforts across disciplines. However, it is not the most critical media type for this indicator compared to TD and DI.

S (Simulation) has a relatively minor role in supporting the Integrative Process, with a score of 2.3. While simulations can provide useful data to inform decision-making during the integrative process, their contribution is less significant compared to other media types. The focus of this indicator is more on collaboration and integration rather than performance-based outcomes, which explains the lower reliance on simulations.

DI (Data Integration) is the most critical media type for the Integrative Process, scoring 8.7. This emphasizes the importance of integrating external data sources, such as environmental analysis, energy performance metrics, or GIS data, into Revit models to support the integrative design process. DI facilitates a holistic approach by allowing data from various disciplines to be integrated and analyzed together, making it a key tool for achieving the LEED IP credit.

In summary, Data Integration (DI) plays the most important role in supporting the Integrative Process indicator, reflecting the need for a collaborative approach that integrates multiple data sources. Text Documentation (TD) also plays a significant role in documenting the interdisciplinary efforts required for the credit, while Modeling (M) provides a useful but secondary support. Simulation (S) has a minor role, indicating that the focus of this credit is more on collaboration and integration rather than performance evaluation. Table 39 highlights the varying levels of importance for each media type, emphasizing the collaborative nature of the Integrative Process credit in LEED.

4.2.7.4 Assessment of Revit Support for LEED IP Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for LEED IP indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the

indicators) and Task -2 of (i.e. assessment based on Case study “CS”). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of LEED indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a ‘fraction of 10’) were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 43 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements “DR”) and task-2 (T2: data based on case study “CS”).

Table 43 Aggregate assessment of the Experts for the level of support of Revit for LEED IP indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

Indicators of IP category	Indicator Type	Level of Support based on T1- Q1 & T2- Q1		Level of Support based on T1- Q2 & T2- Q2	
		Mean (out of 10)	IQR	Mean (out of 7)	IQR
Integrative Process	<i>Cr</i>	10.0	0.0	6.3	1.0

(Legend: *Cr* : Credit , *Pr*: Prerequisite)

To be able to identify aggregated level of support of Revit for the IP indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (**Q2**) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where mean ≤ 3 . Then also for the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where mean ≤ 4 .

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the LT indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 43 for **Q1** (Mean achievable points out of 10) provide a detailed view of Revit's support level across the LEED IP indicators. The aggregated data from both Task-1 and Task-2 reveal that Revit demonstrates high support for the "Integrative Process" indicator, achieving a perfect mean score of 10.0 in Q1, which places it firmly in the high support category with no variability, as indicated by its interquartile range (IQR) of 0.0. This high score signifies a strong consensus among experts on Revit's capability to support the integrative process, highlighting its effectiveness in facilitating collaboration and streamlined project workflows, essential elements of the LEED IP category.

For **Q2** (mean level of support out of 7), the results show that Revit continues to maintain a high support level for the "Integrative Process" indicator, with a mean score of 6.3 and an IQR of 1.0. This score reflects a consistent agreement among experts that Revit is effective in supporting integrative design processes. The minimal variability in these scores underscores Revit's robust functionality in meeting the requirements for holistic project management and interdisciplinary integration as specified by LEED's IP criteria.

Table 44 Aggregated level of support of Revit for LEED IP indicators based on the results of Task-1 and Task2.

Indicators of IP category	Type	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
		Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Integrative Process	Cr	10.0	0.0		6.3	1.0		

(HC: High with consensus, MC: Moderate with consensus, LC: Moderate with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1 & Q2**, an aggregated level of support is presented in Table 44. The measurement used to measure the aggregated level of support was mentioned in Figure 14 :*(Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators)* in Section 3.2.3.4 in the Methodology chapter 3.

According to the results of the aggregated level of support presented in Table 44, the indicator "Integrative Process" is classified as "High with consensus" (HC). With a perfect mean score of 10.0 in Q1 and a high mean of 6.3 in Q2, along with low interquartile ranges (IQRs of 0.0 and 1.0, respectively), experts agree that Revit provides substantial support for this indicator. This strong consensus underscores Revit's capability to facilitate the integrative design process, a fundamental component in LEED IP requirements.

The consistently high scores for "Integrative Process" reflect Revit's effectiveness in enabling collaboration and data integration essential for holistic project workflows. The minimal variability across expert responses further highlights Revit's reliability in supporting a structured, interdisciplinary approach to design, positioning it as a valuable tool within the LEED IP category.

4.3 Results of Assessment of Revit support for MOSTADAM indicator

The study has conducted two sessions for the Expert Panel. Session-1 was conducted on 26 September 2024 and dedicated to assess the level of support of Revit for LEED. Session-2 was conducted on 30 September 2024 and dedicated to assess the level of support of Revit for MOSTADAM indicators. Each session is consisted of 3 tasks. Task-1 (assessment of Revit support based on the documented requirements “DR” of the indicators), Task-2 (assessment of Revit Support based on Case study “CS” of the indicators), and Task-3 (Assessment of the support of Revit Media channels for the indicators). In this section the results and analysis of **session 2** will be presented.

4.3.1 Assessment of Revit Support for MOSTADAM SS Indicators

The assessment of Revit support for SS indicators in MOSTADAM are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements “DR” of the indicators), T2: (assessment of Revit Support based on Case study “CS” of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.3.1.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-2 of the Expert Panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each MOSTADAM indicator: Q1) “indicate the

number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by MOSTADAM”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified MOSTADAM indicator using a 7-point Likert scale”. Appendix A3-T1 presents the detailed responses of each expert in the Expert Panel for each question in task-1: T1-Q1 and T1-Q2. Table 45 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Site Sustainability (SS) category using the two measurements (Q1 and Q2). While Figure 36 provides a graphical representation (radar chart) of the data in Table 45. These two measurements capture the experts’ assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each MOSTADAM SS indicators.

Table 45 Experts assessment of the level of support of Revit for indicators in the SS category based on the documented requirements (DR) of MOSTADAM indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of SS category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points <i>(out of max possible points)</i>	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
Flood, Rainwater and Sewage Management	2	0.8	3.8	3.5
Ecological Assessment and Protection	2	0.5	2.3	2.5
Construction Environmental Management	1	0.2	2.3	1.0
Ecological Enhancement	1	0.4	4.4	4.0
Heat Island Effect	2	1.3	6.6	5.5
Light Pollution	1	1.0	10.0	7.0

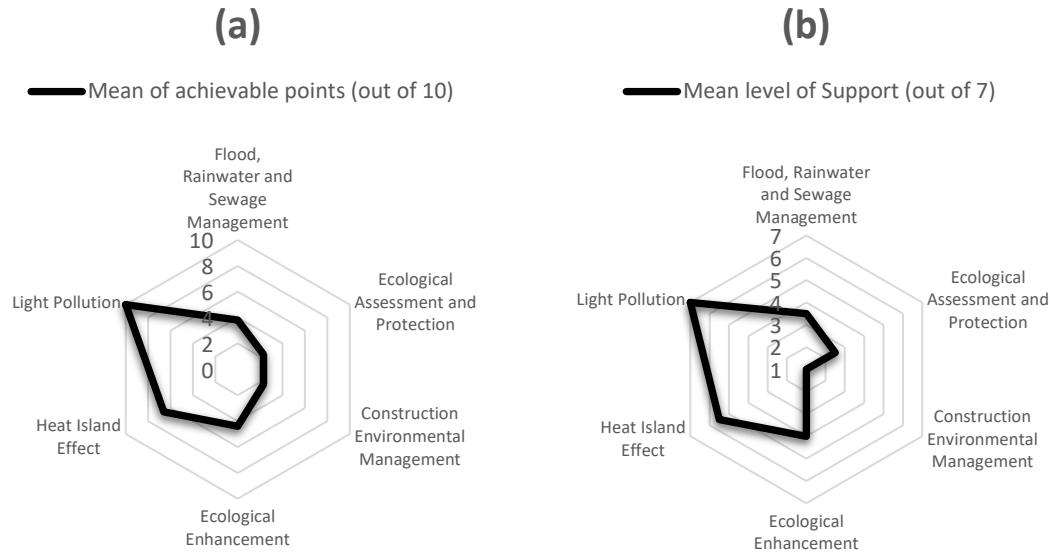


Figure 36 Radar Chart of Expert's assessment of the level of support of Revit for MOSTADAM indicators in the SS category based on the documented requirements (DR) of MOSTADAM using two measurements (Q1 and Q2)

(a) Mean achievable points-Q1 (out of 10) (b) Mean level of Revit support for the indicator-Q2 (out of 7)

The results presented in Table 45 and Figure 36(a) for Q1 (mean achievable points for each indicator in the SS category based on the documented requirements) show that Revit provides limited support for most MOSTADAM indicators in the Sustainable Sites (SS) category. Specifically, indicators such as "Ecological Assessment and Protection" and "Construction Environmental Management" have notably low mean achievable points, with Revit scoring 0.5 and 0.2 out of the maximum possible, respectively. As Figure 36(a) illustrates, these indicators fall significantly short of their maximum potential, suggesting that Revit's tools may not adequately support the ecological and environmental management requirements stipulated by MOSTADAM. This limited support underscores areas where Revit's current functionality could be expanded or enhanced to better address comprehensive site sustainability needs.

However, as also shown in Figure 36(a), Revit demonstrates relatively higher support for indicators like "Heat Island Effect" and "Light Pollution," with each achieving close to the maximum possible points in Q1. For instance, "Light Pollution" scored a full 1.0 out of 1.0, indicating that Revit provides solid support for specific SS indicators that address urban heat and light pollution mitigation. This pattern, as seen in Figure 35(a), highlights Revit's strengths in supporting simpler, infrastructure-related sustainability criteria compared to those involving detailed ecological or construction management considerations.

Regarding Q2 (mean level of support out of 7), the results show that Revit's support level varies across MOSTADAM SS indicators, as demonstrated in Figure 36(b). Indicators like "Heat Island Effect" and "Light Pollution" score relatively high, with mean support levels of 5.5 and 7.0, respectively. Figure 36(b) visually reinforces these scores, suggesting that Revit is equipped to meet certain sustainability requirements in the SS category, providing architects and designers with useful tools for addressing urban heat and light pollution criteria.

In contrast, indicators involving more complex environmental and ecological management, such as "Flood, Rainwater and Sewage Management" and "Ecological Assessment and Protection," have lower mean support levels. For example, "Ecological Assessment and Protection" scored only 2.5 out of 7, while "Construction Environmental Management" scored 1.0, as depicted in Figure 36(b). These low scores emphasize Revit's limited ability to effectively address comprehensive environmental management requirements within the SS category. The overall pattern across both charts suggests that while Revit is well-suited to address certain urban sustainability and pollution control indicators, it may require

further enhancements or complementary tools to fully support MOSTADAM requirements for site and ecological management.

4.3.1.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study “CS”

During task-2 of session-2 of the Expert Panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each MOSTADAM indicator based on the results of the case study presented to them (CS): Q1) “indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the data of case study presented”, and Q2) “on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the MOSTADAM indicator based on the data of case study presented”. Appendix A3-T2 presents the detailed responses of each expert in the Expert Panel for each question in this task. Table 46 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Site Sustainability (SS) category using the two measurements (Q1 and Q2). While Figure 37 provides a graphical representation radar chart of the data in Table 46. These two measurements capture the experts’ assessment of Revit's ability to meet/support MOSTADAM requirements for each indicator based on the results of the case study.

Table 46 Experts assessment of the level of support of Revit for MOSTADAM indicators in the SS category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of SS category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (out of max possible points)	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
Flood, Rainwater and Sewage Management	2	1.1	5.3	4.3
Ecological Assessment and Protection	2	0.3	1.6	2.3
Construction Environmental Management	1	0.3	3.1	2.5
Ecological Enhancement	1	0.5	5.0	5.0
Heat Island Effect	2	1.5	7.3	5.5
Light Pollution	1	1.0	10.0	7.0

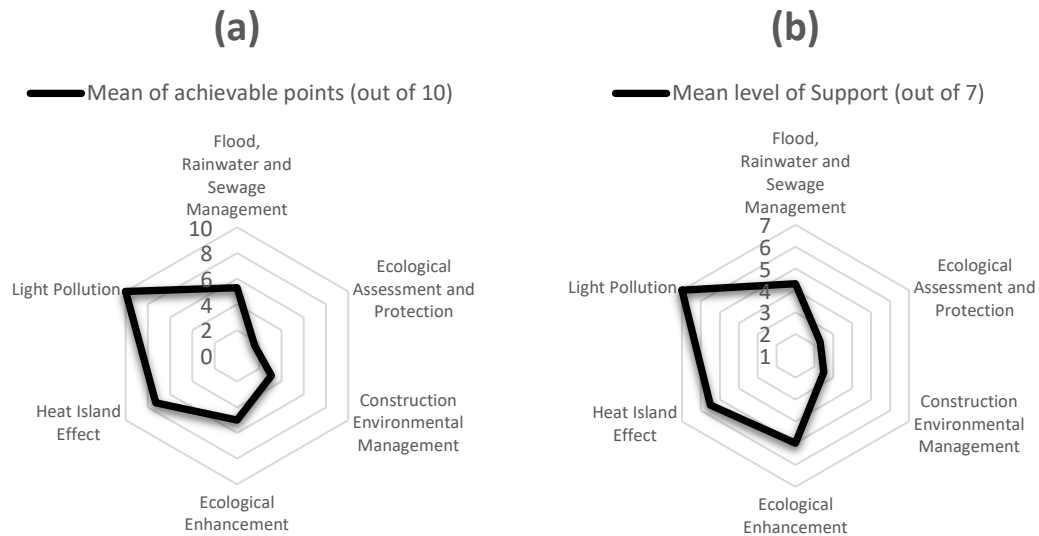


Figure 37 Radar Chart of expert's assessment of the level of support of Revit for MOSTADAM indicators in the SS category based on based on the case study (CS) results using two measurements (Q1 and Q2)

(a) Mean Achievable points- Q1 (out of 10) (b) Mean level of Revit support - Q2 (out of 7)

The results presented in Table 46 and Figure 37(a) for **Q1** (mean achievable points for each indicator in the SS category based on the case study) indicate a varied level of Revit's

support for MOSTADAM indicators in the Sustainable Sites (SS) category. Specifically, indicators such as "Ecological Assessment and Protection" and "Construction Environmental Management" show low mean achievable points, with Revit scoring only 1.6 and 3.1 out of 10, respectively. As illustrated in Figure 37(a), these indicators fall significantly short of their maximum potential, highlighting limitations in Revit's functionality to address in-depth ecological protection and environmental management needs as outlined by MOSTADAM. This finding suggests that enhancements or additional tools may be required to fully meet these requirements.

In contrast, Figure 37(a) shows that Revit demonstrates relatively higher support for indicators like "Heat Island Effect" and "Light Pollution," where the mean achievable points are 7.3 and a full 10.0 out of 10, respectively. This high level of support suggests that Revit is effective in addressing urban heat mitigation and light pollution control, indicating strengths in areas of the SS category that are more infrastructure-focused.

For **Q2** (mean level of support on a 7-point scale), the results, as shown in Figure 37(b), reveal that Revit's support for MOSTADAM SS indicators continues to vary. Indicators such as "Heat Island Effect" and "Light Pollution" achieve high mean support levels of 5.5 and 7.0, respectively, reinforcing Revit's capability in these specific areas. This pattern in Figure 37(b) confirms that Revit provides robust tools to meet certain SS requirements that are crucial for sustainable urban development.

However, for indicators requiring more nuanced ecological support, such as "Ecological Assessment and Protection" and "Construction Environmental Management," Revit shows lower mean support levels of 2.3 and 2.5, respectively, as depicted in Figure 37(b). These

lower scores underscore Revit's limited ability to address comprehensive environmental and ecological management requirements effectively within the SS category. The patterns in both charts suggest that while Revit is well-suited to meet straightforward SS requirements like heat island mitigation and light pollution, further development or complementary software may be necessary to fulfill the broader ecological and environmental sustainability goals set forth by MOSTADAM.

4.3.1.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-2 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked “to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator using a scale from 1 to 10”. A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 47 provides a summary of the experts' assessment of Revit of Mean ranking level for the support of each Media Type for MOSTADAM SS indicators in the SS category. While Figure 38 provides a graphical representation (radar chart) of the data in Table 47.

Table 47 Mean ranking level for the support of each Media Type Support for MOSTADAM SS indicator .

INDICATOR	Mean Ranking of the support of Revit media channel for MOSTADAM			
	TD	M	S	DI
Flood, Rainwater and Sewage Management	6.0	4.7	0.0	3.7
Ecological Assessment and Protection	5.3	3.0	0.0	0.0
Construction Environmental Management	6.7	3.3	0.0	2.0
Ecological Enhancement	5.7	5.3	0.0	3.0
Heat Island Effect	4.7	6.3	7.0	4.3
Light Pollution	3.7	6.3	8.0	0.0

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration).

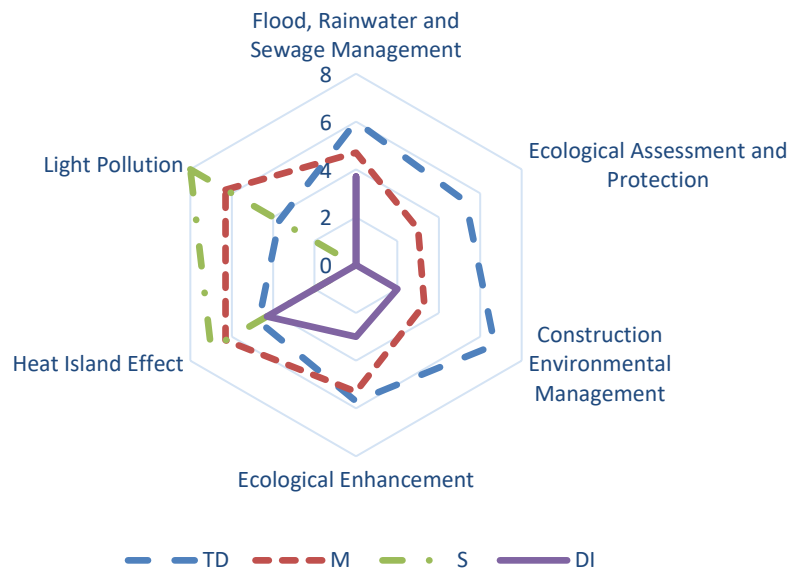


Figure 38 Media Channel Support for Revit MOSTADAM Indicators in SS Category.
(M1: Text Documentation, M2: Modeling, M3: Simulation, and M4: Data Integration)

The table 47 provides a detailed analysis of the media types used in Revit to support the indicators in the Site Sustainability (SS) category of MOSTADAM. The media types evaluated are text documentation (TD), modeling (M), simulation (S), and data integration (DI). Each media is ranked on a scale from 1 to 10, weighing its significance in achieving

the indicator requirements. Figure 38 illustrates the application of different media types in Revit for each MOSTADAM SS indicator, with a comparison of rankings across the six indicators in this category.

TD (Text Documentation) shows a strong presence in several indicators within the SS category, as observed in both Table 47 and Figure 38. Indicators like "Flood, Rainwater and Sewage Management" (6.0), "Ecological Assessment and Protection" (5.3), and "Construction Environmental Management" (6.7) all display high reliance on TD. This indicates that detailed textual documentation is critical in demonstrating compliance with the criteria outlined in MOSTADAM, especially in areas concerning environmental management and assessments. These results reflect Revit's documentation strength in areas involving process-driven assessments rather than purely technical modeling or simulations.

M (Modeling) plays a significant role in supporting certain indicators, especially in "Heat Island Effect" (6.3) and "Light Pollution" (6.3), as highlighted in Table 51 and Figure 52. The capability of Revit to generate and analyze 3D models proves crucial in achieving design solutions that mitigate environmental impacts, such as reducing urban heat and controlling light pollution. Additionally, "Ecological Enhancement" (5.3) shows moderate reliance on modeling, further reinforcing Revit's capacity to visualize and model environmental improvements within a project. This trend demonstrates the key role of modeling in providing the structural and spatial framework necessary to meet MOSTADAM's environmental design requirements.

S (Simulation) sees a substantial contribution in specific indicators such as "Heat Island Effect" (7.0) and "Light Pollution" (8.0), as seen in Table 47. This reflects the need for

dynamic performance analysis, where Revit's simulation tools are essential in evaluating thermal and light impacts in built environments. However, simulation is absent in other indicators, highlighting a focused application of Revit's simulation capabilities for performance-driven aspects of sustainability.

DI (Data Integration) plays a more moderate role across indicators, with notable contributions in "Flood, Rainwater and Sewage Management" (3.7) and "Ecological Enhancement" (3.0), indicating the need to incorporate external datasets, such as environmental or hydrological data, into Revit models to meet these criteria. However, data integration is minimal or absent in simpler indicators like "Light Pollution" and "Ecological Assessment and Protection," suggesting that Revit's internal capabilities suffice for such assessments without relying heavily on external data.

In summary, Table 47 and Figure 38 illustrate that Revit primarily relies on TD and M to achieve most MOSTADAM credits in the Site Sustainability category, with TD taking a leading role in documentation-heavy indicators and M supporting design-oriented indicators. S plays a key role in performance-based assessments such as thermal and lighting analysis, while DI has limited but essential contributions in data-driven environmental management indicators.

4.3.1.4 Assessment of Revit Support for MOSTADAM SS Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for MOSTADAM SS indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study "CS"). Data collected from

the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of MOSTADAM indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a ‘fraction of 10’) were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 48 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements “DR”) and task-2 (T2: data based on case study “CS”).

Table 48 Aggregate assessment of the Experts for the level of support of Revit for MOSTADAM SS indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

Indicators of SS category	Level of Support based on T1-Q1 & T2-Q1		Level of Support based on T1-Q2 & T2-Q2	
	Mean (out of 10)	IQR	Mean (out of 7)	IQR
Flood, Rainwater and Sewage Management	4.5	0.3	3.9	1.3
Ecological Assessment and Protection	1.9	0.9	2.4	1.0
Construction Environmental Management	2.7	0.5	1.8	1.3
Ecological Enhancement	4.7	0.0	4.5	1.0
Heat Island Effect	6.9	1.0	5.5	1.0
Light Pollution	10.0	0.0	7.0	0.0

To be able to identify aggregated level of support of Revit for the SS indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (**Q2**) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where $\text{mean} \leq 3$. Then also for

the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where mean ≤ 4 .

Data based on Q2 (7-point Likert)		Level of support	Data based on Q1 (achievable point out of 10)		Level of support
Mean	IQR		Mean	IQR	
≥ 5.5	$\text{IQR} \leq 1$	High Support with consensus	≥ 7.7	$\text{IQR} \leq 2$	High Support with consensus
≥ 5.5	$\text{IQR} > 1$	High Support without consensus	≥ 7.7	$\text{IQR} > 2$	High Support without consensus
$3 < \text{mean} < 5.5$	$\text{IQR} \leq 1$	Moderate Support with consensus	$4 < \text{mean} < 7.7$	$\text{IQR} \leq 2$	Moderate Support with consensus
$3 < \text{mean} < 5.5$	$\text{IQR} > 1$	Moderate Support without consensus	$4 < \text{mean} < 7.7$	$\text{IQR} > 2$	Moderate Support without consensus
≤ 3	$\text{IQR} \leq 1$	Low Support with consensus	≤ 4	$\text{IQR} \leq 2$	Low Support with consensus
≤ 3	$\text{IQR} > 1$	Low Support without consensus	≤ 4	$\text{IQR} > 2$	Low Support without consensus

Figure 39 level of agreement /consensus among the experts regarding level of support of Revit for indicators.

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the SS indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 48 for **Q1** (mean achievable points out of 10) provide a detailed view of Revit's support level across the MOSTADAM SS indicators. The aggregated data from both Task-1 and Task-2 reveal that Revit demonstrates high support for certain sustainability indicators, particularly "Light Pollution" and "Heat Island Effect." These indicators achieved mean scores of 10.0 and 6.9, respectively, placing them firmly in the high support category. Notably, "Light Pollution" scored a perfect 10.0 with zero variability ($\text{IQR} = 0.0$), indicating unanimous

agreement among experts regarding Revit's capability to support this requirement. The "Heat Island Effect" also shows strong support with an IQR of 1.0, further reflecting consensus among experts.

In contrast, indicators such as "Ecological Assessment and Protection" and "Construction Environmental Management" received much lower mean scores, indicating limited support within Revit. For example, "Ecological Assessment and Protection" scored 1.9 in Q1 with a relatively low IQR of 0.9, and "Construction Environmental Management" achieved a mean of 2.7 with an IQR of 0.5. These low scores and low variability suggest consensus among experts that Revit provides minimal support for these more complex environmental indicators, highlighting potential limitations in Revit's capabilities for addressing these aspects of sustainable site development.

For **Q2** (mean level of support out of 7), the results similarly show varied levels of Revit's support across MOSTADAM SS indicators. Indicators such as "Flood, Rainwater and Sewage Management" and "Ecological Enhancement" achieved moderate support levels with mean scores of 3.9 and 4.5, respectively, with IQRs of 1.3 and 1.0, reflecting moderate agreement among experts on Revit's adequacy for these indicators. However, the low scores and high IQRs for "Construction Environmental Management" (mean of 1.8, IQR = 1.3) reinforce the view that Revit's functionality may not fully meet the MOSTADAM SS criteria for this indicator.

Overall, the high scores and strong consensus for indicators like "Light Pollution" underscore Revit's strengths in handling specific site-related requirements, while the low support levels for indicators such as "Ecological Assessment and Protection" and

"Construction Environmental Management" highlight areas where Revit's capabilities may be limited in supporting certain MOSTADAM SS indicators.

Table 49 Aggregated level of support of Revit for MOSTADAM SS indicators based on the results of Task-1 and Task2.

Indicators of SS category	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
	Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Flood, Rainwater and Sewage Management	4.5	0.3	MC	3.9	1.3	MN	MN
Ecological Assessment and Protection	1.9	0.9	LC	2.4	1.0	LC	LC
Construction environmental Management	2.7	0.5	LC	1.8	1.3	LN	LN
Ecological Enhancement	4.7	0.0	MC	4.5	1.0	MC	MC
Heat Island Effect	6.9	1.0	MC	5.5	1.0	HC	Inconsistent with agreement
Light Pollution	10.0	0.0	HC	7.0	0.0	HC	HC

(HC: High with consensus, MC: Moderate with consensus, LC: low with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1 & Q2**, an aggregated level of support is presented in Table 49. The measurement used to measure the aggregated level of support was mentioned in Figure 14 :(*Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators*) in Section 3.2.3.4 in the Methodology chapter 3.

According to the results in Table 49, the indicator "Flood, Rainwater, and Sewage Management" is classified as "Moderate with No Consensus" (MN). With mean scores of 4.5 in Q1 and 3.9 in Q2, and IQRs of 0.3 and 1.3 respectively, the moderate support level reflects that while Revit addresses aspects of flood management, there is notable variability in expert opinion, indicating an absence of strong consensus.

The indicator "Ecological Assessment and Protection" falls under "Low with Consensus" (LC), with mean scores of 1.9 in Q1 and 2.4 in Q2, both with IQRs of 0.9 and 1.0

respectively. This classification suggests that Revit provides minimal support for this indicator, with experts largely in agreement about its limitations in addressing ecological assessment requirements.

"Construction Environmental Management" is also categorized as "Low with No Consensus" (LN), achieving mean scores of 2.7 in Q1 and 1.8 in Q2, with IQRs of 0.5 and 1.3 respectively. This low support level, combined with the lack of consensus, highlights Revit's limited utility for construction-related environmental management in MOSTADAM requirements.

In contrast, "Heat Island Effect" shows an "Inconsistent with Agreement" classification. While it achieves moderately high scores of 6.9 in Q1 and 5.5 in Q2, IQRs of 1.0 in both metrics reflect variability among experts, indicating differing perspectives on Revit's ability to address this indicator adequately.

"Light Pollution" stands out with a high level of support, classified as "High with Consensus" (HC). This indicator achieved perfect scores of 10.0 in Q1 and 7.0 in Q2, both with IQRs of 0.0, reflecting unanimous agreement among experts regarding Revit's strong capability to manage light pollution requirements effectively.

4.3.2 Assessment of Revit Support for MOSTADAM TC Indicators

The assessment of Revit support for TC indicators in MOSTADAM are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements "DR" of the indicators), T2: (assessment of Revit Support based on Case study "CS" of the

indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.3.2.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-2 of the Expert Panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each MOSTADAM indicator: Q1) “indicate the number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by MOSTADAM”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified MOSTADAM indicator using a 7-point Likert scale”. Appendix A3-T1 presents the detailed responses of each expert in the Expert Panel for each question in task-1: T1-Q1 and T1-Q2. Table 50 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Transportation & Connectivity (TC) category using the two measurements (Q1 and Q2). While Figure 40 provides a graphical representation (radar chart) of the data in Table 50. These two measurements capture the experts’ assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each MOSTADAM TC indicators.

Table 50 Experts assessment of the level of support of Revit for indicators in the TC category based on the documented requirements (DR) of MOSTADAM indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of TC category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points <i>(out of max possible points)</i>	Mean of achievable points <i>(out of 10)</i>	Mean level of Support <i>(out of 7)</i>
Electric Vehicle Provisions	1	1.0	10.0	7.0
Access to Public Transportation	2	0.0	0.0	1.0
Access to Amenities	2	0.0	0.0	1.0
Home	1	1.0	10.0	6.8
Individual Sustainable Transport	1	0.4	4.0	3.8

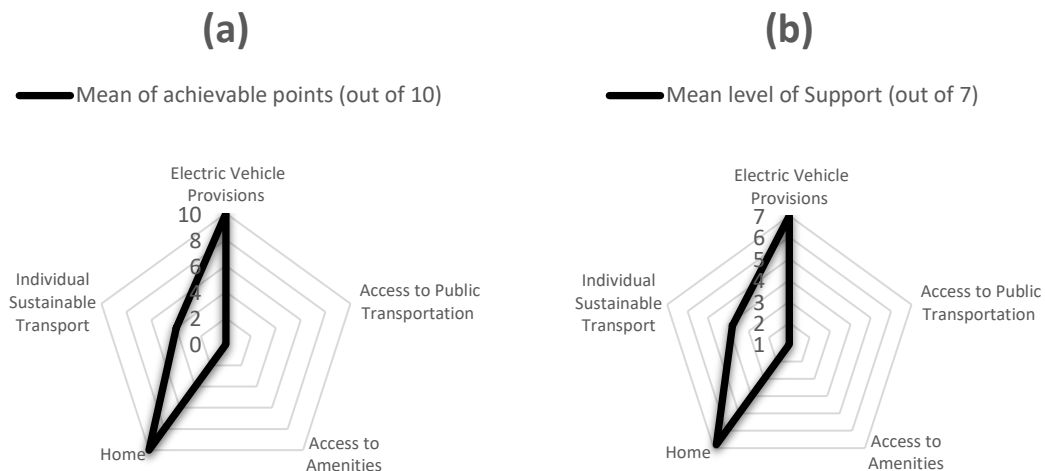


Figure 40 Radar Chart of Expert's assessment of the level of support of Revit for MOSTADAM indicators in the TC category based on the documented requirements (DR) of MOSTADAM using two measurements (Q1 and Q2)

(a) Mean achievable points-Q1 (out of 10) (b) Mean level of Revit support for the indicator-Q2 (out of 7)

The results presented in Table 50 and Figure 40(a) regarding Q1 (mean achievable points for each indicator in the TC category based on the documented requirements) reveal varied levels of Revit's support for MOSTADAM indicators within the Transport and

Connectivity (TC) category. Notably, indicators like "Electric Vehicle Provisions" and "Home" exhibit high mean achievable points, with Revit scoring 10.0 and 10.0 out of 10, respectively. As shown in Figure 40(a), these indicators achieve their maximum potential, suggesting that Revit's current tools are well-suited to meet specific TC requirements such as electric vehicle support and sustainable home transport options.

In contrast, indicators such as "Access to Public Transportation" and "Access to Amenities" have a mean score of 0.0 in Q1, indicating no achievable points within Revit. This absence of support, as illustrated in Figure 40(a), highlights Revit's limitations in addressing connectivity and access requirements central to the TC category, which may necessitate enhancements or additional tools to fulfill these aspects of MOSTADAM criteria effectively.

For **Q2** (mean level of support on a 7-point scale), as seen in Figure 40(b), "Electric Vehicle Provisions" and "Home" maintain high support levels, scoring 7.0 and 6.8, respectively. These scores demonstrate strong expert consensus that Revit is capable of supporting certain sustainable transport measures within the TC category.

Conversely, "Access to Public Transportation" and "Access to Amenities" have lower mean support levels of 1.0, reinforcing the finding that Revit lacks robust support for indicators requiring access and connectivity features. These patterns, evident in both Figure 40(a) and Figure 40(b), suggest that while Revit is effective for straightforward TC requirements like electric vehicle provisions, it may benefit from further development to support more complex connectivity and access indicators central to comprehensive transport and connectivity goals in sustainable design.

4.3.2.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study “CS”

During task-2 of session-2 of the Expert Panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each MOSTADAM indicator based on the results of the case study presented to them (CS): Q1) “indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the data of case study presented”, and Q2) “on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the MOSTADAM indicator based on the data of case study presented”. Appendix A3-T2 presents the detailed responses of each expert in the Expert Panel for each question in this task. Table 51 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Transportation & Connectivity (TC) category using the two measurements (Q1 and Q2). While Figure 41 provides a graphical representation radar chart of the data in Table 51. These two measurements capture the experts’ assessment of Revit's ability to meet/support MOSTADAM requirements for each indicator based on the results of the case study.

Table 51 Experts assessment of the level of support of Revit for MOSTADAM indicators in the TC category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of TC category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points <i>(out of max possible points)</i>	Mean of achievable points <i>(out of 10)</i>	Mean level of Support <i>(out of 7)</i>
Electric Vehicle Provisions	1	1.0	10.0	6.3
Access to Public Transportation	2	0.0	0.0	1.0
Access to Amenities	2	0.0	0.0	1.0
Home	1	0.9	8.9	6.5
Individual Sustainable Transport	1	0.2	2.4	3.3

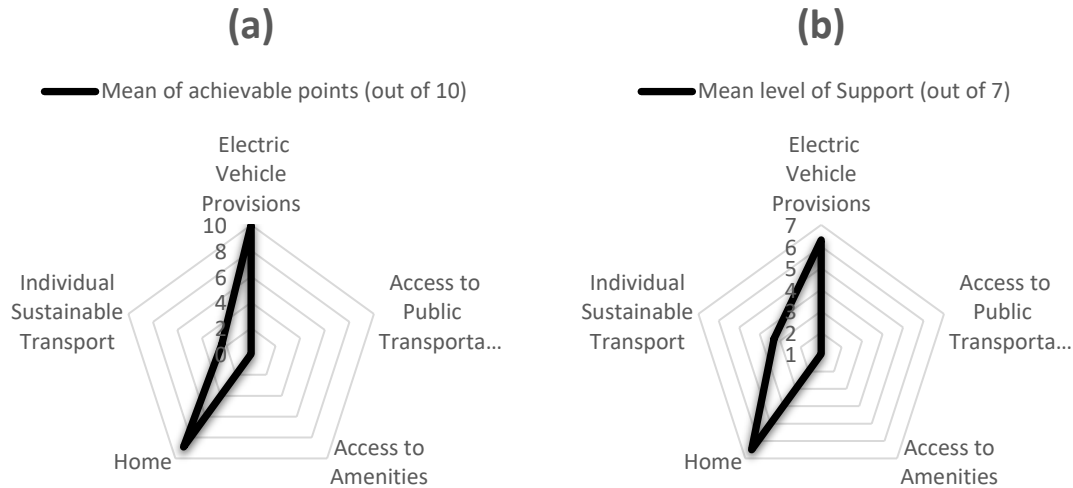


Figure 41 Radar Chart of expert's assessment of the level of support of Revit for MOSTADAM indicators in the TC category based on the case study (CS) results using two measurements (Q1 and Q2)

(a) Mean Achievable points- Q1 (out of 10) **(b)** Mean level of Revit support - Q2 (out of 7)

The results presented in Table 51 and Figure 41(a) concerning **Q1** (mean achievable points for each indicator in the TC category based on the case study results) indicate a varied level of Revit's support for MOSTADAM indicators within the Transport and Connectivity (TC) category. For instance, "Electric Vehicle Provisions" and "Home" stand out, achieving high mean scores of 10.0 and 8.9 out of 10, respectively. As shown in Figure 41(a), these indicators are close to their maximum potential, suggesting that Revit's functionalities are well-aligned with the specific requirements for electric vehicle accommodations and sustainable home transport solutions within the TC category.

In contrast, indicators such as "Access to Public Transportation" and "Access to Amenities" reveal a mean score of 0.0 in Q1, indicating no achievable points within Revit for these indicators. Figure 41(a) visually reinforces this absence of support, highlighting significant gaps in Revit's ability to address connectivity-focused requirements, which are

fundamental to comprehensive transport and accessibility goals in the MOSTADAM framework.

Regarding **Q2** (mean level of support on a 7-point scale), as illustrated in Figure 41(b), "Electric Vehicle Provisions" and "Home" maintain relatively high support levels with mean scores of 6.3 and 6.5, respectively. These scores demonstrate expert consensus that Revit is capable of supporting certain sustainable transport measures in the TC category.

Conversely, "Access to Public Transportation" and "Access to Amenities" scored lower at 1.0, underscoring Revit's limitations in supporting indicators related to public transportation and amenities. As depicted in both Figure 41(a) and Figure 41(b), this pattern suggests that while Revit effectively supports straightforward TC requirements, further development may be necessary to accommodate the broader connectivity and accessibility requirements integral to sustainable urban design within the MOSTADAM framework.

4.3.2.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-2 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked “to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator using a scale from 1 to 10”. A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 52 provides a summary of

the experts' assessment of Revit of Mean ranking level for the support of each Media Type for MOSTADAM TC indicators in the TC category. While Figure 42 provides a graphical representation (radar chart) of the data in Table 52.

Table 52 Mean ranking level for the support of each Media Type Support for MOSTADAM TC indicator .

INDICATOR	Mean Ranking of the support of Revit media channel for MOSTADAM			
	TD	M	S	DI
Electric Vehicle Provisions	4.3	6.7	0.0	0.0
Access to Public Transportation	7.0	0.0	0.0	0.0
Access to Amenities	7.0	0.0	0.0	0.0
Home	5.0	6.7	0.0	0.0
Individual Sustainable Transport	6.0	5.0	0.0	2.3

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration)

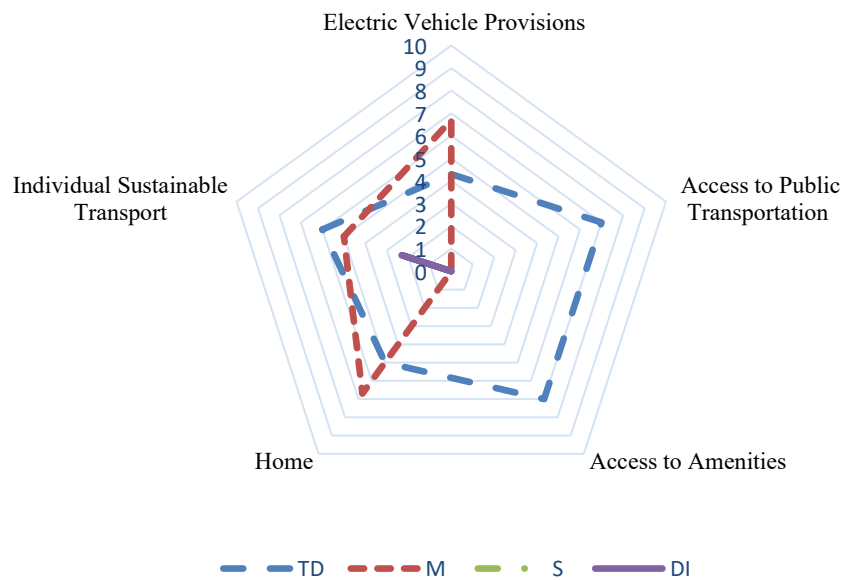


Figure 42 Media Channel Support for Revit MOSTADAM Indicators in the TC Category.
(M1: Text Documentation, M2: Modeling, M3: Simulation, and M4: Data Integration)

Table 52 provides a detailed breakdown of the media channels used in Revit to support the indicators in the Transportation and Connectivity (TC) category of MOSTADAM. The

media channels evaluated include text documentation (TD), modeling (M), simulation (S), and data integration (DI), with each channel ranked on a scale of 1 to 10. Figure 52 visually illustrates the varying degrees to which these media channels contribute to the achievement of the TC indicators.

TD (Text Documentation) plays a significant role in multiple indicators within the TC category, particularly in "Access to Public Transportation" and "Access to Amenities," both receiving a high score of 7.0. This reflects the importance of documentation in verifying compliance with these indicators, as Revit's ability to manage and present necessary reports and textual validation is crucial. Additionally, TD shows notable contributions in "Individual Sustainable Transport" (6.0) and "Home" (5.0), indicating that documentation is relied upon in areas involving transport-related planning and housing provisions.

M (Modeling) has the most substantial impact in certain indicators, especially for "Electric Vehicle Provisions" (6.7) and "Home" (6.7), demonstrating the capability of Revit to generate detailed 3D models that align with sustainable transportation and housing requirements. "Individual Sustainable Transport" also benefits from modeling, with a score of 5.0, showing the relevance of visualizing and planning transport-related features. However, modeling shows no contribution for "Access to Public Transportation" and "Access to Amenities," where documentation alone seems sufficient.

S (Simulation) is not utilized in the TC category, as indicated by the 0.0 scores across all indicators in Table 52. This suggests that simulation tools in Revit are not needed or relied upon for transportation and connectivity indicators, reflecting the fact that these indicators

may not require performance-based or dynamic assessments that simulations typically support.

DI (Data Integration) is used minimally, with the only contribution being for "Individual Sustainable Transport" (2.3). This reflects the potential for integrating external datasets, such as geographic information or third-party transport data, into Revit models for this specific indicator. However, DI is not used at all for other indicators in this category, suggesting that Revit's internal data and modeling capabilities are generally sufficient without the need for significant external data integration.

In summary, Table 52 and Figure 42 show that Revit primarily relies on TD and M to achieve MOSTADAM credits in the Transportation and Connectivity category. TD plays a leading role in documentation-heavy indicators, while M supports design and model-driven requirements such as for electric vehicle provisions and housing. S is not used, and DI only plays a minimal role in select indicators.

4.3.2.4 Assessment of Revit Support for MOSTADAM TC Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for MOSTADAM TC indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study "CS"). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of MOSTADAM indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a ‘fraction of 10’) were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 53 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements “DR”) and task-2 (T2: data based on case study “CS”).

Table 53 Aggregate assessment of the Experts for the level of support of Revit for MOSTADAM TC indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

Indicators of TC category	Level of Support based on T1-Q1 & T2-Q1		Level of Support based on T1-Q2 & T2-Q2	
	Mean (out of 10)	IQR	Mean (out of 7)	IQR
Electric Vehicle Provisions	10.0	0.0	6.6	0.3
Access to Public Transportation	0.0	0.0	1.0	0.0
Access to Amenities	0.0	0.0	1.0	0.0
Home	9.4	0.5	6.6	1.0
Individual Sustainable Transport	3.2	1.5	3.5	1.0

To be able to identify aggregated level of support of Revit for the TC indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (Q2) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where $\text{mean} \leq 3$. Then also for the 10 point scale (Q1) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where $\text{mean} \leq 4$.

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the TC indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 53 for **Q1** (mean achievable points out of 10) provide a comprehensive view of Revit's support level across the MOSTADAM TC indicators. The aggregated data from both Task-1 and Task-2 reveal that Revit demonstrates high support for certain transportation and connectivity requirements, particularly "Electric Vehicle Provisions" and "Home." These indicators achieved mean scores of 10.0 and 9.4, respectively, placing them firmly in the high support category. Notably, "Electric Vehicle Provisions" achieved a perfect mean score of 10.0 with zero variability (IQR = 0.0), indicating unanimous agreement among experts on Revit's capacity to support this indicator. Similarly, "Home" scored high with an IQR of 0.5, reflecting consensus among experts regarding Revit's ability to support residential connectivity requirements effectively.

In contrast, indicators like "Access to Public Transportation" and "Access to Amenities" received much lower mean scores, highlighting limited support within Revit for these connectivity aspects. For instance, "Access to Public Transportation" and "Access to Amenities" both scored 0.0 in Q1 with no variability (IQR = 0.0), suggesting that experts unanimously agree Revit lacks the tools to address these more complex transportation access requirements effectively.

For **Q2** (mean level of support out of 7), the results similarly indicate varied levels of Revit's support across MOSTADAM TC indicators. Indicators such as "Individual Sustainable Transport" achieved moderate support levels, with a mean score of 3.5 and an IQR of 1.0, reflecting moderate agreement among experts on Revit's adequacy for this indicator. However, the consistently low scores and zero variability for "Access to Public Transportation" and "Access to Amenities" (mean of 1.0, IQR = 0.0) reinforce the view that Revit's functionality does not meet the MOSTADAM TC criteria for these indicators.

Overall, the high scores and strong consensus for indicators like "Electric Vehicle Provisions" highlight Revit's strengths in supporting certain transportation provisions, while the low support levels for indicators such as "Access to Public Transportation" and "Access to Amenities" underscore areas where Revit's capabilities may be limited in meeting MOSTADAM TC requirements.

Table 54 Aggregated level of support of Revit for MOSTADAM TC indicators based on the results of Task-1 and Task2.

Indicators of TC category	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
	Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Electric Vehicle Provisions	10.0	0.0	HC	6.6	0.3	HC	HC
Access to Public Transportation	0.0	0.0	LC	1.0	0.0	LC	LC
Access to Amenities	0.0	0.0	LC	1.0	0.0	LC	LC
Home	9.4	0.5	HC	6.6	1.0	HC	HC
Individual Sustainable Transport	3.2	1.5	LC	3.5	1.0	MC	Inconsistent with agreement

(HC: High with consensus, MC: Moderate with consensus, LC: low with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1 & Q2**, an aggregated level of support is presented in Table 54. The measurement used to measure the aggregated level of support

was mentioned in Figure 14 :(*Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators*) in Section 3.2.3.4 in the Methodology chapter 3.

According to the results in Table 54, the indicator "Electric Vehicle Provisions" is classified as "High with Consensus" (HC). With mean scores of 10.0 in Q1 and 6.6 in Q2, and IQRs of 0.0 and 0.3, respectively, this high support level and strong consensus reflect that experts agree Revit effectively supports provisions for electric vehicles within MOSTADAM TC requirements.

"Access to Public Transportation" falls under "Low with Consensus" (LC), with both Q1 and Q2 scoring 0.0, accompanied by IQRs of 0.0 in both metrics. This classification indicates a consensus among experts that Revit lacks the functionality to support access to public transportation, suggesting a significant gap in addressing this indicator.

Similarly, "Access to Amenities" is also classified as "Low with Consensus" (LC), with mean scores of 0.0 in both Q1 and Q2, and consistent IQRs of 0.0. This uniformity suggests expert agreement on Revit's limited support for access to amenities, highlighting another area for improvement within the TC category.

"Home" is classified as "High with Consensus" (HC), with mean scores of 9.4 in Q1 and 6.6 in Q2, and IQRs of 0.5 and 1.0, respectively. These high scores indicate that Revit is well-regarded for its support in home-related indicators, with consensus among experts on its capability in this area.

Lastly, "Individual Sustainable Transport" is categorized as "Inconsistent with Agreement." It scored a mean of 3.2 in Q1 and 3.5 in Q2, with IQRs of 1.5 and 1.0,

respectively. The moderate support level combined with variability in expert opinion suggests mixed perspectives on Revit's capacity to address sustainable transport requirements comprehensively.

4.3.3 Assessment of Revit Support for MOSTADAM RC Indicators

The assessment of Revit support for RC indicators in MOSTADAM are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements “DR” of the indicators), T2: (assessment of Revit Support based on Case study “CS” of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.3.3.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-2 of the Expert Panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each MOSTADAM indicator: Q1) “indicate the number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by MOSTADAM”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified MOSTADAM indicator using a 7-point Likert scale”. Appendix A3-T1 presents the detailed responses of each expert in the Expert Panel for each question in task-1: T1-Q1 and T1-Q2. Table 55 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Region & Culture (RC) category using the two

measurements (Q1 and Q2). While Figure 43 provides a graphical representation (radar chart) of the data in Table 55. These two measurements capture the experts' assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each MOSTADAM RC indicators.

Table 55 Experts assessment of the level of support of Revit for indicators in the RC category based on the documented requirements (DR) of MOSTADAM indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of RC category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (<i>out of 10</i>)	Mean level of Support (<i>out of 7</i>)
Thriving Economy	2	0.0	0.0	1.0
Heritage & Culture	2	1.0	5.0	4.8
Vibrant Society	1	0.8	7.5	5.5
Regional Focus	2	1.0	5.0	4.5

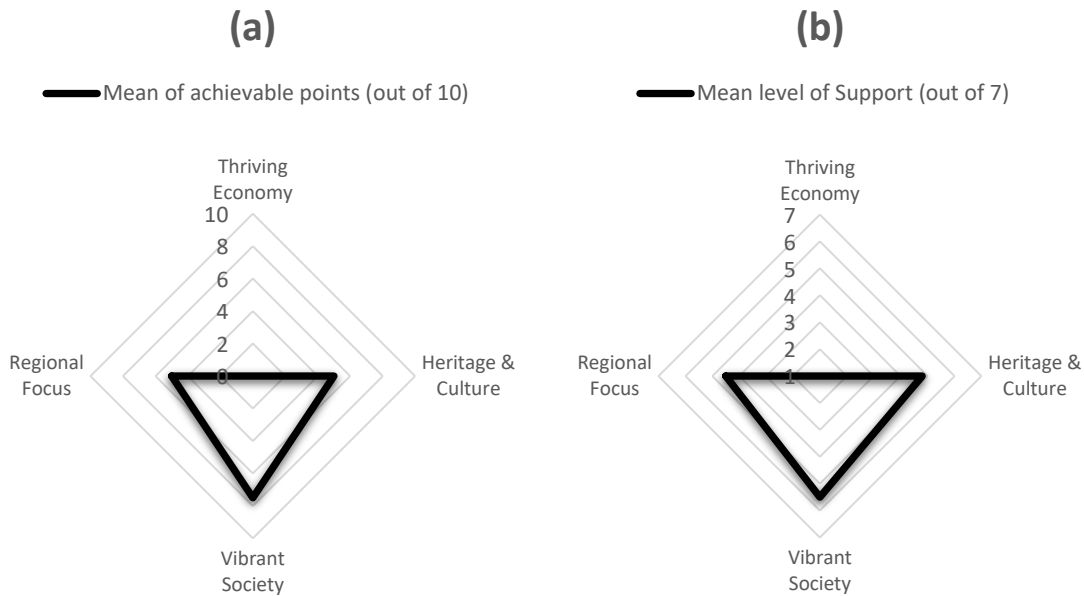


Figure 43 Radar Chart of Expert's assessment of the level of support of Revit for MOSTADAM indicators in the RC category based on the documented requirements (DR) of MOSTADAM using two measurements (Q1 and Q2)

(a) Mean achievable points-Q1 (out of 10) **(b)** Mean level of Revit support for the indicator-Q2 (out of 7)

The results presented in Table 55 and Figure 43(a) regarding **Q1** (mean achievable points for each indicator in the RC category based on the documented requirements) indicate that Revit provides varied levels of support for MOSTADAM's Regional Context (RC) indicators. For example, the "Vibrant Society" indicator achieves a mean score of 7.5 out of 10, suggesting that Revit's tools align relatively well with MOSTADAM's social vitality objectives in this category. Figure 43(a) illustrates this support level, positioning "Vibrant Society" close to its maximum potential, which implies that Revit's capabilities are somewhat suited to supporting social elements within regional contexts.

Conversely, "Thriving Economy" has a mean achievable point score of 0.0, indicating no support for this economic sustainability indicator. As highlighted in Figure 43(a), this lack of points underscores a significant gap in Revit's ability to address economic aspects within MOSTADAM's RC category. This absence of support suggests areas where Revit's functionality could be expanded to better address regional economic considerations.

With respect to **Q2** (mean level of support on a 7-point scale), as shown in Figure 43(b), "Heritage & Culture" and "Vibrant Society" demonstrate moderate support with mean scores of 4.8 and 5.5, respectively. These indicators reflect expert consensus that Revit offers some capability to meet cultural and social requirements within MOSTADAM's RC category. In contrast, "Thriving Economy" scores only 1.0 in Q2, underscoring the limited applicability of Revit for economic-focused indicators.

Overall, the findings from both Q1 and Q2, as depicted in Figures 43(a) and 43(b), reveal that while Revit can support certain social and cultural aspects of the RC category, it lacks robust functionality for addressing economic sustainability. This disparity points to

potential areas for Revit’s enhancement to fully support the broader sustainability and regional context requirements set out by MOSTADAM.

4.3.3.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study “CS”

During task-2 of session-2 of the Expert Panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each MOSTADAM indicator based on the results of the case study presented to them (CS): Q1) “indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the data of case study presented”, and Q2) “on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the MOSTADAM indicator based on the data of case study presented”. Appendix A3-T2 presents the detailed responses of each expert in the Expert Panel for each question in this task. Table 56 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Region & Culture (RC) category using the two measurements (Q1 and Q2). While Figure 44 provides a graphical representation radar chart of the data in Table 56. These two measurements capture the experts’ assessment of Revit's ability to meet/support MOSTADAM requirements for each indicator based on the results of the case study.

Table 56 Experts assessment of the level of support of Revit for MOSTADAM indicators in the RC category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of RC category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (<i>out of 10</i>)	Mean level of Support (<i>out of 7</i>)
Thriving Economy	2	0.0	0.0	1.0
Heritage & Culture	2	1.0	4.9	4.3
Vibrant Society	1	0.5	5.0	4.0
Regional Focus	2	1.0	5.0	5.5

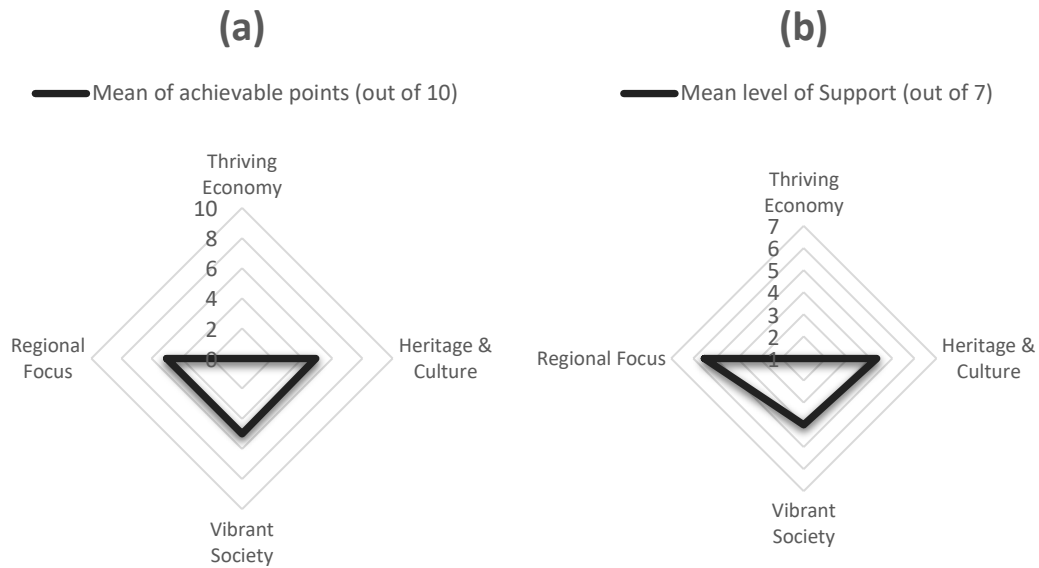


Figure 44 Radar Chart of expert's assessment of the level of support of Revit for MOSTADAM indicators in the RC category based on based on the case study (CS) results using two measurements (Q1 and Q2)

(a) Mean Achievable points- Q1 (out of 10) **(b)** Mean level of Revit support - Q2 (out of 7)

The results presented in Table 56 and Figure 44(a) regarding **Q1** (mean achievable points for each indicator in the RC category based on the case study results) reveal that Revit's support for MOSTADAM's Regional Context (RC) indicators is varied. Notably, the "Regional Focus" indicator achieves a moderate mean score of 5.0 out of 10, suggesting that Revit provides some level of support for this indicator's requirements. As depicted in

Figure 44(a), "Regional Focus" approaches the midpoint of its achievable points, indicating moderate alignment with MOSTADAM's emphasis on regional contextual factors.

In contrast, "Thriving Economy" shows no support, with a mean achievable point score of 0.0, indicating that Revit is not equipped to address the economic aspects highlighted in MOSTADAM's RC criteria. Figure 44(a) underscores this gap in functionality, emphasizing the lack of alignment between Revit's current capabilities and the economic sustainability focus required by MOSTADAM.

Regarding **Q2** (mean level of support on a 7-point scale), Figure 44(b) illustrates a moderate level of support for "Regional Focus", scoring 5.5, which is the highest among the RC indicators. This score indicates that experts perceive Revit as reasonably supportive in addressing regional contextual considerations. However, the "Thriving Economy" indicator again scores low at 1.0, underscoring limited expert agreement on Revit's relevance for economic sustainability.

Overall, the insights from both Q1 and Q2, as shown in Figures 44(a) and 44(b), suggest that while Revit has some capacity to support cultural and social indicators like "Heritage & Culture" and "Vibrant Society," it does not adequately address economic sustainability within the RC category. This analysis highlights areas for potential improvement in Revit's tools to better align with the comprehensive sustainability goals outlined by MOSTADAM.

4.3.3.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-2 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked “to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator using a scale from 1 to 10”. A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 57 provides a summary of the experts’ assessment of Revit of Mean ranking level for the support of each Media Type for MOSTADAM RC indicators in the RC category. While Figure 45 provides a graphical representation (radar chart) of the data in Table 57.

Table 57 Mean ranking level for the support of each Media Type Support for MOSTADAM RC indicator .

INDICATOR	Mean Ranking of the support of Revit media channel for MOSTADAM			
	TD	M	S	DI
Thriving Economy	7.0	0.0	0.0	0.0
Heritage & Culture	6.0	4.0	0.0	2.0
Vibrant Society	5.3	4.0	0.0	2.0
Regional Focus	5.7	5.7	0.0	3.3

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration)

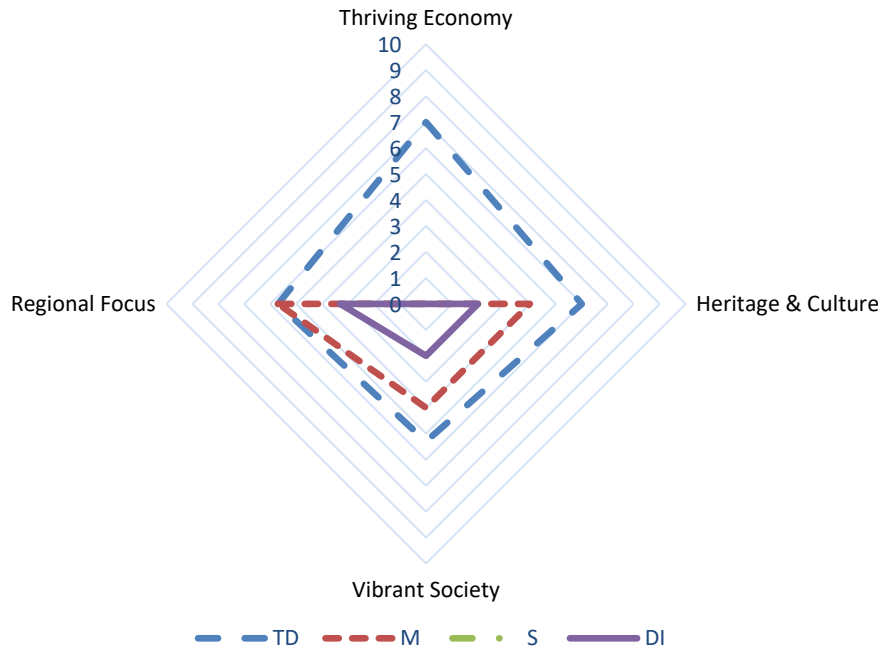


Figure 45 Media Channel Support for Revit MOSTADAM Indicators in the RC Category.
(TD: text documentation, M: modeling, S: simulation, and DI: data integration)

Table 57 provides a comprehensive analysis of the media channels utilized in Revit to support the indicators in the Region and Culture (RC) category of MOSTADAM. The media channels evaluated include text documentation (TD), modeling (M), simulation (S), and data integration (DI), each rated on a scale of 1 to 10. Figure 60 offers a visual representation of the importance and application of these media channels in supporting MOSTADAM RC indicators.

TD (Text Documentation) emerges as the most prominent media channel in this category, particularly in "Thriving Economy" with a high score of 7.0. This demonstrates the importance of documentation in assessing economic factors, where detailed reports and textual validation are crucial. Similarly, for indicators such as "Heritage & Culture" (6.0) and "Vibrant Society" (5.3), TD plays a significant role, indicating Revit's reliance on descriptive and contextual documentation to meet the criteria for these culturally sensitive

indicators. TD also shows a strong presence in "Regional Focus" (5.7), reflecting the need for well-documented regional data.

M (Modeling) shows a moderate contribution in the "Heritage & Culture" (4.0), "Vibrant Society" (4.0), and "Regional Focus" (5.7) indicators. This emphasizes the value of visualizing and modeling cultural and regional architectural elements within Revit. These scores suggest that while modeling plays a role in designing and representing heritage sites or societal elements, it is not the dominant medium for all RC indicators.

S (Simulation) does not contribute at all to the RC indicators, as seen in the 0.0 ratings across all indicators. This indicates that simulation tools in Revit are not required for assessing cultural, societal, or regional aspects of MOSTADAM. The absence of simulation use reflects the static nature of these indicators, where performance-based modeling or dynamic analysis is not essential.

DI (Data Integration) plays a minor role in "Heritage & Culture" (2.0), "Vibrant Society" (2.0), and "Regional Focus" (3.3). The need for external data, such as regional or cultural datasets, is moderate, indicating that while some indicators benefit from integrating third-party data, Revit's internal capabilities are often sufficient for achieving these MOSTADAM criteria without heavy reliance on external data sources.

In conclusion, Table 57 and Figure 45 highlight that TD remains the most important media channel for achieving MOSTADAM RC credits, particularly in areas like economy, heritage, and society. M provides support where visual representation is needed, especially in cultural and regional indicators. S is not required, and DI plays a secondary role,

contributing mainly to indicators where external regional or cultural data might enhance Revit's internal capabilities.

4.3.3.4 Assessment of Revit Support for MOSTADAM RC Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for MOSTADAM RC indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study "CS"). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of MOSTADAM indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a 'fraction of 10') were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 58 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements "DR") and task-2 (T2: data based on case study "CS").

Table 58 Aggregate assessment of the Experts for the level of support of Revit for MOSTADAM RC indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

INDICATORS of RC category	Level of Support based on T1- Q1 & T2- Q1		Level of Support based on T1- Q2 & T2- Q2	
	Mean (out of 10)	IQR	Mean (out of 7)	IQR
Thriving Economy	0.0	0.0	1.0	0.0
Heritage & Culture	5.0	0.6	4.5	1.3
Vibrant Society	6.3	1.3	4.8	1.3
Regional Focus	5.0	0.0	5.0	0.5

To be able to identify aggregated level of support of Revit for the RC indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (**Q2**) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where mean ≤ 3 . Then also for the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where mean ≤ 4 .

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the SS indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 58 for **Q1** (mean achievable points out of 10) provide insights into Revit's support level across the MOSTADAM RC (Region & Culture) indicators. The aggregated data from Task-1 and Task-2 reveal that Revit demonstrates moderate support for some indicators within this category, notably "Vibrant Society" and "Regional Focus." The "Vibrant Society" indicator achieved a mean score of 6.3 with an IQR of 1.3, indicating a moderate level of support with some variability

in expert agreement. Similarly, "Regional Focus" scored 5.0 with a low IQR of 0.0, reflecting unanimous agreement among experts regarding Revit's adequacy for addressing regionally contextual requirements within MOSTADAM.

In contrast, the "Thriving Economy" indicator scored a mean of 0.0 in Q1, with zero variability (IQR = 0.0), highlighting a lack of support for economic sustainability aspects. This unanimous low score indicates consensus among experts that Revit currently lacks functionality to meet the economic criteria specified by MOSTADAM. "Heritage & Culture" also scored relatively lower, with a mean of 5.0 and an IQR of 0.6, reflecting moderate support with slight variability in expert responses.

For **Q2** (mean level of support out of 7), the results mirror the findings in Q1, with indicators such as "Regional Focus" receiving a moderate mean score of 5.0 and an IQR of 0.5, reflecting moderate agreement among experts. However, "Thriving Economy" again scored low at 1.0, with an IQR of 0.0, underscoring the limited alignment between Revit's tools and the economic dimensions required by MOSTADAM's RC criteria.

Overall, the high scores and consensus for indicators like "Regional Focus" emphasize Revit's potential in supporting certain contextual aspects, while the low scores for "Thriving Economy" reveal areas where Revit may need enhancements to align more fully with the economic sustainability goals of MOSTADAM.

Table 59 Aggregated level of support of Revit for MOSTADAM RC indicators based on the results of Task-1 and Task2.

Indicators of RC category	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
	Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Thriving Economy	0.0	0.0	LC	1.0	0.0	LC	LC
Heritage & Culture	5.0	0.6	MC	4.5	1.3	MC	MC
Vibrant Society	6.3	1.3	MC	4.8	1.3	MC	MC
Regional Focus	5.0	0.0	MC	5.0	0.5	MC	MC

(HC: High with consensus, MC: Moderate with consensus, LC: Moderate with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1 & Q2**, an aggregated level of support is presented in Table 59. The measurement used to measure the aggregated level of support was mentioned in Figure 14 :(*Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators*) in Section 3.2.3.4 in the Methodology chapter 3.

Based on the classifications presented in Table 59, the indicator "Thriving Economy" is categorized as "Low with Consensus" (LC). With mean scores of 0.0 in Q1 and 1.0 in Q2, and consistent IQRs of 0.0 across both metrics, experts unanimously agree that Revit provides minimal support for this indicator, indicating a notable gap in functionality to meet economic sustainability requirements.

The indicator "Heritage & Culture" is classified as "Moderate with Consensus" (MC), achieving mean scores of 5.0 in Q1 and 4.5 in Q2, with IQRs of 0.6 and 1.3, respectively. This moderate support level reflects that while Revit provides some capability for addressing heritage and cultural considerations within MOSTADAM RC indicators, there is room for enhancement to meet the full requirements.

Similarly, "Vibrant Society" is also classified as "Moderate with Consensus" (MC), with mean scores of 6.3 in Q1 and 4.8 in Q2, and matching IQRs of 1.3. This consistency highlights moderate agreement among experts that Revit offers a fair level of support for indicators related to social vibrancy, though its capabilities may not entirely align with the comprehensive societal goals of MOSTADAM.

"Regional Focus" achieves a "Moderate with Consensus" (MC) classification as well, with mean scores of 5.0 in both Q1 and Q2, and low IQRs of 0.0 and 0.5. This stable agreement suggests that Revit moderately supports regional contextual factors, aligning reasonably well with MOSTADAM's regional focus requirements.

Overall, these results suggest that while Revit demonstrates moderate support for indicators like "Heritage & Culture," "Vibrant Society," and "Regional Focus," it falls short in addressing economic sustainability under the "Thriving Economy" indicator. This analysis points to potential areas where Revit's tools could be expanded to better align with the diverse sustainability objectives outlined by MOSTADAM's RC category.

4.3.4 Assessment of Revit Support for MOSTADAM E Indicators

The assessment of Revit support for E indicators in MOSTADAM are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements "DR" of the indicators), T2: (assessment of Revit Support based on Case study "CS" of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.3.4.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-2 of the Expert Panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each MOSTADAM indicator: Q1) “indicate the number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by MOSTADAM”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified MOSTADAM indicator using a 7-point Likert scale”. Appendix A3-T1 presents the detailed responses of each expert in the Expert Panel for each question in task-1: T1-Q1 and T1-Q2. Table 60 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Energy (E) category using the two measurements (Q1 and Q2). While Figure 46 provides a graphical representation (radar chart) of the data in Table 60. These two measurements capture the experts’ assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each MOSTADAM E indicators.

Table 60 Experts assessment of the level of support of Revit for indicators in the E category based on the documented requirements (DR) of MOSTADAM indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of E category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
Energy Performance	15	15.0	10.0	7.0
Systems Commissioning	1	0.0	0.0	1.0
Envelope Commissioning	1	0.0	0.0	1.0
Energy Metering	1	0.8	7.5	5.8
Energy Efficient Appliances	1	0.0	0.0	1.0
Renewable Energy	7	7.0	10.0	7.0

Ozone Impact	<i>I</i>	0.3	2.5	2.5
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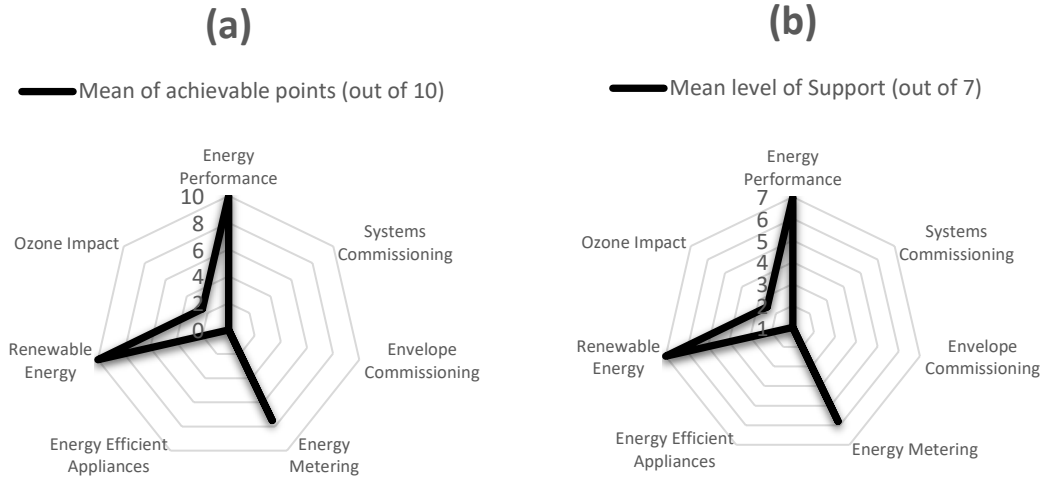


Figure 46 Radar Chart of Expert's assessment of the level of support of Revit for MOSTADAM indicators in the "E" category based on the documented requirements (DR) of MOSTADAM using two measurements (Q1 and Q2)

(a) Mean achievable points-Q1 (out of 10) (b) Mean level of Revit support for the indicator-Q2 (out of 7)

The results presented in Table 60 and Figure 46(a) regarding **Q1** (mean achievable points for each indicator in the E category based on the documented requirements) show that Revit demonstrates strong support for certain energy-related indicators within MOSTADAM's Energy (E) category. Notably, "Energy Performance" and "Renewable Energy" achieve the maximum mean scores of 10.0 out of 10 in Q1, indicating that Revit fully meets the requirements for these indicators. This robust support is further highlighted in Figure 46(a), where these indicators reach the upper limit of their achievable points, suggesting Revit's capabilities are well-aligned with MOSTADAM's goals for optimizing energy efficiency and renewable energy integration.

However, several indicators exhibit low support levels, such as "Systems Commissioning," "Envelope Commissioning," and "Energy Efficient Appliances," each scoring 0.0, indicating that Revit lacks functionality to address these commissioning and appliance-

related requirements effectively. Figure 46(a) underscores this gap in support, showing these indicators falling significantly short of their potential, thereby identifying areas where Revit's tools may need enhancement to align with comprehensive energy management practices.

Regarding Q2 (mean level of support out of 7), Figure 46(b) illustrates that indicators like "Energy Performance" and "Renewable Energy" also received high support ratings on the 7-point scale, each scoring a mean of 7.0. This strong consensus among experts reinforces the assessment that Revit provides substantial support for achieving MOSTADAM's energy efficiency standards. In contrast, "Ozone Impact" received a lower mean level of support at 2.5, highlighting Revit's limited capabilities in addressing environmental impact related to ozone depletion.

Overall, the analysis from both Q1 and Q2, as depicted in Figures 46(a) and 46(b), indicates that Revit is highly capable in supporting primary energy efficiency goals within the E category. However, it lacks the necessary features to address other critical areas such as systems commissioning, appliance efficiency, and ozone impact. These findings suggest specific areas where Revit could be improved to provide a more holistic approach to energy sustainability in alignment with MOSTADAM's comprehensive energy management objectives.

4.3.4.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study "CS"

During task-2 of session-2 of the Expert Panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session,

experts were asked two questions about each MOSTADAM indicator based on the results of the case study presented to them (CS): Q1) “indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the data of case study presented”, and Q2) “on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the MOSTADAM indicator based on the data of case study presented”. Appendix A3-T2 presents the detailed responses of each expert in the Expert Panel for each question in this task. Table 61 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Energy (E) category using the two measurements (Q1 and Q2). While Figure 47 provides a graphical representation radar chart of the data in Table 61. These two measurements capture the experts’ assessment of Revit's ability to meet/support MOSTADAM requirements for each indicator based on the results of the case study.

Table 61 Experts assessment of the level of support of Revit for MOSTADAM indicators in the E category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of E category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
Energy Performance	15	15.0	10.0	7.0
Systems Commissioning	1	0.0	0.0	1.0
Envelope Commissioning	1	0.0	0.0	1.0
Energy Metering	1	0.5	5.0	5.0
Energy Efficient Appliances	1	0.1	1.3	1.0
Renewable Energy	7	7.0	10.0	7.0
Ozone Impact	1	0.5	5.0	4.8

(Legend: Cr: Credit , Pr: Prerequisite)

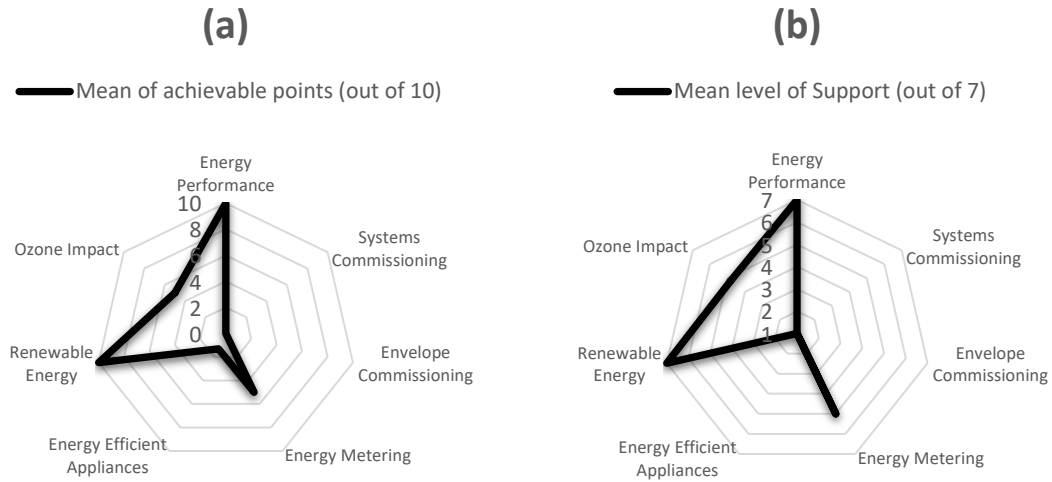


Figure 47 Radar Chart of expert's assessment of the level of support of Revit for MOSTADAM indicators in the "E" category based on based on the case study (CS) results using two measurements (Q1 and Q2)

(a) Mean Achievable points- Q1 (out of 10) (b) Mean level of Revit support - Q2 (out of 7)

The results presented in Table 61 and Figure 47(a) provide an assessment of Revit's support for the MOSTADAM Energy (E) indicators based on the case study (CS) results, using two metrics: **Q1** (mean achievable points out of 10) and **Q2** (mean level of support out of 7). For "Energy Performance" and "Renewable Energy", Revit achieves the maximum possible scores in Q1, with both indicators receiving a mean score of 10.0 out of 10. This high support level is depicted in Figure 47(a), where these indicators reach their maximum achievable points, confirming Revit's effectiveness in meeting MOSTADAM's requirements for optimizing energy efficiency and renewable energy integration.

Conversely, certain indicators, including "Systems Commissioning" and "Envelope Commissioning", scored 0.0, indicating that Revit lacks the necessary functionality to address commissioning processes effectively within the energy category. This limitation is evident in Figure 47(a), where these indicators fall far below their maximum potential,

highlighting areas where Revit's tools could be enhanced to support comprehensive energy management and system testing requirements.

In terms of **Q2** (mean level of support out of 7), as shown in Figure 47(b), "Energy Performance" and "Renewable Energy" again achieve high support levels, each scoring 7.0. This consensus among experts indicates strong support from Revit for these key energy-related indicators. However, indicators such as "Energy Metering" and "Ozone Impact" received lower but moderate levels of support, with mean scores of 5.0 and 4.8, respectively. These scores suggest that while Revit offers some support for tracking energy usage and assessing ozone impact, its functionality may not fully satisfy MOSTADAM's rigorous sustainability standards in these areas.

Overall, the combined analysis of Q1 and Q2, illustrated in Figures 47(a) and 47(b), indicates that Revit is well-suited to support the primary energy efficiency and renewable energy goals within the E category. However, additional functionality may be required to comprehensively address system commissioning and appliance efficiency, ensuring that Revit aligns more fully with MOSTADAM's holistic approach to energy sustainability.

4.3.4.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-2 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked "to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM

indicator using a scale from 1 to 10”. A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 62 provides a summary of the experts’ assessment of Revit of Mean ranking level for the support of each Media Type for MOSTADAM “E” indicators in the “E” category. While Figure 48 provides a graphical representation (radar chart) of the data in Table 62.

Table 62 Mean ranking level for the support of each Media Type Support for MOSTADAM E indicator .

INDICATOR	Mean Ranking of the support of Revit media channel for MOSTADAM			
	TD	M	S	DI
Energy Performance	6.7	9.3	10.0	8.0
Systems Commissioning	5.7	0.0	0.0	0.0
Envelope Commissioning	5.7	0.0	0.0	0.0
Energy Metering	5.0	5.7	0.0	5.0
Energy Efficient Appliances	6.0	0.0	0.0	0.0
Renewable Energy	7.0	9.3	9.0	8.0
Ozone Impact	6.0	6.0	0.0	4.0

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration)

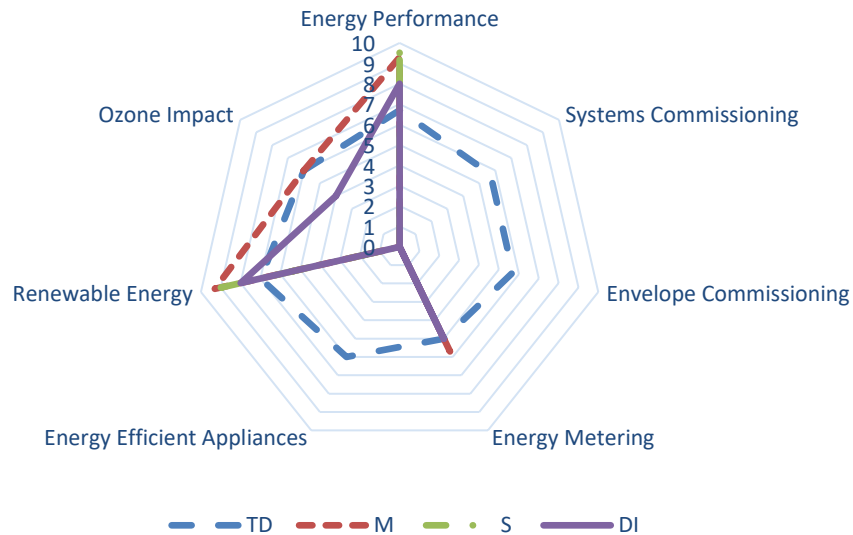


Figure 48 Media Channel Support for Revit MOSTADAM Indicators in the E Category.
(TD: text documentation, M: modeling, S: simulation, and DI: data integration)

Table 62 provides a detailed analysis of the media channels used in Revit to support indicators in the Energy (E) category of MOSTADAM. The media types used include text documentation (TD), modeling (M), simulation (S), and data integration (DI), with rankings based on their importance for achieving the objectives of each indicator. Figure 58 illustrates the significance of each media type in supporting the energy-related MOSTADAM indicators.

TD (Text Documentation) plays a significant role across most indicators, particularly in "Renewable Energy" (7.0), "Energy Efficient Appliances" (6.0), and "Ozone Impact" (6.0). This suggests that Revit relies on extensive documentation to meet these criteria, particularly for renewable energy systems and their environmental impact. However, TD shows a slightly lower level of support for indicators such as "Energy Performance" (6.7), where modeling and simulation take precedence.

M (Modeling) demonstrates strong support, particularly for performance-based indicators like "Energy Performance" (9.3) and "Renewable Energy" (9.3). Revit's modeling capabilities are essential for creating detailed 3D models that meet the requirements for energy-efficient systems and renewable energy integration. M plays a secondary role in "Ozone Impact" (6.0) but is absent in areas like "Systems Commissioning" and "Energy Efficient Appliances," where modeling is not critical.

S (Simulation) is vital in supporting indicators such as "Energy Performance" (10.0) and "Renewable Energy" (9.0). This reflects Revit's reliance on simulation tools to evaluate energy efficiency and the performance of renewable energy systems in a building's design.

However, for indicators like "Energy Metering" and "Ozone Impact," simulation plays no role, as these areas do not require performance-based simulations within Revit.

DI (Data Integration) also shows a high level of support for "Energy Performance" (8.0) and "Renewable Energy" (8.0), indicating that integrating external datasets into Revit models is crucial for achieving energy-related objectives. Data integration is moderately important in areas like "Energy Metering" (5.0) and "Ozone Impact" (4.0), where third-party data sources contribute to the overall assessment.

In summary, Revit relies heavily on modeling and simulation to meet the energy-related MOSTADAM criteria, particularly in areas requiring detailed performance analysis, such as "Energy Performance" and "Renewable Energy." Text documentation supports Revit's ability to fulfill requirements across most indicators, while data integration plays a crucial role in certain areas where external data enhances Revit's capabilities. Figure 48 visually reinforces the strong reliance on modeling and simulation for energy-related assessments in MOSTADAM.

4.3.4.4 Assessment of Revit Support for MOSTADAM E Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for MOSTADAM "E" indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study "CS"). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of MOSTADAM indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a ‘fraction of 10’) were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 63 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements “DR”) and task-2 (T2: data based on case study “CS”).

Table 63 Aggregate assessment of the Experts for the level of support of Revit for MOSTADAM “E” indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

Indicators of SS category	Level of Support based on T1-Q1 & T2-Q1		Level of Support based on T1-Q1 & T2-Q1	
	Mean (out of 10)	IQR	Mean (out of 7)	IQR
Energy Performance	10.0	0.0	7.0	0.0
Systems Commissioning	0.0	0.0	1.0	0.0
Envelope Commissioning	0.0	0.0	1.0	0.0
Energy Metering	6.3	1.3	5.4	1.5
Energy Efficient Appliances	0.6	0.0	1.0	0.0
Renewable Energy	10.0	0.0	7.0	0.0
Ozone Impact	3.8	1.3	3.6	2.3

To be able to identify aggregated level of support of Revit for the E indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (**Q2**) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where mean ≤ 3 . Then also for the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where mean ≤ 4 .

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the SS indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 63 for **Q1** (Mean achievable points out of 10) illustrate Revit's level of support across MOSTADAM "E" (Energy) indicators. The aggregated data from Task-1 and Task-2 highlight that Revit provides high support for key energy-related indicators, particularly "Energy Performance" and "Renewable Energy." Both of these indicators achieved perfect mean scores of 10.0 with zero variability (IQR = 0.0), indicating unanimous expert consensus regarding Revit's strong capability to support these energy-focused requirements.

In contrast, indicators such as "Systems Commissioning," "Envelope Commissioning," and "Energy Efficient Appliances" received significantly lower mean scores, indicating limited or no support from Revit in these areas. For example, both "Systems Commissioning" and "Envelope Commissioning" scored 0.0 in Q1 with no variability (IQR = 0.0), reflecting consensus among experts that Revit does not adequately address these commissioning and appliance-related aspects in energy management.

For **Q2** (mean level of support out of 7), the results align with Q1 findings, with "Energy Performance" and "Renewable Energy" receiving high support levels, both scoring 7.0 with IQRs of 0.0, further reinforcing expert agreement on Revit's strong suitability for these indicators. However, "Ozone Impact" scored lower in Q2 with a mean of 3.6 and a higher

IQR of 2.3, indicating variability in expert opinions on Revit's capacity to address this environmental concern.

Overall, the high scores and strong consensus for "Energy Performance" and "Renewable Energy" underscore Revit's effectiveness in managing core energy requirements, while the consistently low support for "Systems Commissioning" and "Envelope Commissioning" points to areas where Revit may need further development to fully align with MOSTADAM's comprehensive energy criteria.

Table 64 Aggregated level of support of Revit for MOSTADAM "E" indicators based on the results of Task-1 and Task2.

Indicators of E category	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
	Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Energy Performance	10.0	0.0	HC	7.0	0.0	HC	HC
Systems Commissioning	0.0	0.0	LC	1.0	0.0	LC	LC
Envelope Commissioning	0.0	0.0	LC	1.0	0.0	LC	LC
Energy Metering	6.3	1.3	MC	5.4	1.5	MN	MN
Energy Efficient Appliances	0.6	0.0	LC	1.0	0.0	LC	LC
Renewable Energy	10.0	0.0	HC	7.0	0.0	HC	HC
Ozone Impact	3.8	1.3	LC	3.6	2.3	MN	Inconsistent without agreement

(HC: High with consensus, MC: Moderate with consensus, LC: Moderate with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1 & Q2**, an aggregated level of support is presented in Table 64. The measurement used to measure the aggregated level of support was mentioned in Figure 14 :(*Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators*) in Section 3.2.3.4 in the Methodology chapter 3.

According to the classifications in Table 64, the indicator "Energy Performance" is categorized as "High with Consensus" (HC). With mean scores of 10.0 in Q1 and 7.0 in Q2, and IQRs of 0.0 in both, experts demonstrate unanimous agreement on Revit's strong capability to support this indicator, highlighting its effectiveness in addressing MOSTADAM's energy performance requirements.

"Systems Commissioning" and "Envelope Commissioning" are both classified as "Low with Consensus" (LC), achieving mean scores of 0.0 in Q1 and 1.0 in Q2, with IQRs of 0.0 across both metrics. This uniformity indicates that experts consistently agree on Revit's minimal support for these indicators, suggesting a significant gap in Revit's ability to meet MOSTADAM's commissioning requirements.

The indicator "Energy Metering" falls into "Moderate with No Consensus" (MN), with a mean score of 6.3 in Q1 and 5.4 in Q2, and higher IQRs of 1.3 and 1.5, respectively. This classification reflects moderate support with notable variability in expert opinion, suggesting that while Revit offers some support for energy metering, there is a lack of strong consensus on its adequacy.

"Energy Efficient Appliances" is rated "Low with Consensus" (LC), with mean scores of 0.6 in Q1 and 1.0 in Q2, both with an IQR of 0.0. This agreement among experts highlights that Revit provides minimal support for integrating energy-efficient appliances in line with MOSTADAM requirements.

"Renewable Energy" also achieves a "High with Consensus" (HC) classification, with perfect scores of 10.0 in Q1 and 7.0 in Q2, and IQRs of 0.0. Experts unanimously agree on

Revit's strong capability in supporting renewable energy initiatives, making it one of the well-supported indicators in the E category.

The indicator "Ozone Impact" shows an "Inconsistent without Agreement" classification, with mean scores of 3.8 in Q1 and 3.6 in Q2, and higher IQRs of 1.3 and 2.3, respectively. This variability reflects differing expert perspectives on Revit's ability to address ozone impact, suggesting inconsistencies in support for this environmental consideration.

4.3.5 Assessment of Revit Support for MOSTADAM W Indicators

The assessment of Revit support for W indicators in MOSTADAM are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements “DR” of the indicators), T2: (assessment of Revit Support based on Case study “CS” of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.3.5.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-2 of the Expert Panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each MOSTADAM indicator: Q1) “indicate the number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by MOSTADAM”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified MOSTADAM indicator using a 7-point Likert scale”. Appendix A3-T1 presents the detailed responses of each expert in the Expert Panel for each question in task-1: T1-Q1

and T1-Q2. Table 65 provides a summary of the experts' assessment of Revit support/coverage for each indicator in the Water (W) category using the two measurements (Q1 and Q2). While Figure 49 provides a graphical representation (radar chart) of the data in Table 65. These two measurements capture the experts' assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each MOSTADAM W indicators.

Table 65 Experts assessment of the level of support of Revit for indicators in the W category based on the documented requirements (DR) of MOSTADAM indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of W category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
Indoor Water Performance	10	10.0	10.0	7.0
Outdoor Water Performance	10	9.6	9.6	6.8
Alternative Water Solutions	3	0.5	1.7	2.3
Water Metering	1	0.6	6.3	5.5

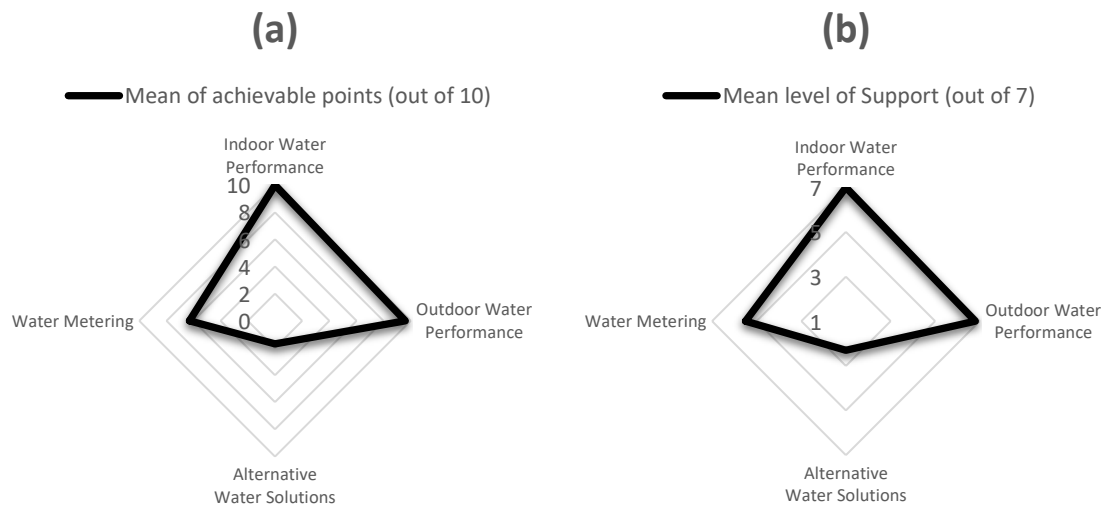


Figure 49 Radar Chart of Expert's assessment of the level of support of Revit for MOSTADAM indicators in the "W" category based on the documented requirements (DR) of MOSTADAM using two measurements (Q1 and Q2)

(a) Mean achievable points-Q1 (out of 10) (b) Mean level of Revit support for the indicator-Q2 (out of 7)

The results presented in Table 65 and Figure 49(a) regarding **Q1** (Mean achievable points for each indicator in the Water (W) category based on the documented requirements) reveal varied levels of support provided by Revit for MOSTADAM's Water indicators. Notably, the "Indoor Water Performance" indicator achieves a perfect mean score of 10.0 out of 10, indicating that Revit fully supports the requirements related to indoor water efficiency. As depicted in Figure 49(a), "Indoor Water Performance" reaches its maximum achievable points, demonstrating strong alignment with MOSTADAM's emphasis on indoor water conservation.

Similarly, "Outdoor Water Performance" shows high support, with a mean score of 9.6 out of 10, suggesting that Revit is well-suited to meet outdoor water management needs. Figure 49(a) visually reinforces this finding, showing "Outdoor Water Performance" as approaching its achievable point maximum, reflecting Revit's robust capability in managing outdoor water efficiency within the MOSTADAM framework.

In contrast, the indicator "Alternative Water Solutions" scores much lower, with a mean achievable point score of only 1.7 out of 10. This result highlights a significant gap in Revit's support for innovative water solutions, indicating that additional tools or integrations may be necessary to meet the sustainability criteria for alternative water sources effectively.

Regarding **Q2** (mean level of support on a 7-point scale), Figure 49(b) illustrates a similarly high level of support for "Indoor Water Performance," scoring a maximum of 7.0, and for "Outdoor Water Performance," scoring 6.8. These scores suggest that experts perceive

Revit as highly supportive in addressing both indoor and outdoor water conservation requirements. However, the "Alternative Water Solutions" indicator again shows limited support, with a low mean score of 2.3, underscoring Revit's limited alignment with alternative water management needs.

Overall, the insights from both Q1 and Q2, as shown in Figures 49(a) and 49(b), indicate that while Revit effectively supports conventional water performance metrics, it falls short in accommodating innovative or alternative water solutions. This analysis highlights areas where Revit's capabilities could be expanded to better align with the comprehensive water sustainability goals outlined by MOSTADAM.

4.3.5.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study "CS"

During task-2 of session-2 of the Expert Panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each MOSTADAM indicator based on the results of the case study presented to them (CS): Q1) "indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the data of case study presented", and Q2) "on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the MOSTADAM indicator based on the data of case study presented". Appendix A3-T2 presents the detailed responses of each expert in the Expert Panel for each question in this task. Table 66 provides a summary of the experts' assessment of Revit support/coverage for each indicator in the Water (W) category using the two measurements (Q1 and Q2). While Figure 50 provides a graphical representation

radar chart of the data in Table 66. These two measurements capture the experts' assessment of Revit's ability to meet/support MOSTADAM requirements for each indicator based on the results of the case study.

Table 66 Experts assessment of the level of support of Revit for MOSTADAM indicators in the W category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of W category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (<i>out of max possible points</i>)	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
Indoor Water Performance	10	10.0	10.0	6.8
Outdoor Water Performance	10	10.0	10.0	6.8
Alternative Water Solutions	3	0.7	2.3	2.3
Water Metering	1	0.5	5.0	5.5

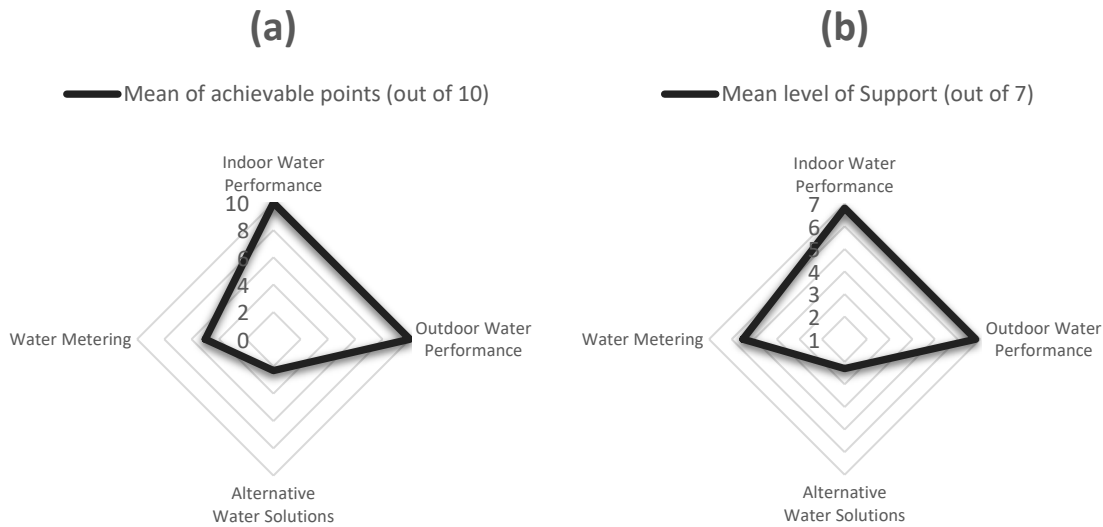


Figure 50 Radar Chart of expert's assessment of the level of support of Revit for MOSTADAM indicators in the "W" category based on based on the case study (CS) results using two measurements (Q1 and Q2)

(a) Mean Achievable points- Q1 (out of 10) (b) Mean level of Revit support - Q2 (out of 7)

The results presented in Table 66 and Figure 50(a) regarding **Q1** (mean achievable points for each indicator in the Water (W) category based on the case study results) show that Revit provides robust support for MOSTADAM's indoor and outdoor water performance requirements. Both "Indoor Water Performance" and "Outdoor Water Performance" achieve the maximum possible mean scores of 10.0 out of 10, indicating that Revit fully addresses the water efficiency needs for both indoor and outdoor applications. As illustrated in Figure 50(a), these indicators reach the top of their achievable points, demonstrating strong alignment with MOSTADAM's water efficiency standards.

In contrast, the "Alternative Water Solutions" indicator reveals much lower support, with a mean achievable point score of only 2.3 out of 10. This score indicates a significant gap in Revit's ability to meet the innovative and alternative water solutions criteria defined by MOSTADAM. Figure 50(a) emphasizes this discrepancy, with "Alternative Water Solutions" far below its maximum potential, suggesting that Revit's existing tools may not fully support the development of sustainable water alternatives.

For **Q2** (mean level of support on a 7-point scale), Figure 50(b) reinforces Revit's high level of support for indoor and outdoor water performance, with both indicators scoring 6.8 out of 7. These results indicate strong expert agreement that Revit is effective in addressing water conservation for standard water uses. In contrast, "Alternative Water Solutions" remains low at 2.3, highlighting limited expert confidence in Revit's ability to support non-standard water management practices.

Overall, the insights from both Q1 and Q2, as shown in Figures 50(a) and 50(b), suggest that while Revit excels in supporting traditional water performance measures, it falls short

in providing tools for alternative water solutions. This analysis underscores potential areas where Revit's functionality could be expanded to better meet the holistic water management goals set forth by MOSTADAM.

4.3.5.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-2 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked “to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator using a scale from 1 to 10”. A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 67 provides a summary of the experts' assessment of Revit of Mean ranking level for the support of each Media Type for MOSTADAM “W” indicators in the “W” category. While Figure 51 provides a graphical representation (radar chart) of the data in Table 67.

Table 67 Mean ranking level for the support of each Media Type Support for MOSTADAM W indicator .

INDICATOR	Mean Ranking of the support of Revit media channel for MOSTADAM			
	TD	M	S	DI
Indoor Water Performance	7.0	7.3	6.3	5.3
Outdoor Water Performance	6.3	7.7	6.3	4.7
Alternative Water Solutions	6.3	5.0	0.0	2.3
Water Metering	6.0	5.7	0.0	5.0

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration)

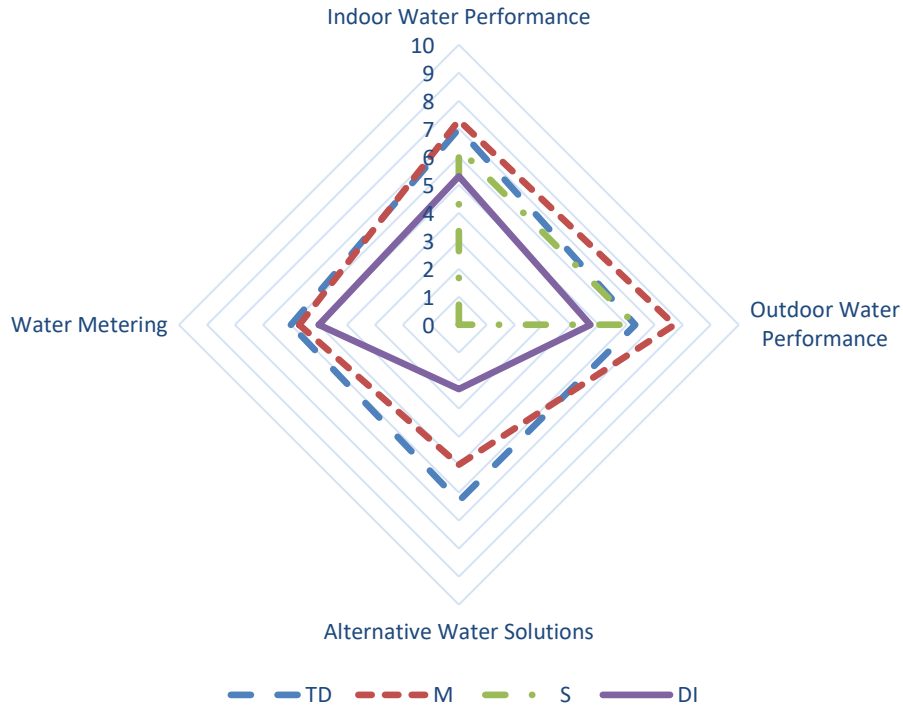


Figure 51 Media Channel Support for Revit MOSTADAM Indicators in the W Category.
(TD: text documentation, M: modeling, S: simulation, and DI: data integration)

Table 67 provides a detailed breakdown of the media channels used in Revit to support indicators in the Water (W) category of MOSTADAM. The table ranks the media types used, including text documentation (TD), modeling (M), simulation (S), and data integration (DI), on a scale from 1 to 10 based on their importance in achieving the indicator requirements. Figure 68 illustrates how these media types contribute to the water-related MOSTADAM indicators.

TD (Text Documentation) plays a significant role across all water-related indicators, particularly in "Indoor Water Performance" (7.0) and "Water Metering" (6.0). This suggests that Revit relies on detailed project documentation to meet water efficiency and performance criteria. TD also has a strong presence in "Outdoor Water Performance" (6.3)

and "Alternative Water Solutions" (6.3), highlighting its importance in documenting water management strategies.

M (Modeling) demonstrates strong support for water-related indicators, particularly in "Outdoor Water Performance" (7.7) and "Indoor Water Performance" (7.3). This reflects Revit's capability to generate 3D models that accurately represent water usage, distribution, and management systems. M plays a key role in visualizing water management strategies, while its lower contribution in "Alternative Water Solutions" (5.0) suggests that modeling is less essential in this context.

S (Simulation) is moderately used in water-related indicators, with the highest support for "Indoor Water Performance" (6.3) and "Outdoor Water Performance" (6.3). Revit's simulation tools are essential in assessing water performance and ensuring that buildings meet water conservation criteria. However, simulation plays no role in "Alternative Water Solutions" and "Water Metering," where dynamic performance analysis is not required.

DI (Data Integration) plays a moderate role, particularly in "Indoor Water Performance" (5.3) and "Water Metering" (5.0), indicating that Revit benefits from integrating external data, such as water usage metrics or environmental datasets, to meet these criteria. However, DI is less critical for "Alternative Water Solutions" (2.3), reflecting a lower reliance on external datasets for this indicator.

In summary, Revit primarily relies on text documentation and modeling to achieve water-related MOSTADAM credits, as indicated in Table 67 and Figure 50. Simulation tools are used to a moderate extent for indoor and outdoor water performance, while data integration plays a supporting role, particularly in metering and performance assessment. The results

highlight the importance of using multiple media channels to meet water conservation and management criteria in the MOSTADAM framework.

4.3.5.4 Assessment of Revit Support for MOSTADAM W Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for MOSTADAM “W” indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study “CS”). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of MOSTADAM indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a ‘fraction of 10’) were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 68 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements “DR”) and task-2 (T2: data based on case study “CS”).

Table 68 Aggregate assessment of the Experts for the level of support of Revit for MOSTADAM “W” indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

Indicators of W category	Level of Support based on T1- Q1 & T2- Q1		Level of Support based on T1- Q2 & T2- Q2	
	Mean (out of 10)	IQR	Mean (out of 7)	IQR
Indoor Water Performance	10.0	0.0	6.9	0.0
Outdoor Water Performance	9.8	0.0	6.8	0.3
Alternative Water Solutions	2.0	0.7	2.3	0.3
Water Metering	5.6	0.0	5.5	1.0

To be able to identify aggregated level of support of Revit for the W indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (**Q2**) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where $\text{mean} \leq 3$. Then also for the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where $\text{mean} \leq 4$.

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the SS indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 68 for **Q1** (mean achievable points out of 10) provide a comprehensive view of Revit's support across MOSTADAM "W" (Water) indicators. The aggregated data from Task-1 and Task-2 reveal that Revit demonstrates strong support for essential water-related indicators, particularly "Indoor Water Performance" and "Outdoor Water Performance." These indicators scored high mean values of 10.0 and 9.8, respectively, with no variability (IQR = 0.0 for both "Indoor

Water Performance" and "Outdoor Water Performance"), indicating unanimous expert consensus on Revit's capability to meet these requirements.

In contrast, "Alternative Water Solutions" received a much lower mean score, with an average of 2.0 and an IQR of 0.7, indicating limited support and reflecting some variability among experts. This lower score suggests that Revit may lack sufficient tools to comprehensively support alternative water solution criteria as outlined by MOSTADAM.

For **Q2** (mean level of support out of 7), the results are similarly varied. "Indoor Water Performance" and "Outdoor Water Performance" continue to receive high scores, with mean values of 6.9 and 6.8 and minimal variability (IQR = 0.0 and 0.3, respectively), reflecting strong consensus among experts regarding Revit's adequacy in these areas. Conversely, "Alternative Water Solutions" has a low mean support score of 2.3 with an IQR of 0.3, further emphasizing its limited support within Revit.

Overall, the high scores and strong agreement for "Indoor Water Performance" and "Outdoor Water Performance" highlight Revit's robustness in addressing primary water management indicators, while the consistently lower support levels for "Alternative Water Solutions" and "Water Metering" suggest areas where Revit's capabilities may need to be expanded to fully align with MOSTADAM's diverse water efficiency standards.

Table 69 Aggregated level of support of Revit for MOSTADAM “W” indicators based on the results of Task-1 and Task2.

Indicators of W category	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
	Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Indoor Water Performance	10.0	0.0	HC	6.9	0.0	HC	HC
Outdoor Water Performance	9.8	0.0	HC	6.8	0.3	HC	HC
Alternative Water Solutions	2.0	0.7	LC	2.3	0.3	LC	LC
Water Metering	5.6	0.0	MC	5.5	1.0	MN	MN

(HC: High with consensus, MC: Moderate with consensus, LC: Moderate with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1 & Q2**, an aggregated level of support is presented in Table 69. The measurement used to measure the aggregated level of support was mentioned in Figure 14 :(*Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators*) in Section 3.2.3.4 in the Methodology chapter 3.

Based on the results in Table 69, the indicator "Indoor Water Performance" is classified as "High with Consensus" (HC). With mean scores of 10.0 in Q1 and 6.9 in Q2, and both having an IQR of 0.0, there is strong expert agreement that Revit provides substantial support for indoor water performance, indicating its adequacy in addressing MOSTADAM’s indoor water efficiency requirements.

Similarly, "Outdoor Water Performance" also achieves a "High with Consensus" (HC) classification, with a mean score of 9.8 in Q1 and 6.8 in Q2, and low variability in expert responses (IQR of 0.0 and 0.3, respectively). This consistent high level of support suggests that Revit is well-equipped to handle outdoor water management requirements in line with MOSTADAM standards.

In contrast, "Alternative Water Solutions" is rated "Low with Consensus" (LC), with mean scores of 2.0 in Q1 and 2.3 in Q2, and minimal variability (IQR of 0.7 and 0.3, respectively). This classification indicates that Revit provides limited support for alternative water strategies, with experts in agreement about its limited functionality in this area.

The indicator "Water Metering" falls under "Moderate with No Consensus" (MN), with a mean score of 5.6 in Q1 and 5.5 in Q2, and IQRs of 0.0 and 1.0, respectively. While Revit shows moderate support for water metering, the variability in expert opinion reflects a lack of strong consensus on its adequacy for this particular requirement.

Overall, these results highlight Revit's strong capabilities in managing indoor and outdoor water performance, which are essential for MOSTADAM's water efficiency goals. However, the low support for "Alternative Water Solutions" and the mixed consensus on "Water Metering" indicate areas where Revit's functionalities could be improved to better align with comprehensive water management strategies as outlined by MOSTADAM.

4.3.6 Assessment of Revit Support for MOSTADAM HC Indicators

The assessment of Revit support for HC indicators in MOSTADAM are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements "DR" of the indicators), T2: (assessment of Revit Support based on Case study "CS" of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.3.6.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-2 of the Expert Panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each MOSTADAM indicator: Q1) “indicate the number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by MOSTADAM”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified MOSTADAM indicator using a 7-point Likert scale”. Appendix A3-T1 presents the detailed responses of each expert in the Expert Panel for each question in task-1: T1-Q1 and T1-Q2. Table 70 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Health & Comfort (HC) category using the two measurements (Q1 and Q2). While Figure 52 provides a graphical representation (radar chart) of the data in Table 70. These two measurements capture the experts’ assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each MOSTADAM HC indicators.

Table 70 Experts assessment of the level of support of Revit for indicators in the HC category based on the documented requirements (DR) of MOSTADAM indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of HC category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (out of max possible points)	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
Outdoor Thermal Comfort	2	1.0	5.0	4.0
Indoor Thermal Comfort	2	2.0	10.0	7.0
Ventilation	1	1.0	10.0	7.0
VOCs and Low-Emitting Materials	2	2.0	10.0	6.8

Access for All	1	1.0	10.0	6.8
Daylight and Visual Comfort	2	2.0	10.0	7.0
Acoustics	1	0.6	5.9	4.5
Indoor Air Quality	1	1.0	10.0	6.5
Active Residents	1	0.7	6.5	5.8
Outdoor Space	1	1.0	10.0	7.0

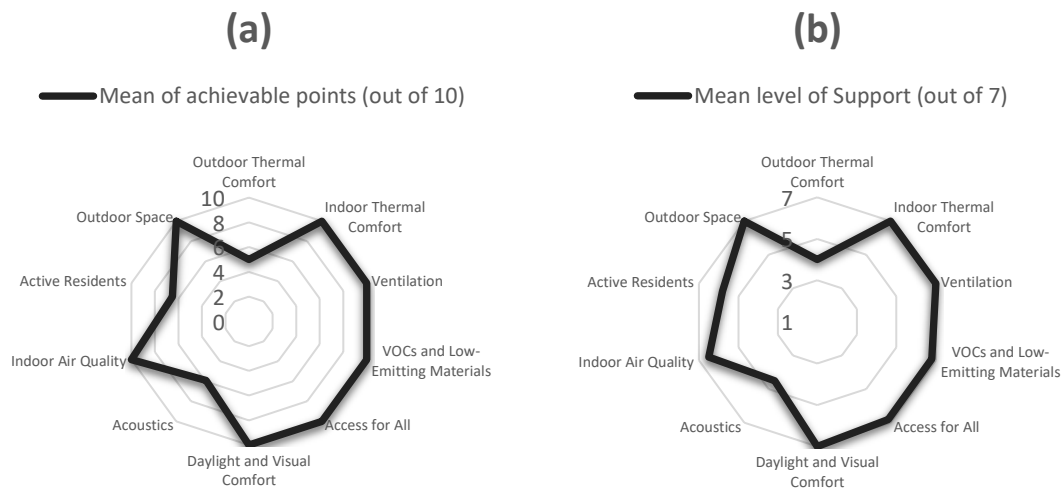


Figure 52 Radar Chart of Expert's assessment of the level of support of Revit for MOSTADAM indicators in the HC category based on the documented requirements (DR) of MOSTADAM using two measurements (Q1 and Q2)

(a) Mean achievable points-Q1 (out of 10) **(b)** Mean level of Revit support for the indicator-Q2 (out of 7)

The results presented in Table 70 and Figure 52(a) regarding **Q1** (mean achievable points for each indicator in the Health and Comfort (HC) category based on the documented requirements) reveal that Revit demonstrates a high level of support for several MOSTADAM indicators related to indoor environments. Specifically, indicators such as "Indoor Thermal Comfort," "Ventilation," "VOCs and Low-Emitting Materials," "Daylight and Visual Comfort," and "Outdoor Space" achieve the maximum possible scores of 10.0 out of 10, indicating that Revit effectively meets these requirements. As illustrated in Figure 52(a), these indicators reach or approach the maximum achievable points,

highlighting Revit's strong alignment with MOSTADAM's standards for indoor comfort and health.

Conversely, "Outdoor Thermal Comfort" and "Acoustics" reflect lower support levels, with mean scores of 5.0 and 5.9 out of 10, respectively. These scores indicate that while Revit provides some functionality to address outdoor comfort and acoustic considerations, it may not fully satisfy MOSTADAM's specific criteria in these areas. Figure 52(a) visually underscores these moderate levels of support, suggesting that enhancements in Revit's capabilities could improve its effectiveness in these aspects of health and comfort.

For **Q2** (mean level of support on a 7-point scale), Figure 52(b) confirms Revit's strong support for indicators such as "Indoor Thermal Comfort," "Ventilation," and "Daylight and Visual Comfort," with each scoring between 6.8 and 7.0. These high scores demonstrate expert consensus that Revit effectively facilitates compliance with MOSTADAM's requirements for thermal, visual, and air quality standards. Meanwhile, "Outdoor Thermal Comfort" and "Acoustics" score moderately, at 4.0 and 4.5, respectively, signaling that while Revit offers some support, it may not fully align with the standards needed for outdoor thermal and acoustic comfort.

In summary, the combined insights from Q1 and Q2, as shown in Figures 52(a) and 52(b), indicate that Revit is well-suited to address many indoor-focused indicators within the HC category, particularly in areas of thermal, visual, and air quality. However, there is room for improvement in its capacity to support outdoor and acoustic-related health and comfort requirements, pointing to areas where further development could enhance Revit's alignment with MOSTADAM's holistic approach to health and comfort.

4.3.6.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study “CS”

During task-2 of session-2 of the Expert Panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each MOSTADAM indicator based on the results of the case study presented to them (CS): Q1) “indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the data of case study presented”, and Q2) “on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the MOSTADAM indicator based on the data of case study presented”. Appendix A3-T2 presents the detailed responses of each expert in the Expert Panel for each question in this task. Table 71 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Health & Comfort (HC) category using the two measurements (Q1 and Q2). While Figure 53 provides a graphical representation radar chart of the data in Table 71. These two measurements capture the experts’ assessment of Revit’s ability to meet/support MOSTADAM requirements for each indicator based on the results of the case study.

Table 71 Experts assessment of the level of support of Revit for MOSTADAM indicators in the HC category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of HC category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (out of max possible points)	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
Outdoor Thermal Comfort	2	1.0	5.0	4.3
Indoor Thermal Comfort	2	2.0	10.0	7.0
Ventilation	1	1.0	10.0	6.3

VOCs and Low-Emitting Materials	2	2.0	10.0	7.0
Access for All	1	1.0	10.0	6.3
Daylight and Visual Comfort	2	2.0	10.0	7.0
Acoustics	1	0.5	5.0	5.0
Indoor Air Quality	1	0.9	8.9	6.3
Active Residents	1	0.6	5.6	5.0
Outdoor Space	1	1.0	10.0	6.8

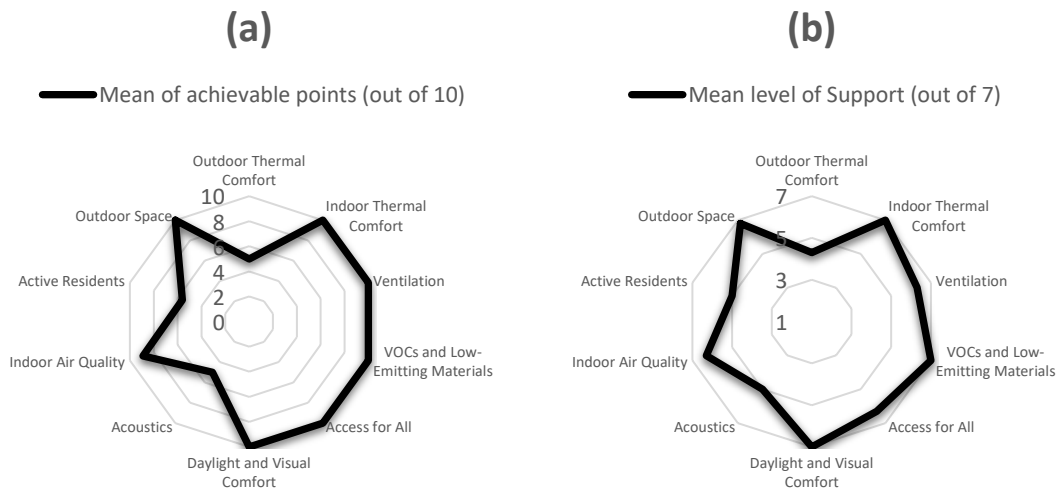


Figure 53 Radar Chart of expert's assessment of the level of support of Revit for MOSTADAM indicators in the HC category based on based on the case study (CS) results using two measurements (Q1 and Q2)

(a) Mean Achievable points- Q1 (out of 10) (b) Mean level of Revit support - Q2 (out of 7)

The results presented in Table 71 and Figure 53(a) regarding **Q1** (mean achievable points for each indicator in the Health and Comfort (HC) category based on the case study results) show that Revit provides a strong level of support for MOSTADAM's indoor-focused health and comfort indicators. Indicators such as "Indoor Thermal Comfort," "Ventilation," "VOCs and Low-Emitting Materials," "Daylight and Visual Comfort," and "Outdoor

Space" achieve the maximum possible mean score of 10.0 out of 10, indicating that Revit is highly capable of meeting these essential requirements. Figure 53(a) visually reinforces these findings, as these indicators reach the upper limit of their achievable points, highlighting Revit's effectiveness in supporting indoor environmental quality within the HC category.

Conversely, "Acoustics" and "Active Residents" show lower levels of support, with mean scores of 5.0 and 5.6 out of 10, respectively. This suggests that while Revit addresses certain aspects of acoustic and activity-promoting spaces, there is room for improvement. "Outdoor Thermal Comfort" also has a moderate support level, scoring 5.0 out of 10, which may indicate some limitations in Revit's functionality for outdoor thermal management, as shown in Figure 53(a).

For **Q2** (mean level of support on a 7-point scale), Figure 53(b) further illustrates Revit's high level of support across various indoor health and comfort indicators. Indicators such as "Indoor Thermal Comfort," "VOCs and Low-Emitting Materials," and "Daylight and Visual Comfort" receive top scores of 7.0 out of 7, indicating unanimous expert agreement on Revit's capability to meet these standards. Meanwhile, "Acoustics" and "Active Residents" receive lower support ratings of 5.0, suggesting moderate agreement on Revit's adequacy for these aspects. "Outdoor Space" also scores relatively high at 6.8, underscoring Revit's capability in addressing outdoor space considerations.

Overall, the insights from both Q1 and Q2, as shown in Figures 53(a) and 53(b), suggest that Revit is highly effective in supporting indoor-focused health and comfort standards in MOSTADAM. However, indicators related to outdoor thermal comfort and acoustic

performance highlight potential areas for improvement to ensure more comprehensive support for health and comfort objectives in sustainable design.

4.3.6.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-2 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked “to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator using a scale from 1 to 10”. A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 72 provides a summary of the experts’ assessment of Revit of Mean ranking level for the support of each Media Type for MOSTADAM HC indicators in the HC category. While Figure 54 provides a graphical representation (radar chart) of the data in Table 72.

Table 72 Mean ranking level for the support of each Media Type Support for MOSTADAM HC indicator.

INDICATOR	Mean Ranking of the support of Revit media channel for MOSTADAM			
	TD	M	S	DI
Outdoor Thermal Comfort	6.0	5.0	5.7	0.0
Indoor Thermal Comfort	6.0	7.0	8.0	5.0
Ventilation	6.0	6.0	7.0	5.0
VOCs and Low-Emitting Materials	7.0	6.0	0.0	5.7
Access for All	6.3	6.0	0.0	0.0
Daylight and Visual Comfort	7.0	7.7	7.0	0.0
Acoustics	5.3	6.0	5.0	0.0
Indoor Air Quality	6.3	6.3	0.0	4.3

Active Residents	5.0	5.0	0.0	4.0
Outdoor Space	6.7	7.0	6.7	0.0

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration)

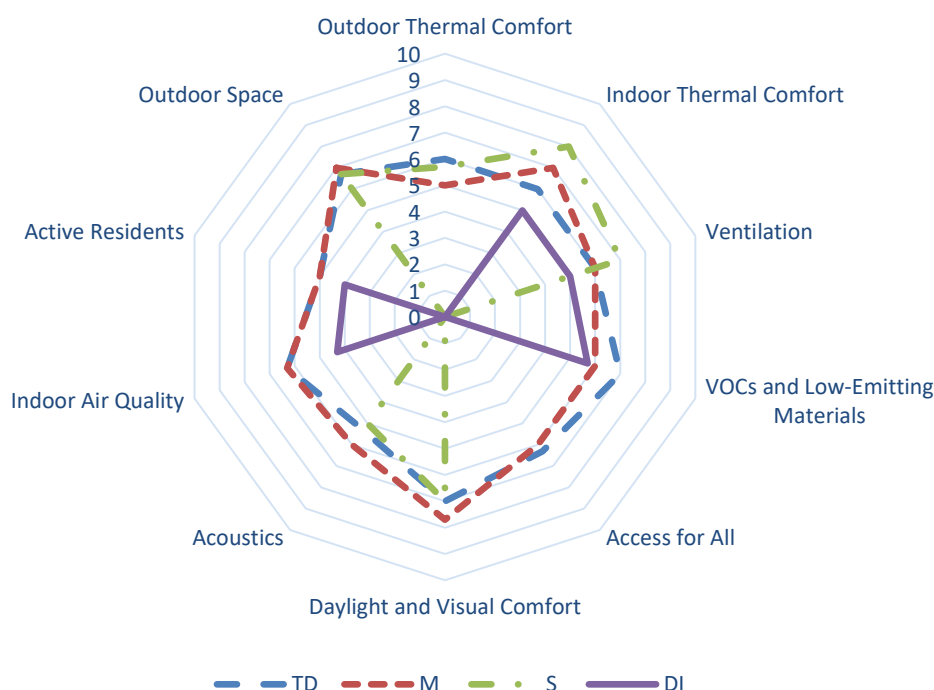


Figure 54 Media Channel Support for Revit MOSTADAM Indicators in the HC Category.
(TD: text documentation, M: modeling, S: simulation, and DI: data integration)

Table 72 provides a comprehensive analysis of the media channels used in Revit to support indicators in the Health and Comfort (HC) category of MOSTADAM. Each media channel—text documentation (TD), modeling (M), simulation (S), and data integration (DI)—is ranked on a scale from 1 to 10 based on its contribution to achieving the indicator requirements. Figure 72 illustrates the breakdown of how different media channels support the HC indicators in Revit.

TD (Text Documentation) plays a prominent role across various indicators, particularly for "VOCs and Low-Emitting Materials" (7.0), "Daylight and Visual Comfort" (7.0), and "Outdoor Space" (6.7). This indicates that detailed documentation is vital for validating

compliance with these indoor environmental quality aspects. TD also contributes significantly to "Ventilation" (6.0), "Indoor Thermal Comfort" (6.0), and "Outdoor Thermal Comfort" (6.0), showcasing its importance in documenting thermal performance and air quality strategies.

M (Modeling) is highly relevant for several HC indicators, particularly for "Daylight and Visual Comfort" (7.7), "Indoor Thermal Comfort" (7.0), and "Outdoor Space" (7.0). This suggests that Revit's modeling capabilities are essential in visualizing and analyzing spatial aspects of comfort, lighting, and air distribution. M plays a critical role in other indicators like "Ventilation" (6.0) and "VOCs and Low-Emitting Materials" (6.0), demonstrating its wide applicability in environmental modeling within Revit.

S (Simulation) plays a critical role in assessing dynamic performance aspects of the HC indicators, particularly for "Indoor Thermal Comfort" (8.0) and "Ventilation" (7.0). Revit's simulation tools are leveraged extensively to assess real-time environmental conditions and their impact on occupant comfort. Simulation is also highly relevant for "Outdoor Space" (6.7) and "Outdoor Thermal Comfort" (5.7), underscoring its importance in outdoor environmental assessments. However, simulation is less utilized in aspects such as "VOCs and Low-Emitting Materials" (0.0) and "Indoor Air Quality" (0.0), where dynamic analysis is not required.

DI (Data Integration) plays a moderate to low role in HC indicators, with the highest contributions in "Ventilation" (5.0), "Indoor Thermal Comfort" (5.0), and "VOCs and Low-Emitting Materials" (5.7). This indicates that external datasets, such as environmental performance data, are sometimes integrated into Revit models to support air quality and

thermal comfort assessments. However, DI shows no contribution for indicators like "Access for All" (0.0) and "Outdoor Space" (0.0), reflecting its limited necessity in simpler accessibility-related and outdoor indicators.

In summary, the HC category in MOSTADAM relies heavily on a combination of text documentation and modeling, as illustrated in Table 72 and Figure 54. Simulation tools are crucial for thermal comfort and ventilation assessments, while data integration plays a supporting role in specific indicators. This breakdown highlights how Revit's various media channels contribute differently depending on the complexity and requirements of each HC indicator.

4.3.6.4 Assessment of Revit Support for MOSTADAM HC Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for MOSTADAM HC indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study "CS"). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of MOSTADAM indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a 'fraction

of 10') were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 73 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements "DR") and task-2 (T2: data based on case study "CS").

Table 73 Aggregate assessment of the Experts for the level of support of Revit for MOSTADAM HC indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

Indicators of HC category	Level of Support based on T1-Q1 & T2-Q1		Level of Support based on T1-Q2 & T2-Q2	
	Mean (out of 10)	IQR	Mean (out of 7)	IQR
Outdoor Thermal Comfort	5.0	0.0	4.1	0.0
Indoor Thermal Comfort	10.0	0.0	7.0	0.0
Ventilation	10.0	0.0	6.6	1.0
VOCs and Low-Emitting Materials	10.0	0.0	6.9	0.0
Access for All	10.0	0.0	6.5	1.0
Daylight and Visual Comfort	10.0	0.0	7.0	0.0
Acoustics	5.4	1.0	4.8	1.0
Indoor Air Quality	9.4	0.5	6.4	1.0
Active Residents	6.1	2.5	5.4	1.0
Outdoor Space	10.0	0.0	6.9	0.0

To be able to identify aggregated level of support of Revit for the HC indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (Q2) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where $\text{mean} \leq 3$. Then also for

the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where $\text{mean} \leq 4$.

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the SS indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 73 for **Q1** (mean achievable points out of 10) provide an in-depth look at Revit's support level across MOSTADAM HC (Health & Comfort) indicators. The aggregated data from Task-1 and Task-2 indicate that Revit demonstrates high support for key human comfort aspects, particularly "Indoor Thermal Comfort," "Ventilation," "VOCs and Low-Emitting Materials," "Daylight and Visual Comfort," and "Outdoor Space." Each of these indicators achieved perfect scores of 10.0 with no variability (IQR = 0.0), signifying unanimous expert agreement on Revit's strong capacity to support these comfort-related requirements.

In contrast, indicators like "Outdoor Thermal Comfort" and "Acoustics" received more moderate scores. For instance, "Outdoor Thermal Comfort" scored 5.0 with an IQR of 0.0, reflecting a lower but still consistent level of support for this indicator. "Acoustics" scored slightly higher with a mean of 5.4 and an IQR of 1.0, suggesting some variability in expert opinions on Revit's effectiveness in handling acoustic considerations.

For **Q2** (mean level of support out of 7), the results similarly highlight strong support levels for several HC indicators. Indicators like "Daylight and Visual Comfort" and "Indoor Thermal Comfort" achieved high mean scores of 7.0 with IQRs of 0.0, reinforcing the

consensus among experts on Revit's suitability for these requirements. In comparison, "Active Residents" scored moderately, with a mean of 5.4 and an IQR of 1.0, suggesting some variability in perceived support but still indicating a generally moderate alignment with MOSTADAM's goals for active lifestyle encouragement.

Overall, the high scores and strong consensus for indicators such as "Indoor Thermal Comfort" and "Daylight and Visual Comfort" underscore Revit's strengths in supporting critical aspects of human comfort. However, the lower support levels and higher variability for indicators like "Active Residents" and "Acoustics" indicate potential areas for enhancement to better address the full spectrum of MOSTADAM's HC criteria.

Table 74 Aggregated level of support of Revit for MOSTADAM HC indicators based on the results of Task-1 and Task2.

Indicators of HC category	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
	Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Outdoor Thermal Comfort	5.0	0.0	MC	4.1	0.0	MC	MC
Indoor Thermal Comfort	10.0	0.0	HC	7.0	0.0	HC	HC
Ventilation	10.0	0.0	HC	6.6	1.0	HC	HC
VOCs and Low-Emitting Materials	10.0	0.0	HC	6.9	0.0	HC	HC
Access for All	10.0	0.0	HC	6.5	1.0	HC	HC
Daylight and Visual Comfort	10.0	0.0	HC	7.0	0.0	HC	HC
Acoustics	5.4	1.0	MC	4.8	1.0	MC	MC
Indoor Air Quality	9.4	0.5	HC	6.4	1.0	HC	HC
Active Residents	6.1	2.5	MN	5.4	1.0	MC	MN
Outdoor Space	10.0	0.0	HC	6.9	0.0	HC	HC

(HC: High with consensus, MC: Moderate with consensus, LC: Moderate with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1 & Q2**, an aggregated level of support is presented in Table 74. The measurement used to measure the aggregated level of support was mentioned in Figure 14 :(*Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators*) in Section 3.2.3.4 in the Methodology chapter 3.

Based on the results in Table 74, the indicator "Outdoor Thermal Comfort" is classified as "Moderate with Consensus" (MC). With mean scores of 5.0 in Q1 and 4.1 in Q2, both with IQRs of 0.0, the results reflect a moderate level of support from Revit for outdoor thermal comfort, with strong consensus among experts on its adequacy.

The "Indoor Thermal Comfort" indicator, on the other hand, achieves a "High with Consensus" (HC) classification. It received perfect mean scores of 10.0 in Q1 and 7.0 in Q2, both with IQRs of 0.0, indicating unanimous agreement on Revit's strong support for indoor thermal comfort requirements.

Similarly, indicators like "Ventilation," "VOCs and Low-Emitting Materials," "Access for All," "Daylight and Visual Comfort," and "Outdoor Space" are also rated "High with Consensus" (HC). Each of these indicators scored a mean of 10.0 in Q1 and a high mean score in Q2, with low IQRs, demonstrating that Revit provides substantial support for these health and comfort-related indicators, with clear expert consensus on its capabilities in these areas.

In contrast, the "Acoustics" indicator is rated "Moderate with Consensus" (MC), with mean scores of 5.4 in Q1 and 4.8 in Q2, and both metrics having an IQR of 1.0. This reflects a moderate level of support for acoustics within Revit, with experts generally in agreement about its capabilities, although to a lesser extent than for thermal comfort.

"Active Residents" is classified as "Moderate with No Consensus" (MN), achieving mean scores of 6.1 in Q1 and 5.4 in Q2, with higher IQRs of 2.5 and 1.0. This variability indicates differing expert opinions on Revit's support for this indicator, reflecting a moderate but somewhat inconsistent level of support.

Overall, the findings show Revit's strong consensus-backed support for critical health and comfort indicators, particularly for "Indoor Thermal Comfort," "Daylight and Visual Comfort," and "Outdoor Space." However, indicators such as "Acoustics" and "Active Residents" show areas where Revit's capabilities may vary, highlighting potential areas for improvement in addressing the full range of MOSTADAM's health and comfort standards.

4.3.7 Assessment of Revit Support for MOSTADAM MW Indicators

The assessment of Revit support for MW indicators in MOSTADAM are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements "DR" of the indicators), T2: (assessment of Revit Support based on Case study "CS" of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.3.7.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-2 of the Expert Panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each MOSTADAM indicator: Q1) "indicate the

number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by MOSTADAM”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified MOSTADAM indicator using a 7-point Likert scale”. Appendix A3-T1 presents the detailed responses of each expert in the Expert Panel for each question in task-1: T1-Q1 and T1-Q2. Table 75 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Materials & Waste (MW) category using the two measurements (Q1 and Q2). While Figure 55 provides a graphical representation (radar chart) of the data in Table 75. These two measurements capture the experts’ assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each MOSTADAM MW indicators.

Table 75 Experts assessment of the level of support of Revit for indicators in the MW category based on the documented requirements (DR) of MOSTADAM indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of MW category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (out of max possible points)	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
Construction Waste Management	1	0.0	0.0	1.0
Non-Polluting Insulation Materials	1	1.0	10.0	7.0
Recycled Materials	2	2.0	10.0	6.8

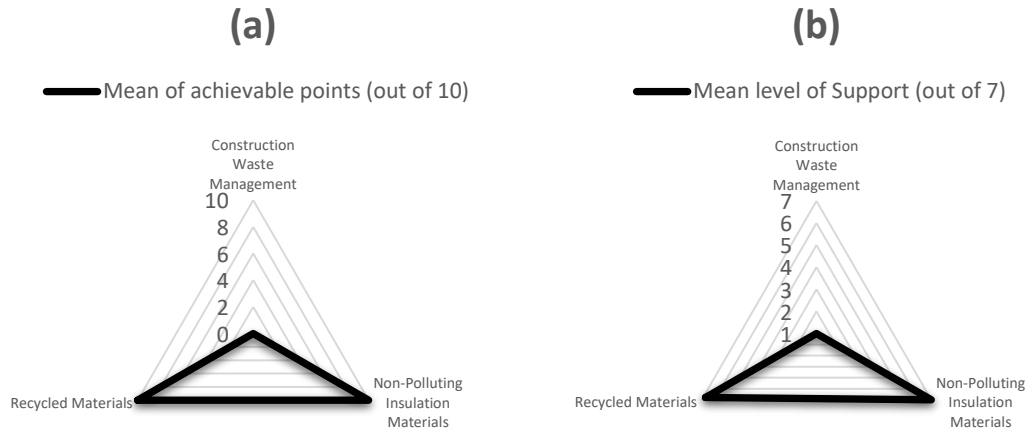


Figure 55 Radar Chart of Expert's assessment of the level of support of Revit for MOSTADAM indicators in the MW category based on the documented requirements (DR) of MOSTADAM using two measurements (Q1 and Q2)

(a) Mean achievable points-Q1 (out of 10) (b) Mean level of Revit support for the indicator-Q2 (out of 7)

The results presented in Table 75 and Figure 55(a) regarding **Q1** (mean achievable points for each indicator in the Materials and Waste (MW) category based on the documented requirements) show that Revit provides high support for indicators focused on sustainable material use. Specifically, "Non-Polluting Insulation Materials" and "Recycled Materials" achieve full mean scores of 10.0 out of 10, suggesting that Revit is well-equipped to support the selection and integration of environmentally friendly materials in construction projects. Figure 55(a) visually reinforces this by displaying these indicators at the upper end of achievable points, demonstrating Revit's strong alignment with MOSTADAM's goals for sustainable material use.

In contrast, "Construction Waste Management" shows no support, with a mean score of 0.0 out of 10. This result indicates that Revit does not currently facilitate construction waste management practices as outlined by MOSTADAM. Figure 55(a) highlights this gap,

underscoring the lack of alignment between Revit's current capabilities and the waste management standards specified in the MW category.

Regarding **Q2** (mean level of support on a 7-point scale), Figure 55(b) shows strong expert consensus on Revit's support for "Non-Polluting Insulation Materials," scoring the highest possible support level of 7.0. Similarly, "Recycled Materials" achieves a mean score of 6.8, further indicating that Revit effectively supports these materials-related indicators with near-unanimous expert agreement. However, "Construction Waste Management" scores only 1.0, highlighting limited perceived support and emphasizing the need for enhanced functionality in Revit to address this aspect.

In summary, the insights from both Q1 and Q2, as presented in Figures 55(a) and 55(b), suggest that while Revit performs well in supporting sustainable materials selection, it lacks the tools necessary for effective construction waste management. This analysis points to potential opportunities for Revit's development to better meet comprehensive waste management objectives within the MW category in sustainable design frameworks like MOSTADAM.

4.3.7.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study "CS"

During task-2 of session-2 of the Expert Panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each MOSTADAM indicator based on the results of the case study presented to them (CS): Q1) "indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the

data of case study presented”, and Q2) “on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the MOSTADAM indicator based on the data of case study presented”. Appendix A3-T2 presents the detailed responses of each expert in the Expert Panel for each question in this task. Table 76 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Materials & Waste (MW) category using the two measurements (Q1 and Q2). While Figure 56 provides a graphical representation radar chart of the data in Table 76. These two measurements capture the experts’ assessment of Revit’s ability to meet/support MOSTADAM requirements for each indicator based on the results of the case study.

Table 76 Experts assessment of the level of support of Revit for MOSTADAM indicators in the MW category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of MW category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (out of max possible points)	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
Construction Waste Management	1	0.0	0.0	1.0
Non-Polluting Insulation Materials	1	1.0	10.0	6.8
Recycled Materials	2	2.0	10.0	6.5

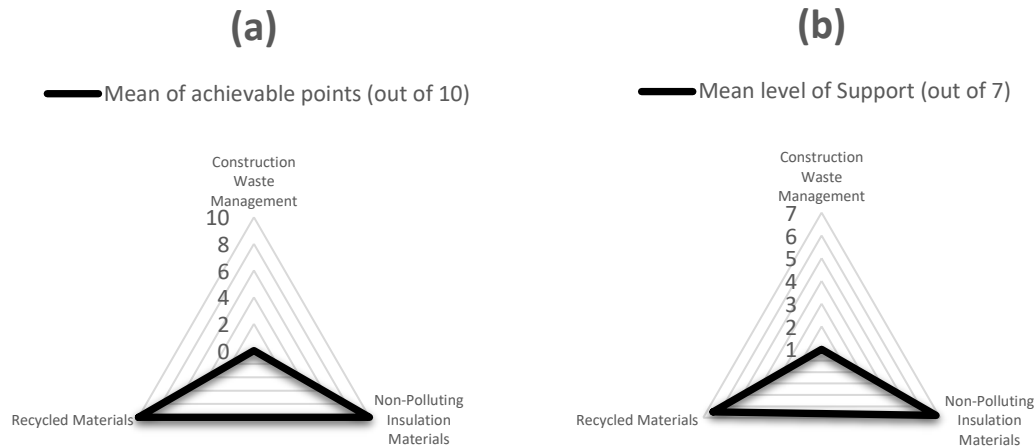


Figure 56 Radar Chart of expert's assessment of the level of support of Revit for MOSTADAM indicators in the MW category based on based on the case study (CS) results using two measurements (Q1 and Q2)

(a) Mean Achievable points- Q1 (out of 10) (b) Mean level of Revit support - Q2 (out of 7)

The results presented in Table 76 and Figure 56(a) regarding **Q1** (mean achievable points for each indicator in the Materials and Waste (MW) category based on the case study results) indicate that Revit shows strong support for sustainable materials indicators, but limited support for waste management. Specifically, "Non-Polluting Insulation Materials" and "Recycled Materials" achieve high mean scores of 10.0 out of 10, suggesting that Revit effectively supports the selection of environmentally friendly and recycled materials in line with MOSTADAM requirements. As illustrated in Figure 56(a), these indicators reach the maximum achievable points, demonstrating Revit's alignment with MOSTADAM's sustainability goals for material use.

Conversely, "Construction Waste Management" received no support, with a mean score of 0.0 out of 10. This outcome reflects a gap in Revit's capabilities, as it does not facilitate construction waste management practices as specified by MOSTADAM. Figure 56(a)

visually underscores this shortfall, highlighting that Revit's current tools are not yet equipped to address the waste management criteria effectively.

In terms of **Q2** (mean level of support on a 7-point scale), Figure 56(b) shows high expert consensus on Revit's support for "Non-Polluting Insulation Materials," scoring 6.8, and "Recycled Materials," with a score of 6.5. These scores confirm that experts recognize Revit's capabilities in supporting sustainable material selection within the MW category. However, "Construction Waste Management" remains low at 1.0, indicating minimal perceived support and highlighting an area where Revit may need additional development to fully meet the waste management standards in MOSTADAM.

Overall, insights from both Q1 and Q2, as shown in Figures 56(a) and 56(b), suggest that while Revit excels in supporting sustainable material use, it lacks necessary features for comprehensive waste management. This analysis points to opportunities for Revit to further align with MOSTADAM's goals by enhancing its functionality in the area of waste management within the MW category.

4.3.7.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-2 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked "to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator using a scale from 1 to 10". A rank of 10 indicates that the media/channel is the

most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 77 provides a summary of the experts' assessment of Revit of Mean ranking level for the support of each Media Type for MOSTADAM MW indicators in the MW category. While Figure 57 provides a graphical representation (radar chart) of the data in Table 77.

Table 77 Mean ranking level for the support of each Media Type Support for MOSTADAM MW indicator

INDICATOR	Mean Ranking of the support of Revit media channel for MOSTADAM			
	TD	M	S	DI
Construction Waste Management	7.0	0.0	0.0	0.0
Non-Polluting Insulation Materials	7.0	6.0	0.0	5.0
Recycled Materials	7.0	6.0	0.0	5.0

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration)

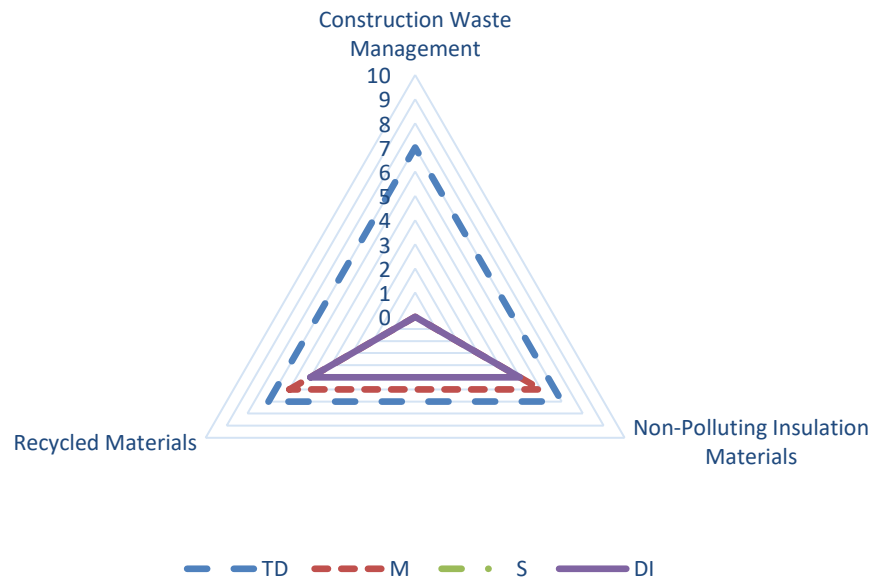


Figure 57 Media Channel Support for Revit MOSTADAM Indicators in the MW Category.
(TD: text documentation, M: modeling, S: simulation, and DI: data integration)

Table 77 provides a detailed analysis of the media types used in Revit to support the Materials and Waste (MW) category indicators in MOSTADAM. The media types include text documentation (TD), modeling (M), simulation (S), and data integration (DI), ranked on a scale from 1 to 10 based on their role in achieving the indicator requirements. Figure 67 illustrates the rankings for each media type's contribution to the MW indicators.

TD (Text Documentation) consistently plays a crucial role across all MW indicators, with a perfect score of 7.0 for "Construction Waste Management," "Non-Polluting Insulation Materials," and "Recycled Materials." This shows that documentation is essential in verifying compliance with waste management and material selection criteria in MOSTADAM. TD remains the dominant media type for these indicators, emphasizing its critical role in describing processes, material specifications, and compliance measures in sustainability assessments.

M (Modeling) is moderately important for "Non-Polluting Insulation Materials" and "Recycled Materials," scoring 6.0 in both indicators. This demonstrates that modeling plays a key role in visualizing and analyzing the material choices and their applications within the Revit environment, especially in sustainable design practices. However, for "Construction Waste Management," M is not used (0.0), indicating that waste management primarily relies on textual documentation and does not benefit much from Revit's modeling capabilities.

S (Simulation) is not utilized in any of the MW indicators, scoring 0.0 across the board. This suggests that simulation tools are not necessary for assessing construction waste

management or material sustainability in MOSTADAM, as these indicators rely more on documentation and modeling rather than performance-based simulations.

DI (Data Integration) shows a moderate level of support for "Non-Polluting Insulation Materials" (5.0) and "Recycled Materials" (5.0), reflecting the need to integrate external datasets, such as environmental product declarations or recycled content information, into Revit models. However, for "Construction Waste Management," DI is not utilized (0.0), indicating that this indicator relies solely on internal documentation without the need for external data integration.

In summary, the MW category in MOSTADAM relies heavily on text documentation, as evidenced by its high scores across all indicators in Table 77 and Figure 57. Modeling plays a supporting role for material-related indicators but is not necessary for waste management. Simulation is not utilized at all, while data integration is moderately important for material sustainability indicators. This distribution reflects Revit's strengths in documentation and modeling for sustainability assessments in the MW category.

4.3.7.4 Assessment of Revit Support for MOSTADAM MW Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for MOSTADAM SS indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study "CS"). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of MOSTADAM indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a ‘fraction of 10’) were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 78 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements “DR”) and task-2 (T2: data based on case study “CS”).

Table 78 Aggregate assessment of the Experts for the level of support of Revit for MOSTADAM MW indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

Indicators of MW category	Level of Support based on T1- Q1 & T2- Q1		Level of Support based on T1- Q2 & T2- Q2	
	Mean (out of 10)	IQR	Mean (out of 7)	IQR
Construction Waste Management	0.0	0.0	1.0	0.0
Non-Polluting Insulation Materials	10.0	0.0	6.9	0.0
Recycled Materials	10.0	0.0	6.6	1.0

To be able to identify aggregated level of support of Revit for the MW indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (**Q2**) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where mean ≤ 3 . Then also for the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where mean ≤ 4 .

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the TC indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 78 for **Q1** (mean achievable points out of 10) offer a clear view of Revit's support level across MOSTADAM MW (Materials and Waste) indicators. The aggregated data from both Task-1 and Task-2 reveal that Revit provides high support for "Non-Polluting Insulation Materials" and "Recycled Materials," with each achieving perfect mean scores of 10.0 and zero variability (IQR = 0.0 for Non-Polluting Insulation Materials and IQR = 1.0 for Recycled Materials). These high scores indicate strong consensus among experts regarding Revit's capacity to support these sustainability-focused material indicators.

In contrast, the indicator "Construction Waste Management" received the lowest possible score, with a mean of 0.0 and an IQR of 0.0 for both Q1 and Q2, highlighting a unanimous agreement on Revit's lack of support for this particular requirement. This result underscores a gap in Revit's capabilities, especially in addressing waste management needs within MOSTADAM's MW category.

For **Q2** (mean level of support out of 7), "Non-Polluting Insulation Materials" and "Recycled Materials" again demonstrate high levels of support, with mean scores of 6.9 and 6.6, respectively. The low IQR values further suggest a strong consensus among experts on Revit's effectiveness in managing these sustainable material requirements.

However, "Construction Waste Management" remains in the low support category with a mean of 1.0 and zero variability, reinforcing Revit's limited applicability in this area.

Overall, the high scores and consensus for indicators such as "Non-Polluting Insulation Materials" emphasize Revit's strengths in material sustainability, while the low scores for "Construction Waste Management" identify a key area where Revit's functionality could be improved to better align with MOSTADAM's comprehensive waste management standards.

Table 79 Aggregated level of support of Revit for MOSTADAM MW indicators based on the results of Task-1 and Task2.

Indicators of MW category	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
	Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Construction Waste Management	0.0	0.0	LC	1.0	0.0	LC	LC
Non-Polluting Insulation Materials	10.0	0.0	HC	6.9	0.0	HC	HC
Recycled Materials	10.0	0.0	HC	6.6	1.0	HC	HC

(HC: High with consensus, MC: Moderate with consensus, LC: Moderate with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1 & Q2**, an aggregated level of support is presented in Table 79. The measurement used to measure the aggregated level of support was mentioned in Figure 14 :*(Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators)* in Section 3.2.3.4 in the Methodology chapter 3.

According to the results in Table 79, the indicator "Construction Waste Management" is classified as "Low with Consensus" (LC). With mean scores of 0.0 in both Q1 and Q2, and IQRs of 0.0 for both, the results highlight that Revit provides minimal support for this

indicator, with unanimous expert agreement on its limitations in addressing construction waste management requirements.

In contrast, the indicators "Non-Polluting Insulation Materials" and "Recycled Materials" demonstrate high support, each achieving a "High with Consensus" (HC) classification. Both indicators received a mean score of 10.0 in Q1, with "Non-Polluting Insulation Materials" and "Recycled Materials" scoring 6.9 and 6.6 in Q2, respectively, and low IQRs (0.0 for "Non-Polluting Insulation Materials" and 1.0 for "Recycled Materials"). These high scores and low variability indicate strong expert agreement on Revit's capabilities in supporting sustainable material choices aligned with MOSTADAM's MW requirements.

Overall, the results reveal a strong consensus that Revit effectively supports sustainable materials, particularly for "Non-Polluting Insulation Materials" and "Recycled Materials." However, "Construction Waste Management" remains a clear area where Revit's functionality is limited, underscoring the need for potential enhancements to better meet the comprehensive waste management criteria outlined by MOSTADAM.

4.3.8 Assessment of Revit Support for MOSTADAM EI Indicators

The assessment of Revit support for EI indicators in MOSTADAM are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements "DR" of the indicators), T2: (assessment of Revit Support based on Case study "CS" of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.3.8.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-2 of the Expert Panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each MOSTADAM indicator: Q1) “indicate the number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by MOSTADAM”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified MOSTADAM indicator using a 7-point Likert scale”. Appendix A3-T1 presents the detailed responses of each expert in the Expert Panel for each question in task-1: T1-Q1 and T1-Q2. Table 80 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Education & Innovation (EI) category using the two measurements (Q1 and Q2). These two measurements capture the experts’ assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each MOSTADAM EI indicators.

Table 80 Experts assessment of the level of support of Revit for indicators in the EI category based on the documented requirements (DR) of MOSTADAM indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of EI category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (out of max possible points)	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
Innovation	2	2.0	10.0	6.3
Mostadam Guide	2	1.1	5.6	5.0

The results presented in Table 80 regarding **Q1** (mean achievable points for each indicator in the Environmental Innovation (EI) category based on the documented requirements)

reveal that Revit provides varying levels of support for MOSTADAM's EI indicators. Specifically, the "Innovation" indicator achieves the highest level of support, with a mean score of 10.0 out of 10 achievable points, reflecting Revit's robust capacity to address innovation-related criteria. This indicates that Revit is well-aligned with MOSTADAM's goals for encouraging innovation in sustainable design.

In contrast, the "Mostadam Guide" indicator shows moderate support, with a mean score of 5.6 out of 10 achievable points. This suggests that while Revit can partially meet the requirements outlined in the Mostadam Guide, there are limitations in fully supporting this particular indicator's detailed requirements.

Regarding Q2 (mean level of support on a 7-point scale), "Innovation" again demonstrates a strong level of support with a mean score of 6.3, suggesting that experts perceive Revit as effective in facilitating innovative sustainability practices. The "Mostadam Guide" indicator scores 5.0, indicating a moderate level of expert-perceived support. This reflects some alignment with MOSTADAM's guidelines, though Revit may require further enhancement to fully meet these standards.

Overall, the insights from both Q1 and Q2 suggest that Revit offers substantial support for innovation within the EI category, as seen in the high scores for "Innovation." However, the "Mostadam Guide" indicator shows a moderate level of support, highlighting potential areas for improvement in Revit's alignment with the comprehensive guidance provided by MOSTADAM for environmental innovation. This analysis emphasizes the strengths of Revit in innovation while identifying opportunities for development to enhance its support for the EI category in MOSTADAM.

4.3.8.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study “CS”

During task-2 of session-2 of the Expert Panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each MOSTADAM indicator based on the results of the case study presented to them (CS): Q1) “indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the data of case study presented”, and Q2) “on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the MOSTADAM indicator based on the data of case study presented”. Appendix A3-T2 presents the detailed responses of each expert in the Expert Panel for each question in this task. Table 81 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Education & Innovation (EI) category using the two measurements (Q1 and Q2). These two measurements capture the experts’ assessment of Revit's ability to meet/support MOSTADAM requirements for each indicator based on the results of the case study.

Table 81 Experts assessment of the level of support of Revit for MOSTADAM indicators in the EI category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of EI category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (out of max possible points)	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
Innovation	2	1.8	9.1	6.3
Mostadam Guide	2	1.0	5.0	4.5

The results presented in Table 81 regarding **Q1** (Mean achievable points for each indicator in the Environmental Innovation (EI) category based on the case study results) indicate that

Revit demonstrates a solid level of support for MOSTADAM's EI indicators. The "Innovation" indicator scores notably high, with a mean of 9.1 out of 10 achievable points, suggesting that Revit is well-suited to support innovative sustainability practices aligned with MOSTADAM's objectives. This high score highlights Revit's capabilities in fostering innovation within sustainable design.

On the other hand, the "Mostadam Guide" indicator shows moderate support, with a mean score of 5.0 out of 10 achievable points. This result suggests that Revit provides some alignment with the Mostadam Guide but may lack full support for all detailed requirements outlined in this indicator.

Regarding **Q2** (mean level of support on a 7-point scale), the "Innovation" indicator again reflects a strong level of expert-perceived support with a mean score of 6.3. This reinforces the view that Revit effectively supports innovative sustainability criteria within the EI category. Conversely, the "Mostadam Guide" scores a lower 4.5, indicating that experts perceive Revit's support for this indicator as moderate, pointing to areas where Revit's functionality could be enhanced to align more closely with MOSTADAM's comprehensive guidance.

Overall, the findings from both Q1 and Q2 suggest that while Revit is well-positioned to support innovation in sustainable design, as demonstrated by the high scores for the "Innovation" indicator, there is room for improvement in fully meeting the guidance provided by MOSTADAM under the "Mostadam Guide" indicator. This assessment underscores Revit's strengths in supporting innovation within the EI category, while also identifying opportunities for further development.

4.3.8.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-2 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked “to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator using a scale from 1 to 10”. A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 82 provides a summary of the experts’ assessment of Revit of Mean ranking level for the support of each Media Type for MOSTADAM EI indicators in the EI category.

Table 82 Mean ranking level for the support of each Media Type Support for MOASTADAM EI indicator .

INDICATOR	Mean Ranking of the support of Revit media channel for MOSTADAM			
	TD	M	S	DI
Innovation	6.3	5.7	3.3	0.0
Mostadam Guide	6.0	5.0	0.0	2.0

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration)

Table 82 provides a detailed analysis of the media types used in Revit to support the Education and Innovation (EI) category indicators in MOSTADAM. The media types used in the table include text documentation (TD), modeling (M), simulation (S), and data integration (DI), each ranked on a scale from 1 to 10 for their contribution to achieving the indicator requirements. This table presents the experts' assessments of the relevance of each media type in achieving the EI category indicators.

TD (Text Documentation) plays a significant role in both "Innovation" (6.3) and "Mostadam Guide" (6.0). This shows that documentation is essential for fulfilling the innovation aspects and adhering to the Mostadam guide criteria, reflecting Revit's capacity to handle descriptive and compliance-related tasks effectively. High scores in TD indicate the importance of written validation and documentation in these indicators.

M (Modeling) shows a moderate level of importance in supporting the "Innovation" indicator (5.7) and "Mostadam Guide" (5.0). This suggests that modeling within Revit is helpful for visualizing innovative elements and understanding how the design aligns with Mostadam guide standards. The moderate role of modeling highlights Revit's ability to create detailed models to meet these sustainability innovation requirements.

S (Simulation) shows limited relevance, with a low score of 3.3 for "Innovation" and no use (0.0) for "Mostadam Guide." This indicates that simulation tools within Revit are not heavily used in supporting these indicators, especially in the context of the Mostadam guide. This suggests that innovation in MOSTADAM relies more on documentation and modeling rather than performance-based simulations.

DI (Data Integration) plays a minimal role in the EI category, with no support (0.0) for "Innovation" and only a limited score of 2.0 for "Mostadam Guide." This reflects that external data sources are not as critical in these areas, and the internal capabilities of Revit are generally sufficient to meet the requirements without significant data integration.

In summary, TD and M are the primary media channels for achieving the EI category indicators in MOSTADAM, as shown in Table 82. TD is crucial for documenting innovation and adhering to the Mostadam Guide, while modeling also plays a supportive

role. Simulation has limited relevance, and data integration is used minimally, highlighting Revit's strengths in documentation and modeling for these indicators.

4.3.8.4 Assessment of Revit Support for MOSTADAM EI Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for MOSTADAM EI indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study "CS"). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of MOSTADAM indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a 'fraction of 10') were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 83 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements "DR") and task-2 (T2: data based on case study "CS").

Table 83 Aggregate assessment of the Experts for the level of support of Revit for MOSTADAM EI indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

Indicators of EI category	Level of Support based on T1- Q1 & T2- Q1		Level of Support based on T1- Q2 & T2- Q2	
	Mean (out of 10)	IQR	Mean (out of 7)	IQR
Innovation	9.5	0.3	6.3	0.3
Mostadam Guide	5.3	0.0	4.8	1.0

To be able to identify aggregated level of support of Revit for the EI indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (**Q2**) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where mean ≤ 3 . Then also for the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where mean ≤ 4 .

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the TC indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 83 for **Q1** (mean achievable points out of 10) provide insight into Revit's support level across MOSTADAM EI indicators. The aggregated data from Task-1 and Task-2 show that Revit demonstrates strong support for the "Innovation" indicator, with a high mean score of 9.5 and minimal variability (IQR = 0.3). This result reflects a strong consensus among experts on Revit's capability to support innovative environmental practices within the MOSTADAM framework.

In contrast, the "Mostadam Guide" indicator achieves a moderate support level, with a mean score of 5.3 out of 10 and an IQR of 0.0 for Q1. The lack of variability suggests a general agreement among experts on Revit's limited but moderate capacity to address the requirements outlined in the Mostadam Guide.

For **Q2** (mean level of support out of 7), the "Innovation" indicator maintains a high level of support with a mean score of 6.3 and an IQR of 0.3, indicating consistent expert agreement on Revit's adequacy in supporting innovation-oriented aspects of MOSTADAM. Meanwhile, the "Mostadam Guide" shows a moderate level of support with a mean of 4.8 and an IQR of 1.0, reflecting a wider range of expert opinions but still suggesting some alignment on Revit's partial adequacy for this requirement.

Overall, the high scores and consensus for "Innovation" underscore Revit's strengths in fostering innovative sustainability practices, while the moderate support level for the "Mostadam Guide" points to an area where Revit could be further enhanced to align more fully with the comprehensive guidance outlined in the Mostadam framework.

Table 84 Aggregated level of support of Revit for MOSTADAM EI indicators based on the results of Task-1 and Task2.

Indicators of EI category	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
	Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Enhanced indoor air quality strategies	9.5	0.3	HC	6.3	0.3	HC	HC
Low-emitting materials	5.3	0.0	MC	4.8	1.0	MC	MC

(HC: High with consensus, MC: Moderate with consensus, LC: Moderate with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1 & Q2**, an aggregated level of support is presented in Table 54. The measurement used to measure the aggregated level of support

was mentioned in Figure 84 :*(Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators)* in Section 3.2.3.4 in the Methodology chapter 3.

According to the results in Table 84, the indicator "Enhanced Indoor Air Quality Strategies" is classified as "High with Consensus" (HC). With mean scores of 9.5 in Q1 and 6.3 in Q2, along with low IQRs of 0.3 for both metrics, these results reflect strong support for Revit's capability to support this indicator, with experts in agreement on its effectiveness in addressing indoor air quality enhancement strategies as outlined by MOSTADAM.

On the other hand, the "Low-Emitting Materials" indicator achieves a "Moderate with Consensus" (MC) classification, with mean scores of 5.3 in Q1 and 4.8 in Q2, and IQRs of 0.0 and 1.0, respectively. These scores indicate that while Revit provides moderate support for low-emitting material requirements, there is a consistent level of agreement among experts, suggesting that Revit's support for this indicator is recognized but may not fully satisfy all requirements in this category.

4.3.9 Assessment of Revit Support for MOSTADAM PMM Indicators

The assessment of Revit support for PMM indicators in MOSTADAM are based on the three tasks which are: T1: (assessment of Revit support based on the documented requirements "DR" of the indicators), T2: (assessment of Revit Support based on Case study "CS" of the indicators), and T3: (Assessment of the support of Revit Media channels for the indicators). The three task assessment is presented in the following sub sections ending with the assessment based on the aggregated data of Task 1 & 2.

4.3.9.1 Results of Task-1 of Expert Panel: assessment of Revit support based on the documented requirements (DR) of the indicators.

During task-1 of session-2 of the Expert Panel assessment, the experts were asked two questions based on their knowledge and the presentation provided on the documented requirements and objectives (DR) of each MOSTADAM indicator: Q1) “indicate the number of points that you think Revit will be able to assess/achieve from the ‘possible points’ assigned for each indicator as specified by MOSTADAM”, and Q2) “rate the level of which you think Revit is able to achieve/cover the requirements of the specified MOSTADAM indicator using a 7-point Likert scale”. Appendix A3-T1 presents the detailed responses of each expert in the Expert Panel for each question in task-1: T1-Q1 and T1-Q2. Table 85 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Policies, Management, and Maintenance (PMM) category using the two measurements (Q1 and Q2). While Figure 58 provides a graphical representation (radar chart) of the data in Table 85. These two measurements capture the experts’ assessment of Revit's ability to meet/support the documented requirements (DR) and objectives of each MOSTADAM PMM indicators.

Table 85 Experts assessment of the level of support of Revit for indicators in the PMM category based on the documented requirements (DR) of MOSTADAM indicators using two measurements: T1-Q1 and T1-Q2.

Indicators of PMM category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (out of max possible points)	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
Residential Waste Management	1	0.0	0.0	1.0
Sustainable Procurement	1	0.0	0.0	1.0
Building Performance Monitoring	2	0.5	2.3	2.3

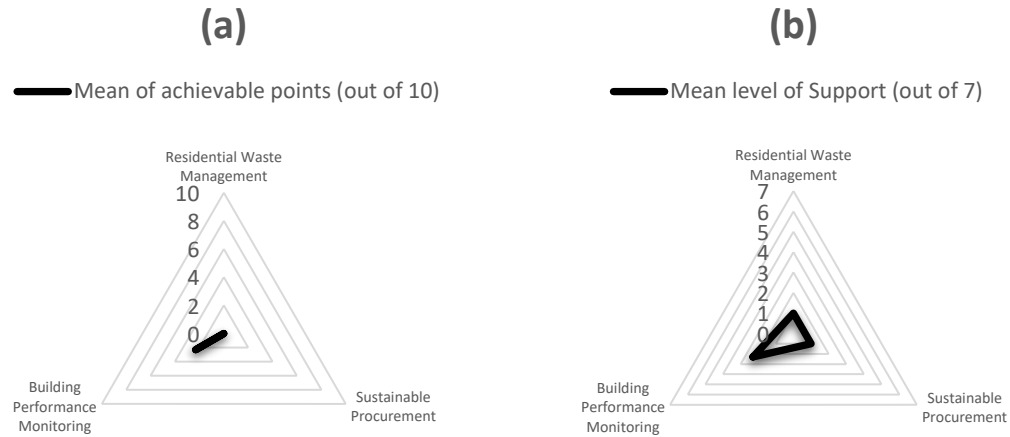


Figure 58 Radar Chart of Expert's assessment of the level of support of Revit for MOSTADAM indicators in the PMM category based on the documented requirements (DR) of MOSTADAM using two measurements (Q1 and Q2)

(a) Mean achievable points-Q1 (out of 10) (b) Mean level of Revit support for the indicator-Q2 (out of 7)

The results presented in Table 85 and Figure 58(a) regarding **Q1** (mean achievable points for each indicator in the Post-Management and Monitoring (PMM) category based on the documented requirements) show that Revit provides limited support for MOSTADAM's PMM indicators. Specifically, the indicators "Residential Waste Management" and "Sustainable Procurement" received a mean achievable score of 0.0 out of the maximum points possible, indicating that Revit currently lacks functionality to address these aspects of post-management and sustainable procurement. As illustrated in Figure 58(a), these indicators fall significantly short of their maximum potential, highlighting a gap in Revit's tools for managing residential waste and supporting sustainable procurement practices.

In contrast, "Building Performance Monitoring" achieves a moderate level of support with a mean score of 2.3 out of 10, suggesting that Revit provides some capacity for monitoring building performance, though still limited. Figure 62(a) visually reflects this result,

indicating that while Revit has some alignment with MOSTADAM's requirements for performance monitoring, it may not fully meet the comprehensive standards set by MOSTADAM.

For **Q2** (mean level of support on a 7-point scale), Figure 58(b) reveals that expert assessments align with the limited support seen in Q1. Both "Residential Waste Management" and "Sustainable Procurement" score the lowest possible rating of 1.0, indicating minimal perceived support and alignment with MOSTADAM's requirements. "Building Performance Monitoring" scores slightly higher with a mean support level of 2.3, as reflected in Figure 58(b), suggesting limited but present support within Revit for building monitoring tasks.

Overall, insights from both Q1 and Q2, as shown in Figures 58(a) and 58(b), underscore that Revit's current capabilities fall short of MOSTADAM's post-management and monitoring expectations. The results point to clear opportunities for Revit to expand its features in areas such as residential waste management and sustainable procurement to enhance alignment with MOSTADAM's sustainability standards in the PMM category.

4.3.9.2 Results of Task -2 of the Expert Panel: assessment of Revit Support based on Case study "CS"

During task-2 of session-2 of the Expert Panel assessment, the experts assessed the performance of Revit based on the results of the case study (CS). During the session, experts were asked two questions about each MOSTADAM indicator based on the results of the case study presented to them (CS): Q1) "indicate the number of points, out the possible points assigned, that Revit able to assess/achieve for each indicator based on the

data of case study presented”, and Q2) “on a 7-point Likert scale, rate the level of which Revit is able to assess/achieve the requirements of the MOSTADAM indicator based on the data of case study presented”. Appendix A3-T2 presents the detailed responses of each expert in the Expert Panel for each question in this task. Table 86 provides a summary of the experts’ assessment of Revit support/coverage for each indicator in the Policies, Management, and Maintenance (PMM) category using the two measurements (Q1 and Q2). While Figure 59 provides a graphical representation radar chart of the data in Table 86. These two measurements capture the experts’ assessment of Revit's ability to meet/support MOSTADAM requirements for each indicator based on the results of the case study.

Table 86 Experts assessment of the level of support of Revit for MOSTADAM indicators in the PMM category based on the case study (CS) results using two measurements: Q1 and Q2.

Indicators of PMM category	Max Possible Points	Q1: number of points achievable		Q2: Rate on 7-Point scale
		Mean of achievable points (out of max possible points)	Mean of achievable points (out of 10)	Mean level of Support (out of 7)
Residential Waste Management	1	0.0	0.0	1.0
Sustainable Procurement	1	0.0	0.0	1.0
Building Performance Monitoring	2	0.6	3.1	4.3

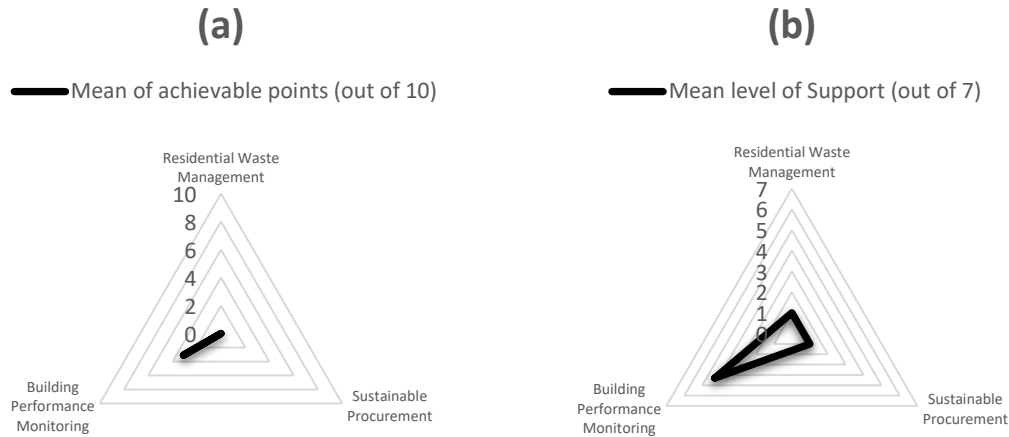


Figure 59 Radar Chart of expert's assessment of the level of support of Revit for MOSTADAM indicators in the PMM category based on based on the case study (CS) results using two measurements (Q1 and Q2)

(a) Mean Achievable points- Q1 (out of 10) **(b)** Mean level of Revit support - Q2 (out of 7)

The results presented in Table 86 and Figure 59(a) regarding **Q1** (mean achievable points for each indicator in the Post-Management and Monitoring (PMM) category based on the case study results) indicate that Revit offers limited support for MOSTADAM's PMM indicators. Specifically, both "Residential Waste Management" and "Sustainable Procurement" achieved a mean score of 0.0 out of the maximum possible points, highlighting Revit's lack of capacity to address these specific requirements. Figure 59(a) visually underscores this gap, suggesting that Revit currently lacks the necessary features for effectively supporting post-management activities related to waste management and sustainable procurement.

In contrast, the "Building Performance Monitoring" indicator shows moderate support, with a mean score of 3.1 out of 10 achievable points. As depicted in Figure 59(a), "Building Performance Monitoring" reaches a mid-range level of support, indicating some alignment

with MOSTADAM's requirements for monitoring building performance, though it remains below full compatibility.

For **Q2** (mean level of support on a 7-point scale), Figure 59(b) reflects a similar pattern, with "Residential Waste Management" and "Sustainable Procurement" both rated at the lowest possible support level of 1.0. "Building Performance Monitoring," however, scored 4.3, indicating a moderate level of expert-perceived support. This suggests that, although Revit provides some functionality for monitoring performance, it does not fully meet MOSTADAM's comprehensive standards in this area.

Overall, insights from both Q1 and Q2, as shown in Figures 59(a) and 59(b), suggest that while Revit has partial alignment with MOSTADAM's "Building Performance Monitoring" requirements, significant opportunities exist for enhancing Revit's capabilities to better support the broader PMM indicators, especially in areas like waste management and sustainable procurement. This analysis highlights potential directions for Revit's development to achieve more robust support for MOSTADAM's sustainability goals in the PMM category.

4.3.9.3 Results of Task-3 of the Expert Panel: Assessment of the support of Revit Media channels

During task-3 of session-2 of the Expert Panel assessment, the experts have assessed the importance/ ability of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM indicator based on the data presented in Task-1 and Task-2. During the session, experts were asked "to rank the ability/importance of each Revit media/channel to achieve/assess the requirements and objectives of each MOSTADAM

indicator using a scale from 1 to 10”. A rank of 10 indicates that the media/channel is the most important in achieving/assessing the indicator requirements/objectives, while 1 indicates that the media/channel is least in importance. Table 87 provides a summary of the experts’ assessment of Revit of Mean ranking level for the support of each Media Type for MOSTADAM PMM indicators in the PMM category. While Figure 60 provides a graphical representation (radar chart) of the data in Table 87.

Table 87 Mean ranking level for the support of each Media Type Support for MOSTADAM PMM indicator .

INDICATOR	Mean Ranking of the support of Revit media channel for MOSTADAM			
	TD	M	S	DI
Residential Waste Management	7.0	0.0	0.0	0.0
Sustainable Procurement	7.0	0.0	0.0	0.0
Building Performance Monitoring	6.0	5.7	0.0	4.7

Legend: (Green gradients: high rate, Yellow gradients: moderate rate, and Red gradient: low rate or none), (TD: text documentation, M: modeling, S: simulation, and DI: data integration)

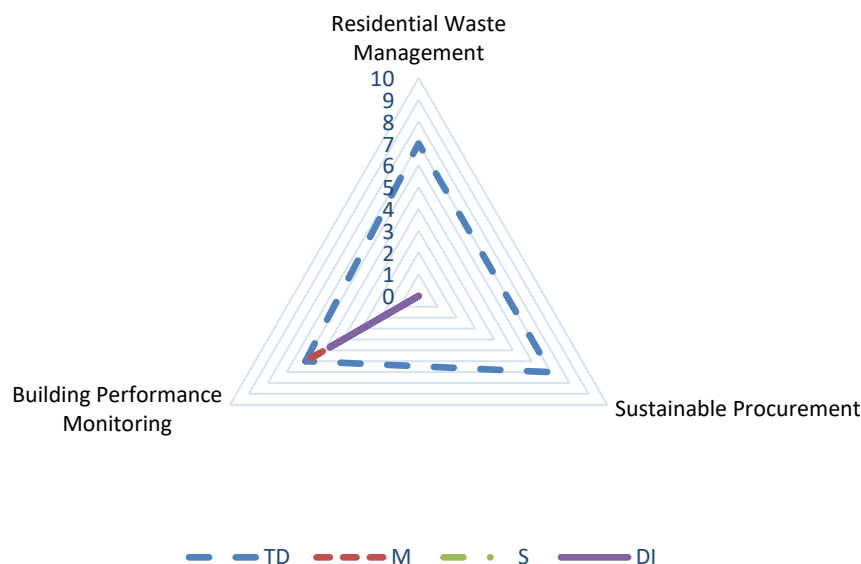


Figure 60 Media Channel Support for Revit MOSTADAM Indicators in the PMM Category.
(TD: text documentation, M: modeling, S: simulation, and DI: data integration)

Table 87 provides a detailed analysis of the media types used in Revit to support the Policies, Management, and Maintenance (PMM) category indicators in MOSTADAM. The media types assessed include text documentation (TD), modeling (M), simulation (S), and data integration (DI), each ranked on a scale from 1 to 10. This table reflects the experts' evaluation of how each media type contributes to achieving the PMM category's indicator requirements.

TD (Text Documentation) plays a crucial role across all PMM indicators. Both "Residential Waste Management" and "Sustainable Procurement" score 7.0, indicating that the documentation process is essential in ensuring compliance and supporting these sustainability indicators. Similarly, "Building Performance Monitoring" receives a high score of 6.0 for TD, suggesting that written documentation is a critical component in tracking building performance and ensuring that management processes align with the MOSTADAM criteria.

M (Modeling) shows limited relevance for most of the PMM indicators, with no support (0.0) for both "Residential Waste Management" and "Sustainable Procurement." However, modeling plays a moderate role in "Building Performance Monitoring" with a score of 5.7, indicating that 3D modeling is helpful for visualizing and managing building performance, even though it is less important for waste management and procurement.

S (Simulation) is not used (0.0) across all three PMM indicators, suggesting that Revit's simulation capabilities do not play a role in these areas. The tasks involved in managing waste, procurement, and building performance do not require dynamic performance simulations, highlighting a gap in the need for Revit's simulation tools for these indicators.

DI (Data Integration) has limited support, particularly in "Building Performance Monitoring," where it receives a score of 4.7. This indicates that integrating external data sources, such as energy use or operational data, is somewhat helpful in monitoring building performance. However, DI is not utilized (0.0) for "Residential Waste Management" and "Sustainable Procurement," reflecting that these indicators are primarily managed through internal documentation and processes rather than through integrating external data.

In summary, Revit's media channel support for the PMM indicators in MOSTADAM relies heavily on text documentation, particularly for waste management and procurement processes. Modeling plays a role in monitoring building performance, while simulation is not used across any of the indicators. Data integration is used moderately in building performance monitoring but is not required for waste management and procurement.

4.3.9.4 Assessment of Revit Support for MOSTADAM PMM Indicators based on the aggregated Data of Tasks 1 and 2 of the Expert Panel

This section presents the results of Revit support for MOSTADAM PMM indicators based on both Task-1 of Expert Panel (i.e. assessment based on the documented requirements of the indicators) and Task -2 of (i.e. assessment based on Case study "CS"). Data collected from the two measurements Task-1 and Task-2 is aggregated in one metric that makes it easy to take a decision regarding Revit support of MOSTADAM indicators.

To aggregate the data from the two tasks (T1 and T2), the researcher aggregated data of the same type in one metric. Data with the same type were aggregated together. Thus, data of question Q2 (7-point Likert scale) were aggregated together across the two tasks; that is T1-Q2 and T2-Q2 were aggregated together in one metric. While data of question Q1 (number of points achieved as a fraction of the total possible points presented as a 'fraction

of 10') were aggregated together across the two tasks; that is T1-Q1 and T2-Q1 were aggregated together in one metric. Table 88 shows the aggregated metrics from the two tasks: Task-1 (T1: data based on documented requirements "DR") and task-2 (T2: data based on case study "CS").

Table 88 Aggregate assessment of the Experts for the level of support of Revit for MOSTADAM PMM indicators based on the results of Task-1 and Task2 (i.e. the DR and the CS).

Indicators of PMM category	Level of Support based on T1-Q1 & T2-Q1		Level of Support based on T1-Q2 & T2-Q2	
	Mean (out of 10)	IQR	Mean (out of 7)	IQR
Residential Waste Management	0.0	0.0	1.0	0.0
Sustainable Procurement	0.0	0.0	1.0	0.0
Building Performance Monitoring	2.7	0.7	3.3	1.5

To be able to identify aggregated level of support of Revit for the PMM indicators, the researcher did several manipulation for the data collected. First, the researcher divided the data of the 7-point Likert scale (**Q2**) to three levels: high support where the mean ≥ 5.5 , moderate support where $3 < \text{mean} < 5.5$, and low support where $\text{mean} \leq 3$. Then also for the 10 point scale (**Q1**) was also divided into three levels: high support where the mean ≥ 7.7 , moderate support where $4 < \text{mean} < 7.7$, and low support where $\text{mean} \leq 4$.

Then, the researcher examined the level of agreement /(i.e consensus) among the members of Expert Panel on the level of support of Revit for the TC indicators. For a 7-point Likert scale and 10 points scales the IQR is used to assess level of agreement/consensus . for more details please refer to section 3.2.3.4 (Analysis) in chapter 3.

Based on these classifications, the results presented in Table 88 for **Q1** (mean achievable points out of 10) provide insight into Revit's support level across MOSTADAM PMM

indicators. The aggregated data from Task-1 and Task-2 reveal that Revit offers minimal support for indicators such as "Residential Waste Management" and "Sustainable Procurement," both achieving a mean score of 0.0 with no variability (IQR = 0.0). This unanimous consensus among experts indicates that Revit does not currently provide functionality to support these indicators, highlighting a gap in addressing waste management and sustainable procurement requirements.

In contrast, "Building Performance Monitoring" received a mean score of 2.7 out of 10 with a moderate IQR of 0.7 for Q1, indicating limited support with some agreement among experts. This suggests that while Revit offers a basic level of support for monitoring building performance, it may not fully meet MOSTADAM's criteria for comprehensive performance measurement.

For **Q2** (mean level of support out of 7), "Building Performance Monitoring" again shows limited support with a mean of 3.3 and a higher IQR of 1.5, reflecting varying expert opinions on Revit's adequacy for this indicator. Meanwhile, both "Residential Waste Management" and "Sustainable Procurement" maintain low support levels, each scoring a mean of 1.0 with no variability, underscoring a consensus on Revit's limited relevance for these specific PMM criteria.

Overall, the results for both Q1 and Q2 suggest that while Revit provides minimal support for MOSTADAM's PMM indicators, "Building Performance Monitoring" represents a modest exception, offering limited yet notable functionality. This analysis points to potential areas for enhancement within Revit to better align with MOSTADAM's sustainability goals for PMM.

Table 89 Aggregated level of support of Revit for MOSTADAM PMM indicators based on the results of Task-1 and Task2.

Indicators of PMM category	Level of Support based on T1-Q1 & T2-Q1			Level of Support based on T1-Q2 & T2-Q2			Aggregated level of Support
	Mean (out of 10)	IQR	Level of Support	Mean (out of 7)	IQR	Level of Support	
Residential Waste Management	0.0	0.0	LC	1.0	0.0	LC	LC
Sustainable Procurement	0.0	0.0	LC	1.0	0.0	LC	LC
Building Performance Monitoring	2.7	0.7	LC	3.3	1.5	LN	LN

(HC: High with consensus, MC: Moderate with consensus, LC: Moderate with consensus, HN: High with no consensus, MN: Moderate with no consensus, LN: Low with no consensus)

Lastly to measure the consensus from the two questions **Q1 & Q2**, an aggregated level of support is presented in Table 89. The measurement used to measure the aggregated level of support was mentioned in Figure 14 :*(Aggregated level of agreement /consensus among the experts regarding level of support of REVIT indicators)* in Section 3.2.3.4 in the Methodology chapter 3.

According to the results in Table 89, the indicator "Residential Waste Management" is classified as "Low with Consensus" (LC). With mean scores of 0.0 in Q1 and 1.0 in Q2, and IQRs of 0.0 for both, the scores indicate unanimous expert agreement on Revit's minimal support for residential waste management requirements, highlighting a notable gap in this area.

Similarly, "Sustainable Procurement" also falls under "Low with Consensus" (LC), achieving mean scores of 0.0 in Q1 and 1.0 in Q2, both with IQRs of 0.0. This consensus suggests that experts agree on Revit's limited capability to address sustainable procurement needs, further emphasizing areas where Revit's functionality may be insufficient for meeting MOSTADAM's PMM criteria.

In contrast, the indicator "Building Performance Monitoring" is classified as "Low with No Consensus" (LN), with mean scores of 2.7 in Q1 and 3.3 in Q2, and IQRs of 0.7 and 1.5, respectively. This low support level, combined with a lack of consensus, reflects differing expert opinions on Revit's adequacy in meeting building performance monitoring requirements.

4.4 Framework to Improve BIM Performance

This research proposes several theoretical frameworks to improve Revit's ability to meet LEED and MOSTADAM indicators. The approach includes integrating GIS for large-scale environmental data, developing custom plugins using Revit's API for handling specific sustainability criteria, incorporating IoT for real-time data in construction and operation phases, and utilizing machine learning (ML) and artificial intelligence (AI) for predictive simulations and energy optimization.

4.4.1 Theoretical Framework to Improve the Ability of Revit

The application of the proposed optimization framework aims to enhance Revit's capabilities to meet LEED and MOSTADAM sustainability indicators across the design, construction, and operational phases of a building's lifecycle. The integration of advanced tools, such as Geographic Information Systems (GIS), Internet of Things (IoT), Artificial Intelligence (AI), and Machine Learning (ML) plugins, is expected to significantly improve Revit's performance in achieving the indicators, especially those which were previously challenging or unattainable.

Table 90 Phase-Specific Indicators and Challenges in Achieving LEED and MOSTADAM Indicators in Revit.

Phase	Category	Indicator	Reason for Difficulty
Design	LEED - Location & Transportation (LT)	LEED for Neighborhood Development Location	Requires GIS data and urban-scale planning tools.
	MOSTADAM - Site Sustainability (SS)	Ecological Assessment and Protection	Requires complex ecological and environmental data.
	LEED - Energy & Atmosphere (EA)	Renewable Energy Production	Needs advanced energy simulations.
	MOSTADAM - Region & Culture (RC)	Thriving Economy	Socio-economic impacts are outside Revit's scope.
	LEED - Materials & Resources (MR)	Building Product Disclosure and Optimization	No built-in life cycle assessment tools.
	MOSTADAM - Water (W)	Alternative Water Solutions	No native water system modeling tools in Revit.
Construction	LEED - Indoor Environmental Quality (IEQ)	Construction Indoor Air Quality Management Plan	Requires real-time site air quality monitoring.
	LEED - Materials & Resources (MR)	Construction Waste Management	Involves on-site waste monitoring during construction.
	MOSTADAM - Materials & Waste (MW)	Construction Waste Management	Needs on-site waste management tracking.
Operation	LEED - Energy & Atmosphere (EA)	Advanced Energy Metering	Requires continuous monitoring and data integration.
	MOSTADAM - Energy (E)	Building Performance Monitoring	Needs post-occupancy performance tracking.
	LEED - Indoor Environmental Quality (IEQ)	Daylight and Visual Comfort	Requires dynamic occupancy-based assessments.
	MOSTADAM - Health & Comfort (HC)	Active Residents	Requires monitoring of resident activity patterns.

Design Phase: The indicators listed here face challenges because Revit lacks the necessary data integration, simulation tools, or specialized plugins. These can be enhanced by integrating additional tools like GIS, energy simulation plugins, or AI-driven assessments to handle ecological, energy, and socio-economic factors.

Construction Phase: Some indicators require real-time monitoring and management on-site, which is beyond Revit's core design capabilities. These can be managed by linking IoT-based sensors or mobile applications with Revit to track indoor air quality, waste management, and construction progress.

Operation Phase: Indicators in this phase involve monitoring performance after the building is occupied, such as energy metering or building performance monitoring. Revit needs to be integrated with smart building systems, IoT devices, or performance tracking software to ensure ongoing compliance with sustainability criteria.

Table 95 presents the phase-specific indicators and challenges associated with achieving LEED and MOSTADAM sustainability criteria in Revit. The table is divided into three main phases—Design, Construction, and Operation—outlining specific categories and indicators within LEED and MOSTADAM where Revit's capabilities encounter difficulties. Each challenge highlights the need for additional tools, data, or monitoring systems that Revit either lacks or cannot fully support within its native environment.

In the design phase, table 95 shows that certain indicators like LEED's "Neighborhood Development Location" and MOSTADAM's "Ecological Assessment and Protection" require integration with GIS and advanced environmental tools. These indicators involve large-scale urban and ecological data, which Revit is not equipped to handle without external datasets and plugins. Similarly, for energy-related indicators such as "Renewable Energy Production" (LEED) and socio-economic-focused criteria like "Thriving Economy" (MOSTADAM), Revit lacks the necessary predictive models and socio-economic analysis tools to adequately support these complex tasks.

In the construction phase, table 68 identifies indicators that involve real-time monitoring and site-specific data, such as LEED's "Construction Indoor Air Quality Management Plan" and MOSTADAM's "Construction Waste Management." These indicators require continuous on-site data collection, which Revit cannot achieve without integrating IoT-based monitoring tools. Revit's limitation in handling dynamic construction data is evident in its inability to support indicators that demand real-time tracking, such as waste management and air quality monitoring.

For the operation phase, table 68 highlights Revit's struggles with indicators like LEED's "Advanced Energy Metering" and MOSTADAM's "Building Performance Monitoring," which require ongoing performance tracking post-occupancy. Revit lacks the capability to continuously monitor building performance, necessitating advanced data integration tools and AI-driven systems to bridge this gap. Additionally, indicators such as "Daylight and Visual Comfort" and "Active Residents" focus on occupant behavior and environmental conditions, further requiring tools that assess dynamic occupancy and resident activity patterns, which are beyond Revit's current capabilities.

In summary, Table 95 illustrates the specific challenges Revit faces in supporting various LEED and MOSTADAM indicators across different phases of a project's lifecycle. It emphasizes the need for integrating external tools and technologies, such as GIS, IoT, and AI, to enhance Revit's ability to meet sustainability standards, particularly for real-time

monitoring, large-scale environmental data integration, and post-occupancy performance tracking.

Table 91 Proposed Improvement Strategies for Enhancing Revit's Support of LEED and MOSTADAM Indicators.

Phase	Category	Indicator	Proposed Improvement Strategy	Suggested Tools/Plugins
Design	LEED - Location & Transportation (LT)	LEED for Neighborhood Development Location	Integrating GIS data with urban-scale planning and environmental tools	GIS Plugin, Urban Planning Tools
	MOSTADAM - Site Sustainability (SS)	Ecological Assessment and Protection	Advanced ecological data integration and environmental simulation	GIS Plugin, Custom Ecological Data Integration Plugins
	LEED - Energy & Atmosphere (EA)	Renewable Energy Production	AI/ML-powered energy simulations for optimization	AI/ML Predictive Energy Models, Energy Simulation Plugin
	MOSTADAM - Region & Culture (RC)	Thriving Economy	Integration of external socio-economic analysis tools	External Socio-Economic Analysis Tools, GIS Plugins
	LEED - Materials & Resources (MR)	Building Product Disclosure and Optimization	Developing C# Plugin for automated life cycle assessment (LCA)	Custom LCA Plugin for Revit
	MOSTADAM - Water (W)	Alternative Water Solutions	Creation of water system simulation tools and data integration	Custom Water System Modeling Plugin, AI Water Efficiency Optimizer
Construction	LEED - Indoor Environmental Quality (IEQ)	Construction Indoor Air Quality Management Plan	IoT-based real-time air quality monitoring	IoT-based Air Quality Monitoring Tools
	LEED - Materials & Resources (MR)	Construction Waste Management	IoT-driven construction waste management tools	IoT-based Waste Monitoring Plugins, Real-Time Waste Tracking
	MOSTADAM - Materials & Waste (MW)	Construction Waste Management	Real-time waste tracking systems integrated with Revit	IoT-based Construction Waste Management
Operation	LEED - Energy & Atmosphere (EA)	Advanced Energy Metering	AI/ML-based tools for energy consumption monitoring and forecasting	AI/ML-driven Energy Monitoring Plugin, Advanced Energy Metering Plugin
	MOSTADAM - Energy (E)	Building Performance Monitoring	AI-powered post-occupancy performance tracking	AI/ML-driven Building Performance Monitoring Plugin

	LEED - Indoor Environmental Quality (IEQ)	Daylight and Visual Comfort	Real-time occupancy assessment and lighting simulations	AI-based Dynamic Daylight and Visual Comfort Plugin
	MOSTADAM - Health & Comfort (HC)	Active Residents	Real-time monitoring tools for tracking resident activities	IoT-based Resident Activity Monitoring Tools

Table 96 outlines a strategic optimization plan aimed at improving Revit's ability to meet the sustainability indicators of LEED and MOSTADAM during the design, construction, and operation phases of building projects. By identifying specific indicators that present challenges to Revit's current capabilities, the table proposes targeted optimization strategies such as integrating Geographic Information Systems (GIS), leveraging AI/ML for simulations, and incorporating Internet of Things (IoT) tools for real-time monitoring. Each challenge is matched with a set of suggested tools or plugins that could be developed or integrated into Revit to enhance its functionality for sustainability assessments.

The data in table 96 shows that Revit's current limitations can be addressed through a combination of advanced technological solutions. For example, challenges in the design phase, such as the lack of integration with urban-scale environmental data for the LEED Neighborhood Development Location indicator, could be resolved by introducing GIS plugins. Similarly, Revit's inability to simulate complex water systems for MOSTADAM's Alternative Water Solutions indicator could be overcome by developing custom water system modeling plugins with AI-based optimizers.

During the construction phase, real-time monitoring emerges as a key challenge. Indicators such as LEED's Construction Indoor Air Quality Management Plan and MOSTADAM's Construction Waste Management require constant data flow from the construction site to

ensure compliance. Here, IoT-based tools for air quality and waste monitoring provide a practical solution, enabling Revit to track real-time data and generate reports on sustainability performance.

In the operation phase, post-occupancy performance tracking is identified as a major challenge, especially for LEED's Advanced Energy Metering and MOSTADAM's Building Performance Monitoring. AI and ML-based tools are proposed as optimization strategies to continuously track energy consumption and predict future performance, providing an ongoing assessment of a building's sustainability performance over time.

Table 96 highlights the importance of integrating external data sources and advanced technologies into Revit to improve its ability to support LEED and MOSTADAM indicators. Key findings include:

1. **GIS integration** is crucial for addressing large-scale environmental and urban planning indicators that Revit struggles within the design phase.
2. **AI/ML-driven simulations** can enhance energy and environmental performance assessments, allowing Revit to conduct more accurate predictive analyses for energy consumption, renewable energy production, and indoor environmental quality.
3. **IoT-based monitoring tools** are essential for ensuring real-time data collection and analysis during the construction phase, addressing Revit's limitations in handling dynamic, site-specific information.
4. **Post-occupancy monitoring** supported by AI/ML plugins can significantly improve Revit's ability to assess and track a building's performance throughout its operational life, particularly for energy management and occupant comfort.

The proposed optimization strategies highlight that Revit, while highly effective for design modeling, needs enhancements to address more complex and dynamic sustainability indicators. Many of these indicators—particularly those in the construction and operation phases—require real-time data integration, predictive analytics, and external datasets, which are beyond Revit’s native capabilities. The integration of GIS, IoT, AI, and ML into Revit's workflow is not only feasible but necessary to bridge these gaps.

The discussion reveals that leveraging these technologies would not only improve Revit's functionality but also align it with the evolving demands of sustainable design and construction practices. Revit's support for real-time monitoring, predictive simulations, and urban-scale analysis would empower architects and engineers to make data-driven decisions that enhance both the environmental and economic performance of buildings.

In conclusion, by integrating advanced tools and technologies, Revit can be optimized to meet LEED and MOSTADAM sustainability requirements more effectively across all phases of a building’s lifecycle. The proposed strategies would ensure that Revit remains a versatile and robust tool for achieving high sustainability standards in modern construction projects.

4.4.2 Sample Application (Recycled content plug-in)

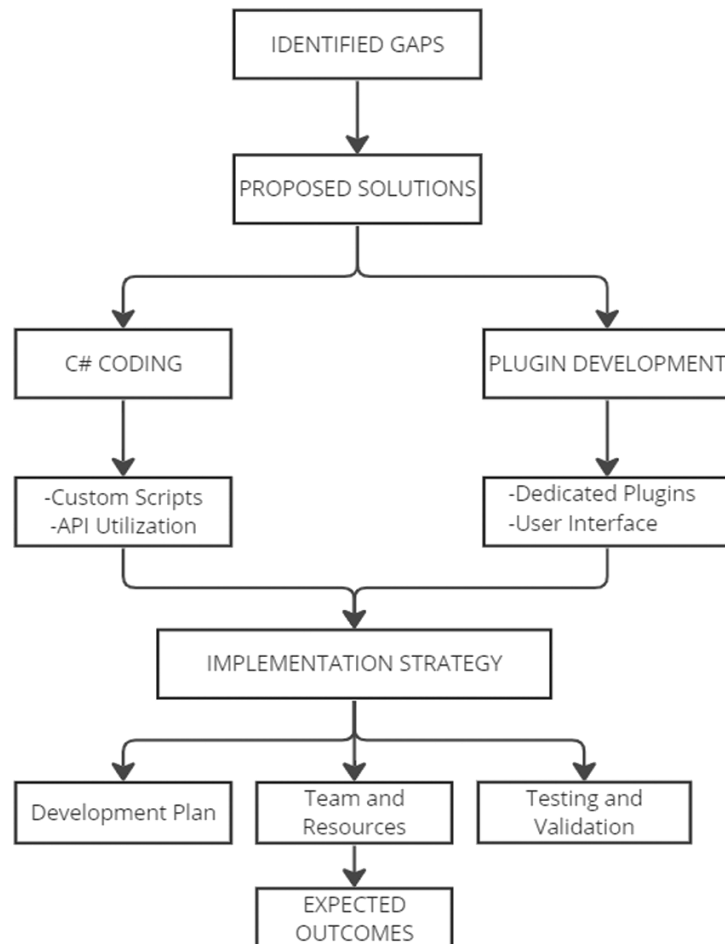


Figure 61 General framework for creating an Add-In

To optimize Building Information Modeling (BIM) performance within the context of LEED certification, a comprehensive plugin was developed that addresses all Material Resources (MR) indicators. This development process involved a detailed examination of various aspects, including recycled content, regional materials, and rapidly renewable materials. The focus was on creating a Revit plugin capable of assessing elements within a project based on the "Recycled Content" indicator.

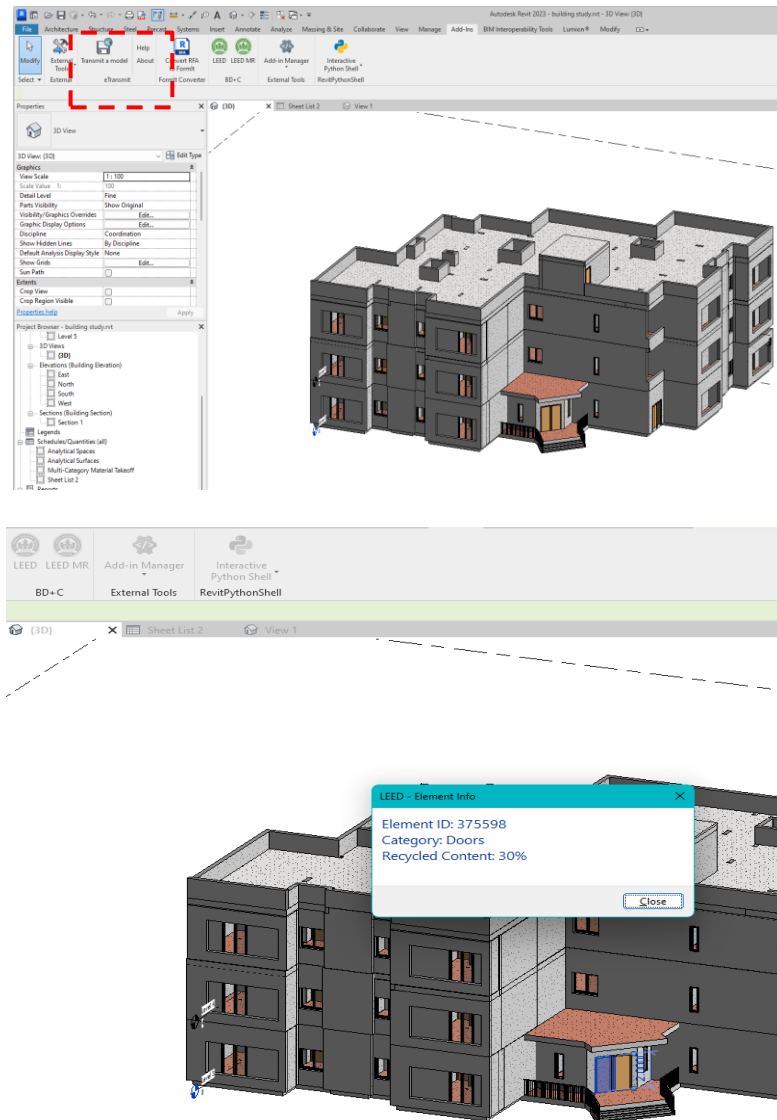
The plugin's implementation involved creating a shared parameter named "Recycled Content," which could be used across multiple families and projects. This parameter was defined as a text type to accommodate the various potential values. Initially, a shared parameter file was created in Revit by navigating to the Manage tab and selecting Shared Parameters. If a shared parameter file did not already exist, it was created and saved appropriately. Within this file, a new group named "LEED Parameters" was added, and the "Recycled Content" parameter was created within this group.

Once the shared parameter was defined, it needed to be added to the relevant family instances. This process involved opening the family that required the parameter and accessing the Family Types dialog under the Create tab. By adding a new shared parameter and selecting the previously defined "Recycled Content" parameter, it was possible to group this parameter under a suitable category, such as Materials and Finishes. The parameter type was set to Instance to allow individual values for each instance or Type if the same value was to be used across all instances of that family type.

After adding the parameter to the family, the family was loaded back into the project. Instances of the family were then placed in the project, and the "Recycled Content" parameter could be seen and edited in the Properties palette. A specific value for this parameter, such as 30% for a wooden door made with 30% recycled wood, was then entered.

To ensure the plugin worked correctly, a custom C# code was integrated into the Revit plugin structure. This plugin iterated through selected family instances in the Revit project and displayed their "Recycled Content" values. If no elements were selected or if an

element did not contain the "Recycled Content" parameter, appropriate messages were displayed to inform the user.



In this example, we focused on recycled content. To cover other LEED MR indicators, you'll need to incorporate additional parameters, calculations, and logic specific to each indicator. Refer to Appendix B to view the process of achieving and coding this plugin.

CHAPTER 5

CONCLUSION & DISCUSSION

5.1 Discussion

This section relates and connects the study’s findings on Revit’s support for LEED and MOSTADAM indicators with the role of Media Channel support (text documentation, modeling, simulation, and data integration) – Task 2, and relevant literature. By synthesizing results from Task 1 (documented requirements “DR”) and Task 2 (case study “CS”), this discussion highlights how Revit’s Media Channels contribute to—or limit—its effectiveness in achieving LEED and MOSTADAM requirements. For Each LEED/MOSTADAM category will be discussed.

LEED LT indicators:

Based on the findings in Table 12, Revit’s support for LEED LT (Location and Transportation) indicators is categorized into high, low, and no support levels, with no indicators in the moderate support range. Indicators with the highest support include *Bicycle Facilities*, *Reduced Parking Footprint*, and *Green Vehicles*, achieving scores of 9.6, 10.0, and 10.0 out of 10 for achievable points and mean support levels of 6.5, 6.9, and 7.0, respectively. The low IQR values (0.3 or 0.0) reflect a high level of consensus among experts, indicating strong agreement on Revit’s effectiveness in meeting straightforward transportation-related requirements. This finding can be attributed to Revit’s robust Modeling capabilities, with scores of 8.0 for *Bicycle Facilities* and *Reduced Parking*

Footprint, which effectively support these infrastructure needs without heavy reliance on Simulation or Data Integration.

In contrast, indicators with low support include *LEED for Neighborhood Development Location*, *Sensitive Land Protection*, and *Access to Quality Transit*, with achievable point scores ranging from 0.6 to 2.3 and support levels between 1.3 and 2.5. These indicators also exhibit low IQR values, suggesting consensus on Revit's limited utility in supporting these more complex site analysis and environmental considerations. This limited support can be explained by Revit's reliance on Text Documentation (with mean scores between 6.0 and 8.0) over Modeling or Data Integration, indicating that Revit's tools may lack the advanced analytical and integration capabilities necessary for comprehensive location assessments and sensitive land protection.

The indicator *High-Priority Site* shows no support, with a score of 0.0 for achievable points and a mean support level of 1.0 out of 7, along with an IQR of 0.0, reflecting unanimous expert agreement on Revit's ineffectiveness in this area. This lack of support is due to Revit's reliance solely on Text Documentation (8.0) and no contributions from Modeling, Simulation, or Data Integration, indicating that Revit's design tools do not extend to high-priority site selection, which typically requires complex spatial data integration and environmental assessment capabilities outside of Revit's offerings.

In summary, Revit's Modeling capabilities provide strong support for indicators like *Bicycle Facilities* and *Green Vehicles*, but the absence of Simulation and Data Integration capabilities limits its effectiveness for indicators requiring detailed site analysis and

environmental considerations, such as *LEED for Neighborhood Development Location and High-Priority Site*.

LEED SS indicators:

Based on the findings in Table 17, Revit's support for LEED SS (Sustainable Sites) indicators can be categorized into high support, low support, and inconsistent support, with varying levels of consensus among experts.

Indicators with the highest level of support include *Open Space*, *Heat Island Reduction*, and *Light Pollution Reduction*, achieving mean scores of 9.8, 10.0, and 9.9 out of 10 for achievable points, and 6.8, 6.5, and 6.5 out of 7 for level of support, respectively. These indicators show strong consensus among experts, with IQR values of 0.0 or 0.3, indicating broad agreement on Revit's effectiveness in meeting these SS requirements. This high support is largely attributed to Revit's Modeling (8.7 for Open Space and 9.0 for Heat Island Reduction) and Simulation (8.3 for Heat Island Reduction) capabilities, which allow detailed visualizations and analyses that meet the design and performance needs for these sustainable site elements, while Text Documentation and Data Integration play smaller roles.

Indicators receiving low support include *Construction Activity Pollution Prevention*, *Site Assessment*, and *Site Development—Protect or Restore Habitat*, with mean scores ranging from 0.0 to 2.4 for achievable points and 1.3 to 1.5 for level of support. These indicators also demonstrate a strong consensus among experts, as shown by low IQR

values (0.0 to 1.1), suggesting that experts agree on Revit's limited capabilities for these requirements. These indicators often involve complex environmental assessments and site-specific data that Revit's core modeling and documentation tools do not fully support. Text Documentation scores moderately for these indicators (5.3 for Construction Activity Pollution Prevention and 6.0 for Site Assessment), but Simulation and Data Integration provide minimal support, highlighting Revit's limitations in tasks that require advanced environmental analysis.

The indicator *Rainwater Management* presents an inconsistent level of support, with moderate scores for achievable points (7.5) and higher scores for level of support (5.6), but high variability in IQR values (5.0 and 2.3), indicating a lack of consensus among experts on Revit's effectiveness in this area. This variability suggests that while Revit offers some foundational support for rainwater management through Data Integration (7.0) and Simulation (5.7), expert opinions differ, possibly due to the complexity of integrating hydrological data and managing dynamic rainwater calculations within Revit's environment.

In summary, Revit's Modeling and Simulation capabilities provide effective support for indicators such as *Open Space*, *Heat Island Reduction*, and *Light Pollution Reduction*. However, indicators that require complex environmental assessments and specific site data, such as *Construction Activity Pollution Prevention* and *Site Assessment*, reveal Revit's limitations, highlighting the need for more advanced data integration and specialized environmental analysis tools to fully meet LEED SS requirements.

LEED WE indicators:

Based on the findings in Table 22, Revit's support for LEED WE (Water Efficiency) indicators is categorized into high support, moderate support, low support, and inconsistent support, with varying levels of expert consensus.

Indicators with the highest level of support include *Water Metering*, which has a mean score of 8.6 out of 10 for achievable points and 6.0 out of 7 for the level of support. The low IQR values (1.3 and 1.0) indicate strong consensus among experts, reflecting broad agreement on Revit's effectiveness in supporting this requirement. This high level of support can be explained by Revit's moderate Simulation (4.3) and Data Integration (4.0) capabilities, which help track water usage but may require further enhancements to manage advanced metering needs fully.

Indicators with moderate support include *Outdoor Water Use Reduction* and *Indoor Water Use Reduction*, with mean scores of 7.0 and 6.9, respectively, for achievable points, and both achieving 5.8 for level of support. While both indicators scored relatively high, the moderate IQR values (1.3 and 2.0) suggest some inconsistency in expert opinions. This variability may stem from differing interpretations of Revit's Modeling (5.3) and Simulation (5.3) capabilities for detailed water efficiency needs. Revit's tools offer foundational support for water reduction calculations but may lack the precision or flexibility experts desire for complex site-specific water management scenarios.

The indicator *Cooling Tower Water Use* falls into the low support category, with mean scores of 1.2 for achievable points and 1.4 for level of support. The low IQR values indicate strong consensus among experts that Revit has limited capability in this area. This finding

reflects Revit's limitations in handling the technical calculations and specialized data integration required for cooling tower water management. Although Simulation offers some assistance (6.0), it remains insufficient for the complex, performance-based calculations typically needed in cooling tower water use assessment.

In summary, Revit's Simulation and Data Integration capabilities provide moderate to high support for indicators like *Water Metering*, *Outdoor Water Use Reduction*, and *Indoor Water Use Reduction*. However, for more specialized requirements, such as *Cooling Tower Water Use*, Revit shows limitations, indicating a need for enhanced simulation tools and data integration functionalities to meet the detailed demands of LEED WE requirements.

LEED EA indicators:

Based on the findings in Table 27, Revit's support for LEED EA (Energy and Atmosphere) indicators can be divided into high, moderate, low, and inconsistent support categories, each reflecting varying levels of consensus among experts.

Indicators with the highest support include *Minimum Energy Performance*, *Building-Level Energy Metering*, *Optimize Energy Performance*, and *Renewable Energy Production*. These indicators have mean scores of 9.4, 8.3, 10.0, and 9.6 out of 10 for achievable points and scores of 6.9, 5.8, 7.0, and 6.9 out of 7 for the level of support, respectively. The low IQR values indicate strong consensus among experts, suggesting broad agreement on Revit's effectiveness in addressing energy-related requirements. This high level of support can be attributed to Revit's robust Modeling (9.0 for Minimum Energy Performance and 9.3 for Renewable Energy Production) and Simulation (9.7 for Optimize Energy

Performance) capabilities, which provide essential tools for energy optimization and metering tasks, complemented by Data Integration where needed (8.7 for Renewable Energy Production).

Indicators with moderate support include *Fundamental Refrigerant Management*, which has scores of 7.1 for achievable points and 5.4 for support level, but with higher IQR values (4.5 and 2.5). This variability suggests some expert disagreement on Revit's capacity to fully support refrigerant management, likely due to differing perspectives on its environmental impact tracking capabilities. The moderate scores in Text Documentation (5.0) and Modeling (5.0) indicate that while Revit offers basic tools for refrigerant management, it may lack specialized functions for comprehensive analysis.

Indicators with low support include *Fundamental Commissioning and Verification*, *Enhanced Commissioning*, and *Green Power and Carbon Offsets*, with mean scores ranging from 0.0 to 1.4 for achievable points and from 1.0 to 1.1 for level of support. These indicators show consistently low support and strong consensus among experts (as evidenced by low IQR values), indicating Revit's limited capacity to meet commissioning and verification requirements. These tasks typically require procedural tracking and environmental offset mechanisms, which are outside Revit's primary modeling functions. Text Documentation provides moderate support (5.3 for Enhanced Commissioning and 4.7 for Fundamental Commissioning), but Modeling, Simulation, and Data Integration play minimal roles.

Lastly, indicators showing inconsistent support include *Advanced Energy Metering*, *Demand Response*, and *Enhanced Refrigerant Management*. For example, *Advanced*

Energy Metering scored 9.0 in achievable points but exhibited a high IQR of 1.3, indicating expert variability in opinions regarding Revit's performance in this area. This may stem from differing experiences with Revit's ability to handle advanced metering requirements. For these indicators, Data Integration (4.7 for Advanced Energy Metering) and Modeling (4.7) show moderate support but with variations in expert perspectives, suggesting that while Revit offers partial functionality, experts recognize limitations in Revit's capacity for comprehensive energy data management.

In summary, Revit's Modeling and Simulation capabilities provide strong support for high-impact energy indicators, such as *Minimum Energy Performance* and *Optimize Energy Performance*. However, indicators requiring detailed procedural management, such as *Commissioning and Verification* and *Green Power and Carbon Offsets*, highlight the need for enhanced data tracking and specialized tools.

LEED MR indicators:

Based on the findings in Table 32, Revit's support for LEED MR (Materials and Resources) indicators primarily falls into low and moderate support categories, with varying levels of consensus among experts.

Indicators with moderate support include *Building Life-Cycle Impact Reduction*, which has mean scores of 5.8 out of 10 for achievable points and 4.6 out of 7 for level of support. The relatively low IQR values (1.5 and 1.0) indicate moderate agreement among experts on Revit's capabilities. This finding suggests that Revit's Modeling (6.3) and Simulation (7.0)

tools are beneficial in supporting life-cycle impact assessments, although limitations remain in fully meeting this requirement, as more complex analyses may require additional tools.

Most other indicators, such as *Storage and Collection of Recyclables*, *Construction and Demolition Waste Management*, *Environmental Product Declarations*, *Material Ingredients*, and *Sourcing of Raw Materials*, fall into the low support category. For these indicators, mean scores range from 2.0 to 3.3 for achievable points and from 1.9 to 3.0 for level of support. High IQR values in some of these indicators reflect a lack of consensus, suggesting varied expert perspectives on Revit's effectiveness in handling these requirements. This inconsistency may arise due to the complex nature of materials tracking, waste management, and documentation related to sourcing, which likely extend beyond Revit's core functionalities.

This finding is explained by Revit's reliance on Text Documentation (mean scores of 6.0 to 7.0 for these indicators), with limited support from Modeling, Simulation, and Data Integration. For example, *Storage and Collection of Recyclables* and *Construction and Demolition Waste Management* depend heavily on Text Documentation (7.0 and 6.3, respectively) but have low support from Modeling (1.7 for both) and no support from Simulation (0.0). Similarly, indicators for *Environmental Product Declarations*, *Material Ingredients*, and *Sourcing of Raw Materials* show reliance on Text Documentation (6.0) but lack Modeling and Simulation support, which limits Revit's capacity to address these documentation-heavy requirements effectively.

In summary, while Revit's Text Documentation and Modeling provide moderate support for the *Building Life-Cycle Impact Reduction* indicator, other MR indicators reveal Revit's limitations in areas requiring complex materials tracking and documentation. This highlights the need for more robust Data Integration and Simulation tools to fully meet LEED MR requirements, especially for indicators involving detailed environmental product assessments and waste management processes.

LEED IEQ indicators:

Based on the findings in Table 37, Revit's support for LEED IEQ (Indoor Environmental Quality) indicators varies across high, moderate, and low support levels, with differing levels of consensus among experts. Indicators with the highest support, such as *Minimum Indoor Air Quality Performance*, *Thermal Comfort*, *Interior Lighting*, *Daylight*, *Quality Views*, and *Acoustic Performance*, achieve scores close to the maximum, with mean support levels ranging from 8.0 to 10.0 for achievable points and 6.4 to 6.9 for mean support level, accompanied by low IQR values (mostly 1.0 or lower). This high level of consensus reflects strong agreement on Revit's effectiveness in meeting these IEQ requirements. These findings can be explained by Revit's robust Modeling (mean scores of 7.0 for Thermal Comfort and 7.7 for Interior Lighting) and Simulation capabilities (8.0 for multiple indicators), which support spatial, lighting, and thermal comfort analysis, with limited reliance on Text Documentation (5.7) or Data Integration (4.3).

For indicators with moderate support, such as *Environmental Tobacco Smoke Control* and *Low-Emitting Materials*, Revit's support is more variable. *Environmental Tobacco Smoke Control* achieves a mean support level of 6.8, while *Low-Emitting Materials* scores 5.1 for

achievable points. However, both indicators show moderate variability (IQR values of 2.3 and 2.4), indicating some inconsistency among experts in Revit's capabilities. This suggests that while Revit provides partial support, experts differ in their views on its adequacy, likely due to limitations in Revit's ability to fully assess emissions and air quality control measures.

Indicators with low support, such as *Enhanced Indoor Air Quality Strategies* and *Construction Indoor Air Quality Management Plan*, show limited effectiveness in Revit, with mean scores of 0.1 and 0.9 for achievable points, respectively. These indicators have low IQR values (0.0), indicating consensus on Revit's limited functionality in managing air quality within construction environments. This finding reflects Revit's dependence on Text Documentation (5.0) with minimal contribution from Modeling or Simulation capabilities, highlighting Revit's limitations in areas that require specialized air quality assessment and management tools.

Additionally, the *Indoor Air Quality Assessment* indicator shows inconsistent support. It scores moderately for achievable points (4.6) but receives a lower mean support level (2.8) with an IQR of 1.0, indicating some expert consensus on the need for enhanced assessment capabilities.

In summary, Revit's Modeling and Simulation capabilities effectively support indicators like *Interior Lighting* and *Thermal Comfort*. However, indicators requiring comprehensive air quality management, such as *Construction Indoor Air Quality Management* and *Enhanced Indoor Air Quality Strategies*, highlight the need for stronger Data Integration and more advanced simulation tools to fully meet LEED IEQ requirements.

LEED IP indicators:

Based on the findings in Table 44, Revit provides high support with strong consensus for the LEED IP (Integrative Process) indicator. The "Integrative Process" indicator achieved a mean score of 10.0 out of 10 for achievable points (T1-Q1 & T2-Q1) and a mean support level of 6.3 out of 7 (T1-Q2 & T2-Q2), with low IQR values of 0.0 for achievable points and 1.0 for support level. This high level of consensus among experts indicates broad agreement on Revit's effectiveness in supporting the Integrative Process requirements.

MOSTADAM SS indicators:

Based on the findings in Table 50, Revit's support for MOSTADAM SS (Site Sustainability) indicators varies across high, moderate, and low support levels, with differing levels of consensus among experts. Indicators with the highest support, such as "Light Pollution," achieved a perfect score of 10.0 for achievable points and a mean support level of 7.0, both with IQR values of 0.0. This high level of consensus reflects strong agreement on Revit's effectiveness in managing light pollution. This finding can be explained by Revit's robust modeling (6.3) and simulation (8.0) capabilities, which enable precise control of lighting impacts through design and placement, without significant reliance on Text Documentation (3.7) or Data Integration (0.0).

For indicators with moderate support, such as "Flood, Rainwater and Sewage Management," "Ecological Enhancement," and "Heat Island Effect," Revit's support is more evenly distributed across Media Channels. "Flood, Rainwater and Sewage Management" relies heavily on Text Documentation (6.0) and Modeling (4.7), with

moderate dependence on Data Integration (3.7). This finding can be explained by Revit's capacity to support structural planning for these indicators, though achieving accurate site-specific hydrological assessments would benefit from additional external data and documentation. Similarly, "Ecological Enhancement" demonstrates moderate reliance on Text Documentation (5.7) and Modeling (5.3), suggesting that while Revit can facilitate basic ecological design elements, integrating external ecological data could strengthen its applicability. For "Heat Island Effect," which shows some inconsistency among experts, high Simulation (7.0) and Modeling (6.3) scores indicate Revit's ability to model urban heat dynamics; however, the need for moderate Data Integration (4.3) suggests that Revit's capabilities may be limited for analyzing complex environmental variables, where additional environmental datasets would be beneficial.

Indicators with low support, such as "Ecological Assessment and Protection" and "Construction Environmental Management," depend predominantly on Text Documentation, with scores of 5.3 and 6.7, respectively. This finding can be explained by Revit's strengths in supporting documentation and reporting, but lower scores in Modeling and Data Integration (3.0 and below) reveal limitations in providing comprehensive ecological assessments and environmental management. The absence of Simulation (0.0) further emphasizes these limitations, as tasks involving biodiversity assessments and environmental impacts typically require more advanced simulation tools and ecological data integration than Revit currently offers.

In summary, Revit's Modeling and Simulation capabilities effectively support indicators like "Light Pollution" and "Heat Island Effect." However, indicators that require extensive ecological or environmental data, such as "Flood Management" and "Construction

Environmental Management," reveal the need for stronger data integration and external analysis tools.

MOSTADAM TC indicators:

Based on the findings in Table 54, Revit's support for MOSTADAM TC (Transportation & Connectivity) indicators varies significantly, with indicators falling into high and low support categories and some inconsistency in expert agreement. Indicators with the highest support, such as "Electric Vehicle Provisions" and "Home," achieved mean scores of 10.0 and 9.4 out of 10 for achievable points, and 6.6 out of 7 for level of support, with low IQR values (0.0 and 0.5). This finding can be explained by Revit's strong modeling capabilities, as indicated by high modeling scores (6.7) for both indicators, which support infrastructure planning for electric vehicle provisions and home connectivity. The absence of reliance on Data Integration (0.0) and Simulation (0.0) suggests that Revit's modeling alone effectively fulfills these requirements without needing external data or complex simulations.

Indicators with low support, such as "Access to Public Transportation" and "Access to Amenities," show consistent low scores of 0.0 for achievable points and 1.0 for level of support, with IQR values of 0.0. This finding can be explained by Revit's reliance on Text Documentation (7.0) for these indicators, rather than Modeling, Simulation, or Data Integration, which are generally essential for spatial and accessibility analyses. The lack of functionality in modeling and data integration for these indicators suggests that Revit's capabilities may be insufficient to address accessibility requirements, as comprehensive transportation and amenity access assessments typically require advanced GIS or data integration tools that Revit lacks.

"Individual Sustainable Transport" received moderate support with some variability among experts. It achieved mean scores of 3.2 out of 10 for achievable points and 3.5 out of 7 for level of support, with IQR values of 1.5 and 1.0, indicating inconsistent agreement. This finding can be explained by Revit's moderate reliance on both Text Documentation (6.0) and Modeling (5.0), with a minimal level of Data Integration (2.3). The inconsistency in expert perspectives may reflect differing views on Revit's capacity to address individual transport needs, which involve complex behavioral and infrastructure-related factors that require more dynamic modeling and data integration than Revit typically provides.

In summary, Revit's modeling strengths support high-consensus indicators like "Electric Vehicle Provisions" and "Home," where infrastructure planning is central. However, low-supported indicators like "Access to Public Transportation" and "Access to Amenities" reveal Revit's limitations in transportation accessibility analysis, as these indicators typically need GIS or other data-intensive tools beyond Revit's core functionality.

MOSTADAM RC indicators:

Based on the findings in Table 60, Revit's support for MOSTADAM RC (Region & Culture) indicators is primarily in the moderate to low support categories, with a strong consensus among experts on these levels. The "Thriving Economy" indicator received low support, with a mean score of 0.0 out of 10 for achievable points and 1.0 out of 7 for level of support, both with IQR values of 0.0. This finding can be explained by Revit's reliance on Text Documentation (7.0) without significant contributions from Modeling, Simulation, or Data Integration. Revit's design-oriented focus limits its capacity for economic-related

analysis, as economic indicators typically require advanced data integration and analytics beyond Revit's scope.

Moderate support was found for indicators such as "Heritage & Culture," "Vibrant Society," and "Regional Focus," with mean scores ranging from 5.0 to 6.3 for achievable points and from 4.5 to 5.0 for level of support, all with low IQR values (0.0 to 1.3). This consensus indicates that Revit provides partial support for cultural, societal, and regional considerations. This finding can be explained by Revit's moderate reliance on Text Documentation (5.3 to 6.0) and Modeling (4.0 to 5.7), which are suitable for representing culturally relevant design elements and basic regional characteristics. However, the limited support from Data Integration (0.0 to 3.3) suggests that Revit's internal capabilities may not fully capture the complexities of regional and societal dynamics that require integration with external datasets or specialized cultural assessment tools.

The "Regional Focus" indicator, which shows balanced support across Text Documentation (5.7), Modeling (5.7), and some level of Data Integration (3.3), suggests that Revit can moderately handle certain regional design aspects, although comprehensive regional planning might still require supplementary data sources.

In summary, Revit's strengths in Text Documentation and Modeling provide moderate support for indicators like "Heritage & Culture" and "Regional Focus," where design elements and documentation are central. However, the low-supported indicator "Thriving Economy" underscores Revit's limitations in economic analysis, as Revit lacks tools for detailed economic or data-driven cultural evaluations.

MOSTADAM E indicators:

Based on the findings in Table 64, Revit's support for MOSTADAM "E" (Energy) indicators shows a range from high to low, with varying consensus levels among experts. Indicators with the highest support, such as "Energy Performance" and "Renewable Energy," achieved perfect scores of 10.0 out of 10 for achievable points and 7.0 out of 7 for level of support, both with IQR values of 0.0. This strong consensus can be explained by Revit's strengths in Modeling (9.3) and Simulation (10.0) as well as Data Integration (8.0), which enable it to meet energy performance and renewable energy requirements effectively. These high scores reflect Revit's ability to support energy-efficient design and sustainable practices through robust modeling and simulation tools.

In contrast, indicators with low support, such as "Systems Commissioning," "Envelope Commissioning," and "Energy Efficient Appliances," received mean scores ranging from 0.0 to 0.6 for achievable points and around 1.0 for level of support, all with IQR values of 0.0. This consensus indicates that Revit offers limited support for these indicators, which typically require detailed procedural tracking and verification beyond the primary design and modeling functions Revit provides. This finding can be explained by Revit's reliance on Text Documentation (5.7–6.0) without substantial input from Modeling, Simulation, or Data Integration, highlighting that commissioning processes and appliance efficiency assessments are outside Revit's core capabilities.

The "Energy Metering" indicator falls into the moderate support category, achieving a mean score of 6.3 for achievable points and 5.4 for level of support. However, with IQR values of 1.3 and 1.5, there is some inconsistency in expert consensus. This finding can be

explained by Revit's reliance on moderate Modeling (5.7) and Data Integration (5.0) to support metering requirements, though limited or inconsistent opinions among experts may stem from Revit's lack of real-time energy tracking features or advanced metering integration capabilities.

The "Ozone Impact" indicator shows moderate scores but also reflects variability in expert agreement, with IQR values of 1.3 and 2.3. This finding can be explained by Revit's limited use of Simulation (0.0) and moderate reliance on Text Documentation (6.0) and Data Integration (4.0), suggesting that Revit may partially address ozone impact considerations through documentation, though it lacks specialized environmental assessment tools to fully support this indicator.

In summary, Revit's Modeling, Simulation, and Data Integration capabilities provide strong support for indicators such as "Energy Performance" and "Renewable Energy." However, indicators requiring procedural tracking, such as "Systems Commissioning" and "Envelope Commissioning," reveal Revit's limitations in operational analysis, as Revit lacks tools for detailed commissioning and environmental impact assessments.

MOSTADAM W indicators:

Based on the findings in Table 69, Revit's support for MOSTADAM "W" (Water) indicators varies across high, moderate, and low levels, with distinct expert consensus for each level. Indicators with the highest support, such as "Indoor Water Performance" and "Outdoor Water Performance," achieved mean scores of 10.0 and 9.8 out of 10 for achievable points, and 6.9 and 6.8 out of 7 for level of support, with low IQR values (0.0 and 0.3). This strong consensus reflects agreement among experts on Revit's effectiveness

in meeting these requirements. This finding can be explained by Revit's robust modeling capabilities, evidenced by high Modeling scores (7.3 for Indoor Water Performance and 7.7 for Outdoor Water Performance), which align well with the design and management of both indoor and outdoor water systems.

"Water Metering" shows moderate support, with a mean score of 5.6 for achievable points and 5.5 for level of support, though with some variability in expert opinions (IQRs of 0.0 and 1.0). This finding can be explained by Revit's moderate reliance on both Modeling (5.7) and Data Integration (5.0), which support metering to a certain extent, though opinions on Revit's adequacy vary. This may be due to Revit's limited real-time tracking and advanced data integration capabilities, which are often necessary for effective water metering and monitoring.

In contrast, "Alternative Water Solutions" received low support, with mean scores of 2.0 for achievable points and 2.3 for level of support, with low IQR values, indicating consensus on Revit's limited functionality in this area. This finding can be explained by Revit's reliance on Text Documentation (6.3) and minimal Modeling support (5.0) while lacking significant Simulation (0.0) and low Data Integration (2.3). The limited support likely results from Revit's lack of specialized tools for non-traditional water solutions, as these require detailed environmental analysis and innovative design approaches that go beyond Revit's native functionalities.

In summary, Revit's strong modeling capabilities provide high support for indicators like "Indoor Water Performance" and "Outdoor Water Performance," where design elements are central. However, indicators requiring real-time data or specialized solutions, such as

"Water Metering" and "Alternative Water Solutions," reveal limitations in Revit's data integration and advanced environmental analysis tools.

MOSTADAM HC indicators:

Based on the findings in Table 74, Revit's support for MOSTADAM HC (Health & Comfort) indicators is largely high, with a few indicators showing moderate support levels. Indicators with the highest support, including "Indoor Thermal Comfort," "Ventilation," "VOCs and Low-Emitting Materials," "Access for All," "Daylight and Visual Comfort," "Indoor Air Quality," and "Outdoor Space," achieved perfect scores of 10.0 out of 10 for achievable points and mean support levels ranging from 6.4 to 7.0 out of 7, with low IQR values (mostly 0.0 to 1.0). This strong consensus suggests that Revit's robust modeling (6.0–7.7) and simulation capabilities (up to 8.0) effectively support requirements for thermal comfort, air quality, and accessibility. This finding can be explained by Revit's strengths in modeling and simulation for interior environments, where design considerations align closely with the indicators' requirements.

Moderate support is noted for indicators like "Outdoor Thermal Comfort" and "Acoustics," with mean scores of 5.0 and 5.4 for achievable points, and levels of support around 4.1 to 4.8 out of 7. Both indicators show low IQR values, indicating expert consensus on Revit's moderate effectiveness in these areas. This finding can be explained by Revit's moderate use of Text Documentation (6.0) and Modeling (5.0 to 6.0) for outdoor and acoustic assessments, which, while supportive, may lack the specialized tools necessary for comprehensive environmental comfort analysis specific to outdoor or acoustic contexts.

The indicator "Active Residents" received moderate support with some inconsistency, reflected by a higher IQR of 2.5, indicating variability in expert perspectives. This finding can be explained by differing views on how well Revit's design tools support the spatial layout and amenities that encourage active lifestyles. Revit's moderate reliance on Text Documentation (5.0) and Modeling (5.0) may not fully capture the complexities of designing spaces that actively promote physical engagement, suggesting that more specialized tools or strategies may be needed.

In summary, Revit's capabilities in modeling and simulation effectively support indicators such as "Indoor Thermal Comfort," "Daylight and Visual Comfort," and "Ventilation," where indoor environmental quality is crucial. However, moderate support for indicators like "Outdoor Thermal Comfort," "Acoustics," and "Active Residents" reveals Revit's limitations in areas requiring specialized environmental comfort analysis and design features that promote physical activity.

MOSTADAM MW indicators:

Based on the findings in Table 79, Revit's support for MOSTADAM MW (Materials and Waste) indicators shows significant variation, with high support for some indicators and low support for others. Indicators with the highest support, such as "Non-Polluting Insulation Materials" and "Recycled Materials," achieved perfect scores of 10.0 out of 10 for achievable points and mean scores of 6.9 and 6.6 out of 7 for level of support, both with low IQR values (0.0 to 1.0). This strong consensus reflects agreement among experts on Revit's effectiveness in supporting these criteria. This finding can be explained by Revit's reliance on Text Documentation (7.0) and Modeling (6.0), which facilitate the selection

and documentation of sustainable materials. The high scores indicate that Revit's tools align well with the requirements for managing materials that promote sustainability, particularly for documenting and specifying non-polluting and recycled materials.

In contrast, "Construction Waste Management" shows low support, with a mean score of 0.0 for achievable points and 1.0 out of 7 for level of support, both with IQR values of 0.0, demonstrating a consensus on Revit's limited functionality in this area. This finding can be explained by Revit's sole reliance on Text Documentation (7.0) without contributions from Modeling, Simulation, or Data Integration. Effective construction waste management often requires advanced data integration and specialized tracking tools that exceed Revit's core design capabilities, which limits Revit's role in waste management processes on construction sites.

In summary, Revit's Text Documentation and Modeling capabilities provide high support for materials-related indicators, such as "Non-Polluting Insulation Materials" and "Recycled Materials," where documentation and specification of materials are central to compliance. However, indicators requiring active waste tracking, like "Construction Waste Management," reveal Revit's limitations, as specialized waste tracking tools or plugins are typically necessary.

MOSTADAM EI indicators:

Based on the findings in Table 85, Revit's support for MOSTADAM EI (Education & Innovation) indicators varies between high and moderate levels, with strong consensus among experts. The indicator with the highest support is "Enhanced Indoor Air Quality Strategies," which achieved a mean score of 9.5 out of 10 for achievable points and a mean

support level of 6.3 out of 7, both with low IQR values (0.3). This strong consensus can be explained by Revit's capabilities in Modeling (5.7) and Text Documentation (6.3), which enable detailed planning and management of indoor air quality. Revit's modeling and documentation tools align well with air quality standards, supporting the development of compliance strategies effectively.

"Low-Emitting Materials" shows moderate support, with a mean score of 5.3 out of 10 for achievable points and 4.8 out of 7 for level of support, both with low IQR values (0.0 and 1.0), indicating consensus among experts. This finding can be explained by Revit's reliance on Text Documentation (6.0) and moderate Modeling support (5.0), which partially cover the requirements for selecting and specifying low-emitting materials. However, Revit's lack of Simulation (0.0) and minimal Data Integration (2.0) suggest that its capabilities may not fully address comprehensive emissions control and compliance needs for indoor environments, which often require advanced data or simulation tools for complete analysis.

In summary, Revit's strengths in Modeling and Text Documentation offer robust support for "Enhanced Indoor Air Quality Strategies," where precise environmental control is crucial. For indicators like "Low-Emitting Materials," Revit provides moderate support, though the absence of Simulation and limited Data Integration suggest that additional tools may be needed for comprehensive emissions analysis.

MOSTADAM PMM indicators:

Based on the findings in Table 89, Revit's support for MOSTADAM PMM (Post-Occupancy Maintenance and Management) indicators is generally low, with a strong consensus among experts on its limited functionality for meeting these criteria.

"Residential Waste Management" and "Sustainable Procurement" both received mean scores of 0.0 out of 10 for achievable points and 1.0 out of 7 for level of support, with IQR values of 0.0. This consensus can be explained by Revit's heavy reliance on Text Documentation (7.0) without contributions from Modeling, Simulation, or Data Integration, which reflects its limited role in addressing requirements beyond the design phase, such as operational waste management and procurement tracking. These indicators typically demand advanced tracking and reporting tools that go beyond Revit's core design-focused functionalities.

"Building Performance Monitoring" also shows low support, with slightly higher mean scores of 2.7 out of 10 for achievable points and 3.3 out of 7 for level of support. This indicator, however, shows some variability in expert opinions (IQR values of 0.7 and 1.5), indicating differing perspectives on Revit's capability in supporting ongoing performance monitoring. This finding can be explained by Revit's moderate reliance on Modeling (5.7) and Data Integration (4.7) for basic performance documentation, although more specialized tools or integration with building management systems would be required for effective post-occupancy monitoring.

In summary, Revit's support for MOSTADAM PMM indicators is limited to documentation capabilities, which provides minimal functionality for operational management requirements.

5.2 Conclusion

This section provides a summary of the major conclusions of the study. The conclusions are mapped to the study objectives. Additionally, this summary sufficiently satisfies the previously established research objectives.

LEED:

The analysis of Revit's support for LEED indicators reveals varying degrees of effectiveness across categories. High support with consensus is observed in 18 key indicators spanning the Location and Transportation (LT), Sustainable Sites (SS), Water Efficiency (WE), Energy and Atmosphere (EA), Indoor Environmental Quality (IEQ), and Integrative Process (IP) categories. This demonstrates Revit's strong capabilities in essential areas that rely on robust modeling, simulation, and data integration—especially for transportation infrastructure, site planning, energy performance, water metering, and indoor environmental quality. However, several indicators within the LT, SS, WE, EA, and IEQ categories show low support, reflecting limitations in Revit's ability to handle complex environmental assessments, procedural tasks, and data-intensive requirements, such as site analysis, commissioning, and air quality management.

For other indicators, expert opinion varies significantly, with inconclusive or inconsistent support seen in areas requiring specialized analysis, extensive data integration, or detailed tracking capabilities, particularly in the MR and SS categories. The following is the conclusion of support for LEED indicators

Table 92 LEED summary for level of support by Revit for all indicators.

Category	Indicators	Type	Level of Support
LT	LEED for Neighborhood Development Location	<i>Cr</i>	Low (Consensus)
	Sensitive Land Protection	<i>Cr</i>	Low (Consensus)
	High-Priority Site	<i>Cr</i>	Low (Consensus)
	Surrounding Density and Diverse Uses	<i>Cr</i>	Low (Consensus)
	Access to Quality Transit	<i>Cr</i>	Low (Consensus)
	Bicycle Facilities	<i>Cr</i>	High (Consensus)
	Reduced Parking Footprint	<i>Cr</i>	High (Consensus)
	Green Vehicles	<i>Cr</i>	High (Consensus)
SS	Construction Activity Pollution Prevention	<i>Pr</i>	Low (Consensus)
	Site Assessment	<i>Cr</i>	Low (Consensus)
	Site Development - Protect or Restore Habitat	<i>Cr</i>	Low (Consensus)
	Open Space	<i>Cr</i>	High (Consensus)
	Rainwater Management	<i>Cr</i>	Inconsistent (No Consensus)
	Heat Island Reduction	<i>Cr</i>	High (Consensus)
	Light Pollution Reduction	<i>Cr</i>	High (Consensus)
WE	Outdoor Water Use Reduction	<i>Pr</i>	Inconsistent (Consensus)
	Indoor Water Use Reduction	<i>Pr</i>	Inconsistent (Consensus)
	Outdoor Water Use Reduction	<i>Cr</i>	Inconsistent (Consensus)
	Indoor Water Use Reduction	<i>Cr</i>	Inconsistent (Consensus)
	Cooling Tower Water Use	<i>Cr</i>	Low (Consensus)
	Water Metering	<i>Cr</i>	High (Consensus)
EA	Fundamental Commissioning and Verification	<i>Pr</i>	Low (Consensus)
	Minimum Energy Performance	<i>Pr</i>	High (Consensus)
	Building-Level Energy Metering	<i>Pr</i>	High (Consensus)
	Fundamental Refrigerant Management	<i>Pr</i>	Moderate (No Consensus)
	Enhanced Commissioning	<i>Cr</i>	Low (Consensus)
	Optimize Energy Performance	<i>Cr</i>	High (Consensus)
	Advanced Energy Metering	<i>Cr</i>	High (No Consensus)
	Demand Response	<i>Cr</i>	Low (No Consensus)
	Renewable Energy Production	<i>Cr</i>	High (Consensus)
	Enhanced Refrigerant Management	<i>Cr</i>	High (No Consensus)
	Green Power and Carbon Offsets	<i>Cr</i>	Low (Consensus)
MR	Storage and Collection of Recyclables	<i>Pr</i>	Low (No Consensus)
	Building Life-Cycle Impact Reduction	<i>Pr</i>	Moderate (Consensus)
	Building Product Disclosure and Optimization - Environmental Product Declarations	<i>Cr</i>	Low (No Consensus)
	Building Product Disclosure and Optimization - Material Ingredients	<i>Cr</i>	Low (No Consensus)
	Building Product Disclosure and Optimization - Sourcing of Raw Materials	<i>Cr</i>	Low (No Consensus)
	Construction and Demolition Waste Management	<i>Cr</i>	Low (No Consensus)
		<i>Cr</i>	Low (No Consensus)
IEQ	Minimum Indoor Air Quality Performance	<i>Pr</i>	High (Consensus)
	Environmental Tobacco Smoke Control	<i>Pr</i>	Moderate (No Consensus)
	Enhanced Indoor Air Quality Strategies	<i>Cr</i>	Low (Consensus)
	Low-Emitting Materials	<i>Cr</i>	Moderate (No Consensus)
	Construction Indoor Air Quality Management Plan	<i>Cr</i>	Low (Consensus)
	Indoor Air Quality Assessment	<i>Cr</i>	Inconsistent (Consensus)
	Thermal Comfort	<i>Cr</i>	High (Consensus)
	Interior Lighting	<i>Cr</i>	High (Consensus)
	Daylight	<i>Cr</i>	High (Consensus)
	Quality Views	<i>Cr</i>	High (Consensus)
IP	Acoustic Performance	<i>Cr</i>	High (Consensus)
	*Integrative Process	<i>Cr</i>	High (Consensus)

High Supported LEED indicators:

The data in Table 92 highlights the LEED indicators where Revit provides High Support with Consensus across multiple LEED categories. This high level of support underscores Revit's strengths in meeting a variety of sustainability requirements effectively, especially in areas that demand robust modeling, simulation, and data integration.

Based on the aggregated results, Revit demonstrates strong support for several key LEED indicators across multiple categories, achieving High Support with Consensus in 18 distinct indicators. This high level of consensus among experts highlights Revit's effectiveness in supporting critical sustainability goals, especially in areas that rely heavily on robust modeling, simulation, and data integration capabilities.

In the Location and Transportation (LT) category, Revit provides high support for Bicycle Facilities, Reduced Parking Footprint, and Green Vehicles. These indicators benefit from Revit's modeling capabilities, which effectively address transportation infrastructure and vehicle-related sustainability needs.

In the Sustainable Sites (SS) category, Revit supports indicators like Open Space, Heat Island Reduction, and Light Pollution Reduction with high consensus, emphasizing its capability to contribute to sustainable site planning and environmental impact mitigation.

In the Water Efficiency (WE) category, Revit achieves high support with consensus for Water Metering, reflecting its ability to handle essential water tracking and conservation requirements.

The Energy and Atmosphere (EA) category sees Revit providing high support with consensus for Minimum Energy Performance, Building-Level Energy Metering, Optimize Energy Performance, and Renewable Energy Production. These indicators highlight Revit's strength in energy management, optimization, and tracking, showcasing its role in achieving energy efficiency and renewable energy goals.

For the Indoor Environmental Quality (IEQ) category, Revit achieves high support with consensus in several critical areas: Minimum Indoor Air Quality Performance, Thermal Comfort, Interior Lighting, Daylight, Quality Views, and Acoustic Performance. This demonstrates Revit's comprehensive ability to enhance indoor environmental quality through effective spatial, lighting, and comfort analyses.

Finally, in the Integrative Process (IP) category, Revit provides high support for the Integrative Process indicator, showing consensus on its capability to support collaborative and integrative project approaches.

Moderate Supported LEED indicators:

The data in Table 92 highlights the LEED indicator where Revit provides Moderate Support with Consensus in the Materials and Resources (MR) category. This moderate level of support reflects Revit's strengths in certain aspects of sustainable material selection and building life-cycle impact assessment, even though it may not be as comprehensive in this area compared to other categories that demand higher levels of detailed modeling and simulation.

Based on the aggregated results, Revit demonstrates a moderate level of support for a critical LEED indicator within the Materials and Resources (MR) category, achieving

Moderate Support with Consensus for Building Life-Cycle Impact Reduction. This consensus among experts indicates Revit's capacity to assist in meeting life-cycle sustainability requirements, although it may require supplementary tools or additional workflows for comprehensive analysis across a project's life cycle.

In the Materials and Resources (MR) category, Revit's moderate support for Building Life-Cycle Impact Reduction highlights its ability to contribute to sustainability goals related to material sourcing, selection, and impact assessment. This indicator benefits from Revit's modeling capabilities to a reasonable extent, aiding in tracking materials' environmental impact across the building's lifespan and helping meet LEED objectives focused on life-cycle analysis.

In summary, Revit's Moderate Support with Consensus for Building Life-Cycle Impact Reduction showcases its partial effectiveness in addressing sustainability goals within material impact and lifecycle considerations, making it a supportive, though not exhaustive, tool for material-focused LEED requirements.

Low Supported LEED indicators:

Table 92 identifies the LEED indicators where Revit provides Low Support with Consensus across various categories, pointing to specific areas where Revit's functionality may fall short in meeting certain sustainability requirements.

In the Location and Transportation (LT) category, indicators such as LEED for Neighborhood Development Location, Sensitive Land Protection, High-Priority Site, and Access to Quality Transit are marked with low support. These indicators typically involve

complex site analysis, environmental assessment, and location-specific data integration, which may extend beyond Revit's current modeling and analytical capabilities.

Within Sustainable Sites (SS), Revit shows low support for indicators like Construction Activity Pollution Prevention, Site Assessment, and Site Development—Protect or Restore Habitat. These indicators often require detailed environmental impact assessments and strategies for habitat conservation and pollution control, tasks that Revit may not be fully equipped to handle given its primary focus on building design rather than environmental site analysis.

In the Water Efficiency (WE) category, Cooling Tower Water Use is marked as having low support with consensus. This indicator typically requires advanced water management calculations and specialized data integration for water-cooled systems, which Revit may not fully accommodate with its existing tools.

The Energy and Atmosphere (EA) category includes Fundamental Commissioning and Verification, Enhanced Commissioning, and Green Power and Carbon Offsets as indicators with low support. These tasks usually involve procedural tracking, commissioning protocols, and carbon offset management, which require specialized tools and processes beyond Revit's core modeling functions.

In the Indoor Environmental Quality (IEQ) category, Enhanced Indoor Air Quality Strategies and Construction Indoor Air Quality Management Plan receive low support with consensus. These indicators often necessitate specialized air quality assessment and management tools, which Revit lacks, limiting its ability to fully address air quality control in construction environments.

In conclusion, Table 94 highlights the LEED indicators for which Revit's support is consistently low, even with expert consensus. This indicates areas where Revit's functionalities may need to be extended or enhanced, especially in fields that require advanced environmental, procedural, and data management capabilities. Improving Revit's ability to address these low-support indicators could enhance its effectiveness as a tool for comprehensive LEED certification support

No consensus/ Inconsistent LEED indicators:

Table 92 lists LEED indicators across various categories where no conclusive decision regarding Revit support was reached as a result of lack of consensus among experts. These indicators suggest areas where Revit's capabilities may be perceived differently among experts, or where the software's support might be inconsistent depending on specific project conditions.

In the Energy and Atmosphere (EA) category, indicators such as Advanced Energy Metering and Enhanced Refrigerant Management receive High Support with No Consensus, suggesting that while Revit may provide strong support for these areas, expert opinions diverge on the consistency or completeness of this support. Fundamental Refrigerant Management is rated with Moderate Support with No Consensus, indicating some utility but differing perspectives on Revit's role in managing refrigerants and environmental impacts. Demand Response is marked as Low Support with No Consensus, highlighting the lack of agreement on Revit's ability to support this demand management requirement.

For Indoor Environmental Quality (IEQ), Environmental Tobacco Smoke Control and Low-Emitting Materials both show Moderate Support with No Consensus. These indicators often involve specific health and emission assessments that Revit's tools may only partially address, leading to divergent expert views. Indoor Air Quality Assessment is flagged as Inconsistent with Consensus, suggesting that while there is agreement on Revit's limitations, support levels may vary depending on specific project needs.

In the Location and Transportation (LT) category, Surrounding Density and Diverse Uses receives Low Support with No Consensus, reflecting the challenges Revit faces in handling complex urban density and diversity calculations that require advanced data integration.

The Materials and Resources (MR) category has several indicators with Low Support and No Consensus: Storage and Collection of Recyclables, Construction and Demolition Waste Management, Environmental Product Declarations, Material Ingredients, and Sourcing of Raw Materials. This highlights the variability in expert opinions on Revit's capabilities for materials management, waste tracking, and documentation—areas where Revit may need additional functionalities to fully meet the requirements.

In Sustainable Sites (SS), Rainwater Management is noted as Inconsistent with No Consensus, indicating variability in support for rainwater management tasks that may rely heavily on data integration and hydrological assessments not fully supported by Revit's current tools.

For Water Efficiency (WE), Outdoor Water Use Reduction and Indoor Water Use Reduction are both marked as Inconsistent with Consensus, reflecting that while there is

agreement on Revit's partial support, there are inconsistencies in how effectively it addresses water reduction requirements across different projects.

In conclusion, Table 95 underscores the areas where Revit's support is either inconclusive or inconsistent, often due to complex requirements that involve specialized analysis, environmental data integration, and procedural tracking. These findings suggest that enhancing Revit's capabilities in these areas, particularly in materials management, energy demand response, and detailed site analysis, could help achieve a more consistent and reliable level of support for these LEED indicators.

MOSTADAM:

The analysis of Revit's support for MOSTADAM indicators reveals varying levels of effectiveness across categories. High support with consensus is noted in 17 critical indicators spanning Site Sustainability (SS), Transport and Connectivity (TC), Energy (E), Water (W), Health and Comfort (HC), Materials and Waste (MW), and Enhanced Indoor Environment (EI) categories. This highlights Revit's strong capabilities in key areas that rely on advanced modeling, simulation, and data integration—particularly in energy performance, water efficiency, thermal comfort, air quality, and sustainable transport. However, several indicators within the SS, TC, E, W, HC, and MW categories exhibit low support, reflecting Revit's limitations in handling complex sustainability assessments, procedural requirements, and data-intensive tasks, such as ecological assessments, commissioning, and construction waste management.

For other indicators, expert opinions vary significantly, with inconclusive or inconsistent support seen in areas that require specialized analysis, extensive data integration, or comprehensive tracking capabilities, particularly in the Site Sustainability (SS), Transport and Connectivity (TC), and Enhanced Indoor Environment (EI) categories. Table 93 provides a summary of these findings on Revit’s support for MOSTADAM indicators.

Table 93 MOSTADAM summary for level of support by Revit for all indicators.

Category	Indicator	Level of Support
SS	Light Pollution	High (Consensus)
	Ecological Enhancement	Moderate (Consensus)
	Ecological Assessment and Protection	Low (Consensus)
	Flood, Rainwater, and Sewage Management	Moderate (No Consensus)
	Construction Environmental Management	Low (No Consensus)
	Heat Island Effect	Inconsistent with agreement
TC	Electric Vehicle Provisions	High (Consensus)
	Access to Public Transportation	Low (Consensus)
	Access to Amenities	Low (Consensus)
	Individual Sustainable Transport	Inconsistent with agreement
	Home	High (Consensus)
E	Energy Performance	High (Consensus)
	Renewable Energy	High (Consensus)
	Systems Commissioning	Low (Consensus)
	Envelope Commissioning	Low (Consensus)
	Energy Efficient Appliances	Low (Consensus)
	Energy Metering	Moderate (No Consensus)
	Advanced Energy Metering	High (No Consensus)
	Ozone Impact	Inconsistent without agreement
W	Indoor Water Performance	High (Consensus)
	Outdoor Water Performance	High (Consensus)
	Alternative Water Solutions	Low (Consensus)
	Water Metering	Moderate (No Consensus)
HC	Indoor Thermal Comfort	High (Consensus)
	Ventilation	High (Consensus)
	VOCs and Low-Emitting Materials	High (Consensus)
	Access for All	High (Consensus)
	Daylight and Visual Comfort	High (Consensus)
	Indoor Air Quality	High (Consensus)
	Outdoor Space	High (Consensus)
	Outdoor Thermal Comfort	Moderate (Consensus)
	Acoustics	Moderate (Consensus)
	Active Residents	Moderate (No Consensus)
MW	Non-Polluting Insulation Materials	High (Consensus)
	Recycled Materials	High (Consensus)
	Construction Waste Management	Low (Consensus)
PMM	Residential Waste Management	Low (Consensus)
	Sustainable Procurement	Low (Consensus)
	Building Performance Monitoring	Low (No Consensus)
EI	Enhanced Indoor Air Quality Strategies	High (Consensus)
	Low-Emitting Materials	Moderate (Consensus)

High Supported MOSTADAM indicators:

The data in Table 93 highlights the MOSTADAM indicators where Revit provides High Support with Consensus across multiple MOSTADAM categories. This high level of support underscores Revit's strengths in effectively meeting a wide range of sustainability requirements, especially in areas that demand robust modeling, simulation, and data integration capabilities.

Based on the findings, Revit demonstrates strong support for numerous MOSTADAM indicators across various categories, achieving "High Support with Consensus" for 17 indicators. This high level of consensus among experts highlights Revit's effectiveness in supporting key sustainability objectives, particularly those that leverage its modeling, simulation, and data integration capabilities.

In the Site Sustainability (SS) category, Light Pollution achieves high support with consensus, demonstrating Revit's capability to address environmental impact control measures effectively. In the Transport and Connectivity (TC) category, Revit provides strong support for Electric Vehicle Provisions and Home indicators, reflecting its capacity to support sustainable transport and connectivity.

For the Energy (E) category, Revit offers high support with consensus for Energy Performance and Renewable Energy, underscoring its functionality in energy efficiency and renewable resource integration. Similarly, in the Water (W) category, Indoor Water Performance and Outdoor Water Performance have high support, showcasing Revit's ability to handle critical water efficiency requirements.

In the Health and Comfort (HC) category, Revit is highly supportive across a range of indicators, including Indoor Thermal Comfort, Ventilation, VOCs and Low-Emitting Materials, Access for All, Daylight and Visual Comfort, Indoor Air Quality, and Outdoor Space. This indicates Revit's comprehensive support in promoting health, comfort, and accessibility within built environments.

Furthermore, in the Materials and Waste (MW) category, indicators like Non-Polluting Insulation Materials and Recycled Materials achieve high support, demonstrating Revit's capacity to support sustainable materials management. In the Enhanced Indoor Environment (EI) category, Enhanced Indoor Air Quality Strategies also achieves high consensus, highlighting Revit's utility in managing indoor air quality to enhance occupant health and comfort.

In conclusion, Revit's robust modeling, simulation, and data integration capabilities provide substantial support for MOSTADAM's sustainability goals, particularly in areas emphasizing energy efficiency, water management, indoor environmental quality, and sustainable materials, solidifying its role as an effective tool in achieving high sustainability standards.

Moderate Supported MOSTADAM indicators:

The data in Table 93 identifies the MOSTADAM indicators where Revit provides Moderate Support with Consensus across various MOSTADAM categories. This moderate level of support indicates that while Revit offers foundational capabilities in these areas, there are aspects that may benefit from additional development or supplementary tools to fully meet the requirements.

Revit demonstrates Moderate Support with Consensus for seven indicators, showcasing its ability to partially address sustainability objectives, especially where basic modeling, documentation, and data analysis are required.

In the Site Sustainability (SS) category, Ecological Enhancement receives moderate support, suggesting that Revit is capable of supporting certain ecological design elements but may require further integration with external ecological data for comprehensive analysis.

Within the Regional Culture (RC) category, indicators such as Heritage & Culture, Vibrant Society, and Regional Focus are also moderately supported, reflecting Revit's potential to support culturally significant design considerations. However, these areas could be strengthened with tools tailored to local context and social sustainability considerations.

In the Health and Comfort (HC) category, Outdoor Thermal Comfort and Acoustics demonstrate moderate support. This suggests that while Revit can facilitate some analysis for thermal and acoustic performance, more advanced simulation capabilities might enhance its ability to fully meet these indicators.

Lastly, in the Enhanced Indoor Environment (EI) category, Low-Emitting Materials is marked as moderately supported, highlighting Revit's partial capacity to support indoor air quality through material selection. However, more advanced tools for emissions and materials impact assessment may be required for a thorough evaluation.

In summary, these findings underscore Revit's ability to provide essential support for MOSTADAM's goals across ecological, cultural, and health-related aspects. However,

achieving higher levels of support in these areas may necessitate additional tools and enhancements focused on local context, environmental simulation, and specialized sustainability analysis.

Low Supported MOSTADAM indicators:

The data in Table 93 highlights the MOSTADAM indicators where Revit provides Low Support with Consensus across multiple MOSTADAM categories. This low level of support indicates specific areas where Revit's existing functionalities may not fully meet the sustainability requirements of MOSTADAM, suggesting a need for specialized tools or additional software capabilities to address these indicators effectively.

Revit demonstrates Low Support with Consensus for eleven indicators, showing limited capacity to fulfill certain requirements, particularly in areas that demand specialized environmental, economic, or resource management tools.

In the Site Sustainability (SS) category, Ecological Assessment and Protection is marked as lowly supported, indicating that Revit's core modeling and documentation capabilities may not be sufficient for comprehensive ecological protection and assessment tasks that require advanced environmental analysis tools.

For the Transport and Connectivity (TC) category, both Access to Public Transportation and Access to Amenities receive low support, suggesting limitations in Revit's ability to handle connectivity and accessibility analyses that require extensive site data integration.

Within the Regional Culture (RC) category, Thriving Economy is rated as lowly supported, reflecting the challenges Revit faces in addressing economic indicators related to regional vitality and sustainable economic development.

In the Energy (E) category, indicators such as Systems Commissioning, Envelope Commissioning, and Energy Efficient Appliances are noted as lowly supported. These tasks typically involve commissioning processes and performance evaluations that extend beyond Revit's standard modeling functions, emphasizing the need for dedicated commissioning and energy efficiency tracking tools.

In the Water (W) category, Alternative Water Solutions is marked with low support, indicating that Revit's water management functionalities may not fully address complex water conservation and alternative solutions often necessary for sustainable projects.

For the Materials and Waste (MW) category, Construction Waste Management is also rated with low support, highlighting Revit's limitations in handling comprehensive waste tracking and resource management, which often require specialized data tracking tools.

Finally, in the Post-Occupancy Management and Monitoring (PMM) category, both Residential Waste Management and Sustainable Procurement are rated as lowly supported. This points to Revit's limited capacity for ongoing waste and procurement management, areas that typically require continuous tracking and resource allocation, not fully supported by Revit's current capabilities.

In conclusion, these findings identify key MOSTADAM indicators where Revit provides minimal support, even with consensus among experts. To better align with MOSTADAM's

comprehensive sustainability requirements, Revit could benefit from enhancements or integrations with external tools, particularly in areas requiring in-depth environmental, economic, and resource management functionalities.

No consensus/ Inconsistent MOSTADAM indicators:

The data in Table 93 highlights the MOSTADAM indicators across various categories where no conclusive decision regarding Revit support was reached as a result of lack of consensus among experts. This variability reflects areas where expert opinions diverge or where Revit's capabilities might be perceived differently depending on project requirements. These indicators suggest complex sustainability needs, often requiring specialized analysis, data integration, or consistent monitoring that may not be fully supported by Revit's current functions.

Revit's support is marked as Moderate with No Consensus for several indicators. In the Site Sustainability (SS) category, Flood, Rainwater and Sewage Management lacks consensus, indicating differing expert views on Revit's adequacy for site-specific hydrological assessments. Energy Metering in the Energy (E) category and Water Metering in the Water (W) category also show moderate support without consensus, suggesting that Revit may offer partial functionality for tracking utilities, yet experts disagree on its reliability or integration depth.

In the Human Comfort (HC) category, Active Residents also shows moderate support without consensus, indicating mixed views on Revit's capability to address active lifestyle accommodations within building projects.

Indicators marked with Low Support with No Consensus include Construction Environmental Management in the Site Sustainability (SS) category and Building Performance Monitoring in the Post-Occupancy Management and Monitoring (PMM) category. These indicators often involve procedural tracking and monitoring requirements that go beyond Revit's typical modeling capabilities, leading to inconsistent expert feedback on Revit's effectiveness in these areas.

Indicators labeled Inconsistent with Agreement include Heat Island Effect in the SS category, Individual Sustainable Transport in the Transport and Connectivity (TC) category, and Ozone Impact in the Energy (E) category. These indicators highlight areas where there is general agreement on Revit's limitations, yet the level of support varies depending on specific project conditions, potentially due to the need for complex environmental data and specialized sustainability analysis.

In summary, Table 93 identifies areas where Revit's support is either inconsistent or lacks expert consensus, often in categories demanding specialized analysis, advanced data integration, or continuous monitoring. Enhancing Revit's functionalities to address these requirements could improve its reliability and consistency in supporting these complex MOSTADAM indicators.

5.3 Implications

The findings in the conclusion section reveal significant insights into the areas where Revit provides moderate and low support for LEED and MOSTADAM indicators, highlighting potential gaps in Revit's capabilities and areas for improvement. For indicators where Revit

demonstrates moderate support, there is a foundational level of functionality that addresses some aspects of the sustainability requirements, yet these areas could benefit from additional development to fully satisfy complex environmental, social, and procedural needs.

1- Moderate Support Implications:

Indicators in the moderate support category, including several within the MOSTADAM categories of Site Sustainability (SS), Regional Culture (RC), Health and Comfort (HC), and Enhanced Indoor Environment (EI), indicate that Revit can support baseline sustainability objectives but may not fully meet the requirements without supplementary tools or enhancements. For example:

- Ecological Enhancement and Regional Culture indicators reflect Revit's partial ability to integrate local context and ecological considerations. Improving Revit's data integration capabilities, such as enabling access to ecological and cultural datasets, could strengthen its support in these areas.
- Health and Comfort indicators like Outdoor Thermal Comfort and Acoustics also require advanced simulation and analysis for comprehensive support, suggesting that integrating specialized thermal and acoustic modeling tools could elevate Revit's effectiveness in these aspects.
- Low-Emitting Materials under the EI category reflects Revit's partial ability to assess indoor environmental quality through material selection. Enhancements to support detailed emissions and materials impact tracking would allow for a more thorough evaluation and compliance with stringent health standards.

Overall, indicators receiving moderate support would benefit from Revit incorporating or integrating with external databases, enhancing simulation capabilities, and building additional features for environmental, cultural, and health-related analyses to meet the full scope of sustainability goals.

2- Low Support Implications

For indicators with low support, Revit's current functionalities appear limited, often due to the need for highly specialized or resource-intensive processes that are not typically supported within Revit's core modeling framework. These indicators, which span both LEED and MOSTADAM categories like Site Sustainability (SS), Transport and Connectivity (TC), Energy (E), Materials and Waste (MW), and Post-Occupancy Management and Monitoring (PMM), highlight key areas where Revit may need substantial enhancements or external integrations to address the full range of sustainability requirements.

- Transport and Connectivity (TC) indicators such as Access to Public Transportation and Access to Amenities require complex site and connectivity analyses. These tasks would benefit from integrating Revit with geographic information system (GIS) platforms or transportation data sources to accurately assess accessibility and site-specific connectivity requirements.
- Energy indicators including Systems Commissioning and Envelope Commissioning emphasize the need for Revit to support procedural tracking and verification processes, which are often essential for sustainability certifications. Introducing commissioning support tools or enhancing Revit's ability to track

energy-related data and performance metrics could significantly improve its utility in these areas.

- Materials and Waste (MW) and Post-Occupancy Management and Monitoring (PMM) indicators, such as Construction Waste Management and Sustainable Procurement, require ongoing waste tracking and resource management beyond Revit's traditional scope. Adding waste and resource management functionalities could make Revit more effective in supporting circular economy principles and resource conservation efforts.

In conclusion, addressing these low-support indicators would require Revit to incorporate or link with specialized tools that support procedural, commissioning, waste management, and environmental monitoring needs. This expansion would enable Revit to fulfill more complex sustainability indicators, making it a more comprehensive tool for supporting LEED and MOSTADAM certification requirements.

5.4 Future Research

The findings of this study reveal a significant gap in Revit's ability to consistently address several LEED and MOSTADAM indicators due to inconclusive or inconsistent support levels, as highlighted in Tables 94 and 98. These indicators represent areas where Revit's capabilities may be perceived differently among experts, or where its functions may not fully align with the complex sustainability requirements of certain categories. Future research could explore solutions to address these limitations, focusing on developing specialized tools and techniques for the following areas:

1. For indicators such as Energy Metering, Water Metering, and Flood, Rainwater and Sewage Management, moderate support with no consensus points to Revit's partial effectiveness in handling intricate tracking and analysis needs. Research could investigate advanced data integration methods and supplementary analytical tools to enhance Revit's ability to manage site-specific utilities and environmental assessments accurately. This includes exploring the integration of hydrological modeling tools and utilities tracking systems within Revit for comprehensive data handling.
2. In areas such as Ozone Impact, Heat Island Effect, and Environmental Tobacco Smoke Control, Revit shows inconsistent support, indicating that these indicators often require specialized environmental health assessments and tools beyond Revit's capabilities. Further research is warranted to develop plug-ins or compatible software extensions that can conduct in-depth environmental impact assessments and air quality monitoring. This approach would provide a more robust framework for addressing health and environmental sustainability needs.
3. Indicators like Active Residents and Individual Sustainable Transport reflect the need for adaptive modeling that aligns with lifestyle and cultural context in building projects. Research can explore incorporating behavioral modeling and culturally relevant design tools to enhance Revit's support in these areas. This may involve adapting Revit's interface to better reflect regional planning requirements and sustainability standards, particularly in contexts where occupant behavior and cultural considerations significantly influence sustainability outcomes.

4. Indicators like Construction Environmental Management and Building Performance Monitoring require ongoing procedural and resource management, which Revit currently supports inconsistently. Future studies should focus on incorporating real-time tracking capabilities and resource management frameworks that extend beyond initial project modeling. This can involve integrating Revit with project management software or IoT-based monitoring systems to enhance Revit's reliability in these domains.
5. Given the variability in expert opinion for several indicators across both LEED and MOSTADAM standards, there is an opportunity for research into interdisciplinary approaches that combine architectural modeling with environmental science, health assessments, and sociocultural analysis. Developing frameworks for multi-disciplinary collaborations within Revit could allow for more comprehensive sustainability evaluations, particularly in areas where existing consensus is lacking or inconsistent.

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APPENDIX A1

These are the survey questions used for the Expert Panel study conducted during each GBAT session. There were two sessions: one focused on LEED and the other on MOSTADAM. The same questions were asked for both GBATs (LEED/MOSTADAM). The example provided in the appendix shows the tasks for LEED, which were similarly conducted for MOSTADAM.

Task-1. Revit Coverage of Assigned Points of Each Indicator in LEED.

Based on the presentation provided on each LEED green building indicator and its objectives and requirements, please rate the following two aspects using the form below:

- 1) On a 7-point scale in the form below, please rate the level at which Revit is able to achieve the requirements of the specified LEED/MOSTADAM indicators.
- 2) In the last column of the form below, please indicate the number of points Revit is able to assess/achieve out of the ‘possible points’ for the specified LEED/MOSTADAM indicator. *Note: you can use a fraction in your answer for the achievable points (for example, achievable points can be 0.5 points, 1.5 points, 2.75 points, etc.).*

CATEGORY	INDICATOR	level of the ability of Revit to achieve the requirement of the indicator							Possible Points	Points Achievable via Revit
		1	2	3	4	5	6	7		
LOCATION AND TRANSPORTATION	1. LEED for neighborhood development location								16	
	2. Sensitive land protection								1	
	3. High-priority site								2	
	4. Surrounding density and diverse uses								5	
	5. Access to quality transit								5	
	6. Bicycle facilities								1	
	7. Reduced parking footprint								1	
	8. Green vehicles								1	
SUSTAINABLE SITES	9. prerequisite-Construction activity pollution prevention								Required (pls fill as of 10 points)	
	10. Site assessment								1	
	11. Site development—protect or restore habitat								2	
	12. Open space								1	
	13. Rainwater management								3	
	14. Heat island reduction								2	
WATER EFFICIENCY	15. Light pollution reduction								1	
	16. prerequisite-Outdoor water use reduction								Required (pls fill as of 10 points)	
	17. prerequisite-Indoor water use reduction								Required (pls fill as of 10 points)	
	18. Cooling tower water use								2	
ENERGY AND ATMOSPHERE	19. Water metering								1	
	20. prerequisite-Fundamental commissioning and verification								Required (pls fill as of 10 points)	
	21. prerequisite-Minimum energy performance								Required (pls fill as of 10 points)	
	22. prerequisite-Building-level energy metering								Required (pls fill as of 10 points)	
	23. prerequisite-Fundamental refrigerant management								Required (pls fill as of 10 points)	
	24. Enhanced commissioning								6	
	25. Optimize Energy Performance								18	

CATEGORY	INDICATOR	level of the ability of Revit to achieve the requirement of the indicator							Possible Points	Points Achievable via Revit
		1	2	3	4	5	6	7		
	26. Advanced energy metering								1	
	27. Demand response								2	
	28. Renewable energy production								3	
	29. Enhanced refrigerant management								1	
	30. Green power and carbon offsets								2	
MATERIALS AND RESOURCES	31. prerequisite-Storage and collection of recyclables								Required (pls fill as of 10 points)	
	32. prerequisite-Construction and demolition waste management								Required (pls fill as of 10 points)	
	33. Building life-cycle impact reduction								2	
	34. Building product disclosure and optimization—environmental product declarations								2	
	35. Building product disclosure and optimization – material ingredients								2	
	36. Building product disclosure and optimization – sourcing of raw materials								2	
INDOOR ENVIRONMENTAL QUALITY	37. prerequisite-Minimum indoor air quality performance								Required (pls fill as of 10 points)	
	38. prerequisite-Environmental tobacco smoke control								Required (pls fill as of 10 points)	
	39. Enhanced indoor air quality strategies								2	
	40. Low-emitting materials								3	
	41. Construction indoor air quality management plan								1	
	42. Indoor air quality assessment								2	
	43. Thermal comfort								1	
	44. Interior lighting								2	
	45. Daylight								3	
	46. Quality views								1	
	47. Acoustic performance								1	
Integrative Process	48. Integrative Process								1	

TASK-2. Level of Appropriateness of The Support of Revit case study for Each LEED Indicator.

Based on the presentation provided regarding the **results of the case study**, please do the following:

- 1) On a 7-point scale, please rate the level of which Revit is able to achieve the requirements of the specified LEED/MOSTADAM indicator based on the data of case study presented.
- 2) In the last column of the form below, please indicate the number of points that Revit is able to achieve out of the ‘possible points’ for the specified LEED/MOSTADAM indicator based on the data of case study presented. *Note: you can use a fraction in your answer for the achievable points (for example, achievable points can be 0.5 points, 1.5 points, 2.75 points, etc.).*

CATEGORY	INDICATOR	Level of appropriateness of Revit to achieve/assess the requirements of an indicator based on the Case Study results							Possible Points	Points Achievable via Case Study
		1	2	3	4	5	6	7		
LOCATION AND TRANSPORTATION	1. LEED for neighborhood development location								16	
	2. Sensitive land protection								1	
	3. High-priority site								2	
	4. Surrounding density and diverse uses								5	
	5. Access to quality transit								5	
	6. Bicycle facilities								1	
	7. Reduced parking footprint								1	
	8. Green vehicles								1	
SUSTAINABLE SITES	9. prerequisite-Construction activity pollution prevention								Required (pls fill as of 10 points)	
	10. Site assessment								1	
	11. Site development—protect or restore habitat								2	
	12. Open space								1	
	13. Rainwater management								3	

CATEGORY	INDICATOR	Level of appropriateness of Revit to achieve/assess the requirements of an indicator based on the Case Study results							Possible Points	Points Achievable via Case Study
		1	2	3	4	5	6	7		
	14. Heat island reduction								2	
	15. Light pollution reduction								1	
WATER EFFICIENCY	16. prerequisite-Outdoor water use reduction								Required (pls fill as of 10 points)	
	17. prerequisite-Indoor water use reduction								Required (pls fill as of 10 points)	
	18. Cooling tower water use								2	
	19. Water metering								1	
ENERGY AND ATMOSPHERE	20. prerequisite-Fundamental commissioning and verification								Required (pls fill as of 10 points)	
	21. prerequisite-Minimum energy performance								Required (pls fill as of 10 points)	
	22. prerequisite-Building-level energy metering								Required (pls fill as of 10 points)	
	23. prerequisite-Fundamental refrigerant management								Required (pls fill as of 10 points)	
	24. Enhanced commissioning								6	
	25. Optimize Energy Performance								18	
	26. Advanced energy metering								1	
	27. Demand response								2	
	28. Renewable energy production								3	
	29. Enhanced refrigerant management								1	
	30. Green power and carbon offsets								2	
MATERIALS AND RESOURCE	31. prerequisite-Storage and collection of recyclables								Required (pls fill as of 10 points)	

CATEGORY	INDICATOR	Level of appropriateness of Revit to achieve/assess the requirements of an indicator based on the Case Study results							Possible Points	Points Achievable via Case Study
		1	2	3	4	5	6	7		
	32. prerequisite-Construction and demolition waste management								Required (pls fill as of 10 points)	
	33. Building life-cycle impact reduction								2	
	34. Building product disclosure and optimization—environmental product declarations								2	
	35. Building product disclosure and optimization – material ingredients								2	
	36. Building product disclosure and optimization – sourcing of raw materials								2	
INDOOR ENVIRONMENTAL QUALITY	37. prerequisite-Minimum indoor air quality performance								Required (pls fill as of 10 points)	
	38. prerequisite-Environmental tobacco smoke control								Required (pls fill as of 10 points)	
	39. Enhanced indoor air quality strategies								2	
	40. Low-emitting materials								3	
	41. Construction indoor air quality management plan								1	
	42. Indoor air quality assessment								2	
	43. Thermal comfort								1	
	44. Interior lighting								2	
	45. Daylight								3	
	46. Quality views								1	
	47. Acoustic performance								1	
Integrative Process	48. Integrative Process								1	

Task-3. Best Media Used to support/achieve the requirement of each indicator in LEED.

Based on the provided information in the previous TASKS (*i.e. the indicator requirements and case study results*), please do the following:

In the form below, for each media/channel type in Revit, please rank the ability/importance of each media/channel type to achieving/assessing the objectives and requirement of the corresponding indicator **using a scale from 1 to 10**. A rank of **10 indicates that the media/channel is the most important** in achieving/assessing the indicator objectives/requirements while **1 indicates that the media/channel is least** in importance.

CATEGORY	INDICATORS	Rank media Type of Revit Support for GA			
		Text Documentation	Modeling	Simulation	Data Integration
LOCATION AND TRANSPORTATION	1. LEED for neighborhood development location (16 points)				
	2. Sensitive land protection (1 points)				
	3. High-priority site (2 points)				
	4. Surrounding density and diverse uses (5 points)				
	5. Access to quality transit (5 points)				
	6. Bicycle facilities (1 points)				
	7. Reduced parking footprint (1 points)				
	8. Green vehicles (1 points)				
SUSTAINABLE SITES	9. prerequisite-Construction activity pollution prevention Required				
	10. Site assessment (1 points)				

CATEGORY	INDICATORS	Rank media Type of Revit Support for GA			
		Text Documentation	Modeling	Simulation	Data Integration
	11. Site development—protect or restore habitat (2 points)				
	12. Open space (1 points)				
	13. Rainwater management (3 points)				
	14. Heat island reduction (2 points)				
	15. Light pollution reduction (1 points)				
WATER EFFICIENCY	16. prerequisite-Outdoor water use reduction Required				
	17. prerequisite-Indoor water use reduction Required				
	18. Cooling tower water use (2 points)				
	19. Water metering (1 points)				
ENERGY AND ATMOSPHERE	20. prerequisite-Fundamental commissioning and verification Required				
	21. prerequisite-Minimum energy performance Required				
	22. prerequisite-Building-level energy metering Required				
	23. prerequisite-Fundamental refrigerant management Required				
	24. Enhanced commissioning (6 points)				
	25. Optimize Energy Performance (18 points)				
	26. Advanced energy metering (1 points)				
	27. Demand response (2 points)				
	28. Renewable energy production (3 points)				
	29. Enhanced refrigerant management (1 points)				
	30. Green power and carbon offsets (2 points)				
MATERIALS	31. prerequisite-Storage and collection of recyclables Required				

CATEGORY	INDICATORS	Rank media Type of Revit Support for GA			
		Text Documentation	Modeling	Simulation	Data Integration
	32. prerequisite-Construction and demolition waste management	<i>Required</i>			
	33. Building life-cycle impact reduction	<i>(2 points)</i>			
	34. Building product disclosure and optimization—environmental product declarations	<i>(2 points)</i>			
	35. Building product disclosure and optimization – material ingredients	<i>(2 points)</i>			
	36. Building product disclosure and optimization – sourcing of raw materials	<i>(2 points)</i>			
INDOOR ENVIRONMENTAL QUALITY	37. prerequisite-Minimum indoor air quality performance	<i>Required</i>			
	38. prerequisite-Environmental tobacco smoke control	<i>Required</i>			
	39. Enhanced indoor air quality strategies	<i>(2 points)</i>			
	40. Low-emitting materials	<i>(3 points)</i>			
	41. Construction indoor air quality management plan	<i>(1 points)</i>			
	42. Indoor air quality assessment	<i>(2 points)</i>			
	43. Thermal comfort	<i>(1 points)</i>			
	44. Interior lighting	<i>(2 points)</i>			
	45. Daylight	<i>(3 points)</i>			
	46. Quality views	<i>(1 points)</i>			
	47. Acoustic performance	<i>(1 points)</i>			
Integrative Process	48. Integrative Process	<i>(1 points)</i>			

APPENDIX A2

A2-T1

Results of task 1 of session 1 of the survey. It shows each expert assessment across LEED indicators for each category.

Table: Expert Evaluation based on (RD) of LEED Indicators across Various Categories

CATEGORY	INDICATOR	EXPERT 1		EXPERT 2		EXPERT 3		EXPERT 4	
		Points	Likert 1-7	Points	Likert 1-7	Points	Likert 1-7	Points	Likert 1-7
LOCATION AND TRANSPORTATION	1. LEED for neighborhood development location	0.0	1.0	2.0	2.0	0.0	2.0	0.0	1.0
	2. Sensitive land protection	0.3	1.0	0.0	2.0	0.3	4.0	0.2	1.0
	3. High-priority site	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
	4. Surrounding density and diverse uses	4.0	3.0	1.5	2.0	0.0	1.0	1.0	1.0
	5. Access to quality transit	2.0	4.0	2.0	3.0	0.0	2.0	1.0	1.0
	6. Bicycle facilities	1.0	7.0	1.0	5.0	1.0	6.0	1.0	7.0
	7. Reduced parking footprint	1.0	7.0	1.0	6.0	1.0	7.0	1.0	7.0
	8. Green vehicles	1.0	7.0	1.0	7.0	1.0	7.0	1.0	7.0
SUSTAINABLE SITES	9. prerequisite-Construction activity pollution prevention	0.0	1.0	0.0	1.0	0.0	2.0	0.0	1.0
	10. Site assessment	0.0	1.0	0.5	2.0	0.3	2.0	0.3	1.0
	11. Site development—protect or restore habitat	0.0	1.0	0.0	1.0	0.2	2.0	0.0	1.0

	12. Open space	1.0	6.0	1.0	7.0	1.0	7.0	1.0	7.0
	13. Rainwater management	3.0	7.0	1.5	5.0	2.0	6.0	3.0	7.0
	14. Heat island reduction	2.0	7.0	2.0	6.0	2.0	6.0	2.0	7.0
	15. Light pollution reduction	1.0	7.0	1.0	6.0	1.0	6.0	1.0	7.0
WATER EFFICIENCY	16. prerequisite-Outdoor water use reduction	8.0	6.0	4.0	3.0	7.0	5.0	9.0	7.0
	17. prerequisite-Indoor water use reduction	8.0	6.0	4.0	3.0	7.0	5.0	9.0	7.0
	18. Cooling tower water use	0.0	1.0	0.0	1.0	1.0	2.0	0.0	1.0
	19. Water metering	1.0	7.0	0.5	5.0	1.0	6.0	1.0	6.0
ENERGY AND ATMOSPHERE	20. prerequisite-Fundamental commissioning and verification	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
	21. prerequisite-Minimum energy performance	10.0	7.0	10.0	7.0	8.0	6.0	10.0	7.0
	22. prerequisite-Building-level energy metering	10.0	7.0	10.0	5.0	7.0	5.0	9.0	6.0
	23. prerequisite-Fundamental refrigerant management	10.0	7.0	4.0	3.0	0.0	1.0	10.0	7.0
	24. Enhanced commissioning	0.0	1.0	0.0	1.0	1.0	2.0	0.5	1.0
	25. Optimize Energy Performance	18.0	7.0	18.0	7.0	18.0	7.0	18.0	7.0
	26. Advanced energy metering	1.0	7.0	0.5	5.0	1.0	6.0	1.0	7.0
	27. Demand response	0.0	1.0	0.0	2.0	0.5	3.0	0.0	1.0
	28. Renewable energy production	3.0	7.0	3.0	7.0	2.0	6.0	3.0	7.0
	29. Enhanced refrigerant management	1.0	7.0	0.3	3.0	0.5	3.0	1.0	7.0
	30. Green power and carbon offsets	0.0	1.0	0.0	1.0	1.0	2.0	0.0	1.0

MATERIALS AND RESOURCES	31. prerequisite-Storage and collection of recyclables	2.0	1.0	3.0	2.0	5.0	5.0	5.0	4.0
	32. prerequisite-Construction and demolition waste management	0.0	1.0	0.0	2.0	3.0	4.0	4.0	4.0
	33. Building life-cycle impact reduction	1.0	4.0	1.5	5.0	1.0	5.0	1.0	4.0
	34. Building product disclosure and optimization—environmental product declarations	0.5	2.0	1.0	3.0	1.0	4.0	0.3	2.0
	35. Building product disclosure and optimization – material ingredients	0.0	1.0	1.0	3.0	1.0	4.0	0.0	1.0
	36. Building product disclosure and optimization – sourcing of raw materials	0.0	1.0	1.0	3.0	1.0	4.0	0.0	1.0
INDOOR ENVIRONMENTAL QUALITY	37. prerequisite-Minimum indoor air quality performance	10.0	7.0	8.0	6.0	8.0	6.0	8.0	6.0
	38. prerequisite-Environmental tobacco smoke control	5.0	4.0	8.0	6.0	5.0	4.0	6.0	5.0
	39. Enhanced indoor air quality strategies	0.0	1.0	0.0	1.0	0.2	2.0	0.0	1.0
	40. Low-emitting materials	1.0	4.0	1.5	4.0	2.0	4.0	2.0	5.0
	41. Construction indoor air quality management plan	0.0	1.0	0.0	1.0	0.3	1.0	0.0	1.0
	42. Indoor air quality assessment	1.0	2.0	1.0	3.0	1.0	3.0	1.0	2.0
	43. Thermal comfort	1.0	7.0	1.0	6.0	1.0	7.0	1.0	7.0
	44. Interior lighting	2.0	7.0	2.0	6.0	1.5	6.0	2.0	7.0
	45. Daylight	3.0	7.0	3.0	7.0	2.0	6.0	3.0	7.0
	46. Quality views	1.0	7.0	1.0	6.0	1.0	6.0	1.0	7.0
	47. Acoustic performance	1.0	7.0	1.0	7.0	0.7	6.0	1.0	6.0
Integrative Process	48. Integrative Process	1.0	7.0	1.0	6.0	1.0	5.0	1.0	6.0

A2-T2

Results of task 2 of session 1 of the survey. It shows each expert assessment across LEED indicators for each category.

Table: Expert Evaluation based on (CS) of LEED Indicators across Various Categories

CATEGORY	INDICATOR	EXPERT 1		EXPERT 2		EXPERT 3		EXPERT 4	
		Points	Likert 1-7	Points	Likert 1-7	Points	Likert 1-7	Points	Likert 1-7
LOCATION AND TRANSPORTATION	1. LEED for neighborhood development location	2.0	1.0	1.5	1.0	2.5	1.0	0.0	1.0
	2. Sensitive land protection	0.5	2.0	0.3	2.0	0.0	1.0	0.2	1.0
	3. High-priority site	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
	4. Surrounding density and diverse uses	3.0	4.0	2.0	2.0	1.0	1.0	1.5	2.0
	5. Access to quality transit	1.0	2.0	1.0	3.0	1.0	3.0	1.0	2.0
	6. Bicycle facilities	1.0	7.0	0.8	6.0	0.9	7.0	1.0	7.0
	7. Reduced parking footprint	1.0	7.0	1.0	7.0	1.0	7.0	1.0	7.0
	8. Green vehicles	1.0	7.0	1.0	7.0	1.0	7.0	1.0	7.0
SUSTAINABLE SITES	9. prerequisite-Construction activity pollution prevention	0.0	1.0	0.0	1.0	0.0	2.0	0.0	1.0
	10. Site assessment	0.3	1.0	0.4	3.0	0.3	1.0	0.0	1.0
	11. Site development—protect or restore habitat	0.3	2.0	0.1	1.0	0.1	1.0	0.3	2.0
	12. Open space	1.0	7.0	0.9	6.0	1.0	7.0	1.0	7.0

	13. Rainwater management	2.8	6.0	1.5	4.0	1.3	3.0	3.0	7.0
	14. Heat island reduction	2.0	6.0	2.0	6.0	2.0	7.0	2.0	7.0
	15. Light pollution reduction	1.0	7.0	0.9	5.0	1.0	7.0	1.0	7.0
WATER EFFICIENCY	16. prerequisite-Outdoor water use reduction	6.0	5.0	7.0	6.0	7.0	6.0	8.0	7.0
	17. prerequisite-Indoor water use reduction	7.0	6.0	4.0	5.0	7.0	6.0	9.0	7.0
	18. Cooling tower water use	0.1	1.0	0.8	3.0	0.1	1.0	0.0	1.0
	19. Water metering	1.0	7.0	0.4	3.0	1.0	7.0	1.0	6.0
ENERGY AND ATMOSPHERE	20. prerequisite-Fundamental commissioning and verification	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
	21. prerequisite-Minimum energy performance	9.0	7.0	9.0	7.0	10.0	7.0	9.0	7.0
	22. prerequisite-Building-level energy metering	8.0	6.0	8.0	6.0	6.0	5.0	8.0	6.0
	23. prerequisite-Fundamental refrigerant management	6.0	5.0	8.0	6.0	10.0	7.0	9.0	7.0
	24. Enhanced commissioning	0.0	1.0	1.0	1.0	0.2	1.0	0.0	1.0
	25. Optimize Energy Performance	18.0	7.0	18.0	7.0	18.0	7.0	18.0	7.0
	26. Advanced energy metering	0.8	4.0	0.9	4.0	1.0	5.0	1.0	7.0
	27. Demand response	0.8	4.0	0.6	3.0	0.0	1.0	0.0	1.0
	28. Renewable energy production	3.0	7.0	3.0	7.0	3.0	7.0	3.0	7.0
	29. Enhanced refrigerant management	1.0	7.0	0.8	6.0	1.0	7.0	1.0	7.0
	30. Green power and carbon offsets	0.3	1.0	0.3	1.0	0.6	1.0	0.0	1.0

MATERIALS AND RESOURCES	31. prerequisite-Storage and collection of recyclables	2.5	3.0	3.0	3.0	1.0	2.0	5.0	4.0
	32. prerequisite-Construction and demolition waste management	1.0	2.0	2.0	3.0	2.0	3.0	4.0	4.0
	33. Building life-cycle impact reduction	1.3	5.0	1.3	5.0	1.2	5.0	1.0	4.0
	34. Building product disclosure and optimization—environmental product declarations	0.8	1.0	1.0	2.0	0.2	1.0	0.3	2.0
	35. Building product disclosure and optimization – material ingredients	0.8	2.0	1.0	2.0	0.2	1.0	0.0	1.0
	36. Building product disclosure and optimization – sourcing of raw materials	0.8	2.0	1.0	3.0	0.2	1.0	0.0	1.0
INDOOR ENVIRONMENTAL QUALITY	37. prerequisite-Minimum indoor air quality performance	10.0	7.0	8.0	6.0	8.0	6.0	10.0	7.0
	38. prerequisite-Environmental tobacco smoke control	7.0	5.0	8.0	6.0	7.0	5.0	8.0	6.0
	39. Enhanced indoor air quality strategies	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
	40. Low-emitting materials	1.3	4.0	1.3	4.0	2.0	4.0	2.0	5.0
	41. Construction indoor air quality management plan	0.1	1.0	0.1	1.0	0.3	1.0	0.0	1.0
	42. Indoor air quality assessment	0.5	3.0	0.8	3.0	1.0	4.0	1.0	2.0
	43. Thermal comfort	1.0	7.0	1.0	7.0	1.0	7.0	1.0	7.0
	44. Interior lighting	1.8	6.0	2.0	7.0	2.0	7.0	2.0	7.0
	45. Daylight	2.8	6.0	3.0	7.0	3.0	7.0	3.0	7.0
	46. Quality views	1.0	7.0	0.7	6.0	1.0	7.0	1.0	7.0
	47. Acoustic performance	1.0	7.0	0.8	6.0	1.0	6.0	1.0	6.0
Integrative Process	48. Integrative Process	1.0	7.0	1.0	7.0	1.0	6.0	1.0	6.0

APPENDIX A3

A3-T1

Results of task 1 of session 2 of the survey. It shows each expert assessment across MOSTADAM indicators for each category.

Table: Expert Evaluation based on (RD) of MOSTADAM Indicators across Various Categories.

INDICATOR	EXPERT 1		EXPERT 2		EXPERT 3		EXPERT 4	
	Points	Likert 1-7	Points	Likert 1-7	Points	Likert 1-7	Points	Likert 1-7
Indicators of SS category								
Flood, Rainwater and Sewage Management	1.0	4.0	0.0	1.0	1.0	5.0	1.0	4.0
Ecological Assessment and Protection	0.8	3.0	0.3	2.0	0.5	3.0	0.3	2.0
Construction Environmental Management	0.3	1.0	0.3	1.0	0.1	1.0	0.3	1.0
Ecological Enhancement	0.5	4.0	0.3	3.0	0.5	4.0	0.5	5.0
Heat Island Effect	1.5	6.0	1.0	5.0	1.5	6.0	1.3	5.0
Light Pollution	1.0	7.0	1.0	7.0	1.0	7.0	1.0	7.0
Indicators of TC category								
Electric Vehicle Provisions	1.0	7.0	1.0	7.0	1.0	7.0	1.0	7.0
Access to Public Transportation	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Access to Amenities	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Home	1.0	7.0	1.0	7.0	1.0	6.0	1.0	7.0
Individual Sustainable Transport	0.3	3.0	0.6	5.0	0.5	4.0	0.2	3.0

Indicators of RC category								
Thriving Economy	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Heritage & Culture	1.0	5.0	1.3	6.0	0.8	3.0	1.0	5.0
Vibrant Society	0.5	4.0	1.0	7.0	1.0	6.0	0.5	5.0
Regional Focus	1.0	4.0	1.3	5.0	0.8	4.0	1.0	5.0
Indicators of E category								
Energy Performance	15.0	7.0	15.0	7.0	15.0	7.0	15.0	7.0
Systems Commissioning	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Envelope Commissioning	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Energy Metering	1.0	7.0	1.0	7.0	0.5	4.0	0.5	5.0
Energy Efficient Appliances	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Renewable Energy	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Ozone Impact	0.0	1.0	0.5	4.0	0.0	2.0	0.5	3.0
Indicators of W category								
Indoor Water Performance	10.0	7.0	10.0	7.0	10.0	7.0	10.0	7.0
Outdoor Water Performance	8.5	6.0	10.0	7.0	10.0	7.0	10.0	7.0
Alternative Water Solutions	0.5	2.0	0.8	3.0	0.3	2.0	0.5	2.0
Water Metering	1.0	7.0	0.5	5.0	0.5	5.0	0.5	5.0
Indicators of HC category								
Outdoor Thermal Comfort	1.0	4.0	1.0	4.0	1.0	4.0	1.0	4.0

Indoor Thermal Comfort	2.0	7.0	2.0	7.0	2.0	7.0	2.0	7.0
Ventilation	1.0	7.0	1.0	7.0	1.0	7.0	1.0	7.0
VOCs and Low-Emitting Materials	2.0	7.0	2.0	7.0	2.0	5.0	2.0	7.0
Access for All	1.0	7.0	1.0	6.0	1.0	7.0	1.0	7.0
Daylight and Visual Comfort	2.0	7.0	2.0	7.0	2.0	7.0	2.0	7.0
Acoustics	0.8	5.0	0.5	4.0	0.6	5.0	0.5	4.0
Indoor Air Quality	1.0	6.0	1.0	6.0	1.0	7.0	1.0	7.0
Active Residents	0.6	5.0	0.8	6.0	0.8	6.0	0.5	6.0
Outdoor Space	1.0	7.0	1.0	7.0	1.0	7.0	1.0	7.0
Indicators of MW category								
Construction Waste Management	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Non-Polluting Insulation Materials	1.0	7.0	1.0	7.0	1.0	7.0	1.0	7.0
Recycled Materials	2.0	7.0	2.0	6.0	2.0	7.0	2.0	7.0
Indicators of EI category								
Innovation	2.0	7.0	2.0	6.0	2.0	6.0	2.0	6.0
Mostadam Guide	1.5	6.0	1.0	5.0	1.0	4.0	1.0	5.0
Indicators of PMM category								
Residential Waste Management	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Sustainable Procurement	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Building Performance Monitoring	0.5	3.0	0.3	2.0	0.6	1.0	0.5	3.0

A3-T2

Results of task 2 of session 2 of the survey. It shows each expert assessment across MOSTADAM indicators for each category.

Table: Expert Evaluation based on (CS) of MOSTADAM Indicators across Various Categories

INDICATOR	EXPERT 1		EXPERT 2		EXPERT 3		EXPERT 4	
	Points	Likert 1-7	Points	Likert 1-7	Points	Likert 1-7	Points	Likert 1-7
Indicators of SS category								
Flood, Rainwater and Sewage Management	0.8	3.0	1.0	5.0	1.5	5.0	1.0	4.0
Ecological Assessment and Protection	0.5	3.0	0.3	2.0	0.3	2.0	0.3	2.0
Construction Environmental Management	0.4	4.0	0.3	3.0	0.3	2.0	0.3	1.0
Ecological Enhancement	0.5	5.0	0.5	4.0	0.5	6.0	0.5	5.0
Heat Island Effect	1.5	6.0	1.5	5.0	1.5	6.0	1.3	5.0
Light Pollution	1.0	7.0	1.0	7.0	1.0	7.0	1.0	7.0
Indicators of TC category								
Electric Vehicle Provisions	1.0	6.0	1.0	5.0	1.0	7.0	1.0	7.0
Access to Public Transportation	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Access to Amenities	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Home	0.8	6.0	1.0	7.0	0.8	6.0	1.0	7.0
Individual Sustainable Transport	0.2	3.0	0.3	4.0	0.3	3.0	0.2	3.0
Indicators of RC category								
Thriving Economy	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0

Heritage & Culture	1.0	4.0	1.2	5.0	0.8	3.0	1.0	5.0
Vibrant Society	0.5	3.0	0.5	4.0	0.5	4.0	0.5	5.0
Regional Focus	1.0	6.0	1.0	5.0	1.0	6.0	1.0	5.0
Indicators of E category								
Energy Performance	15.0	7.0	15.0	7.0	15.0	7.0	15.0	7.0
Systems Commissioning	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Envelope Commissioning	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Energy Metering	0.5	5.0	0.5	4.0	0.5	6.0	0.5	5.0
Energy Efficient Appliances	0.0	1.0	0.0	1.0	0.5	1.0	0.0	1.0
Renewable Energy	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0
Ozone Impact	0.5	5.0	0.5	5.0	0.5	6.0	0.5	3.0
Indicators of W category								
Indoor Water Performance	10.0	7.0	10.0	6.0	10.0	7.0	10.0	7.0
Outdoor Water Performance	10.0	7.0	10.0	6.0	10.0	7.0	10.0	7.0
Alternative Water Solutions	0.9	3.0	0.7	2.0	0.7	2.0	0.5	2.0
Water Metering	0.5	6.0	0.5	5.0	0.5	6.0	0.5	5.0
Indicators of HC category								
Outdoor Thermal Comfort	1.0	4.0	1.0	5.0	1.0	4.0	1.0	4.0
Indoor Thermal Comfort	2.0	7.0	2.0	7.0	2.0	7.0	2.0	7.0
Ventilation	1.0	6.0	1.0	6.0	1.0	6.0	1.0	7.0
VOCs and Low-Emitting Materials	2.0	7.0	2.0	7.0	2.0	7.0	2.0	7.0

Access for All	1.0	6.0	1.0	6.0	1.0	6.0	1.0	7.0
Daylight and Visual Comfort	2.0	7.0	2.0	7.0	2.0	7.0	2.0	7.0
Acoustics	0.5	5.0	0.5	5.0	0.5	6.0	0.5	4.0
Indoor Air Quality	0.8	6.0	0.8	5.0	1.0	7.0	1.0	7.0
Active Residents	0.8	5.0	0.5	5.0	0.5	4.0	0.5	6.0
Outdoor Space	1.0	7.0	1.0	7.0	1.0	6.0	1.0	7.0
Indicators of MW category								
Construction Waste Management	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Non-Polluting Insulation Materials	1.0	6.0	1.0	7.0	1.0	7.0	1.0	7.0
Recycled Materials	2.0	6.0	2.0	6.0	2.0	7.0	2.0	7.0
Indicators of EI category								
Innovation	2.0	7.0	1.5	6.0	1.8	6.0	2.0	6.0
Mostadam Guide	1.0	4.0	1.0	4.0	1.0	5.0	1.0	5.0
Indicators of PMM category								
Residential Waste Management	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Sustainable Procurement	0.0	1.0	0.0	1.0	0.0	1.0	0.0	1.0
Building Performance Monitoring	0.8	5.0	0.5	4.0	0.8	5.0	0.5	3.0

APPENDIX B

Detailed Steps for Implementing and Using the LEEDMRPlugin in Revit

This appendix provides step-by-step instructions for implementing and using the LEEDMRPlugin in Revit, starting from scratch. These steps include setting up the shared parameter, adding it to family instances, integrating the plugin into Revit, and executing the plugin to assess the "Recycled Content" parameter.

Step 1: Create a Shared Parameter

1. **Open Revit:** Launch Revit on your computer.
2. **Navigate to the Manage Tab:**
 - Click on the **Manage** tab in the top menu.
3. **Open Shared Parameters:**
 - Click on the **Shared Parameters** button in the **Settings** panel.
4. **Create or Open a Shared Parameter File:**
 - If you do not have a shared parameter file, click **Create**, choose a location, and save the file with a suitable name (e.g., LEEDParameters.txt).
 - If you already have a shared parameter file, click **Open** and select your existing file.
5. **Create a new group:**
 - In the Shared Parameters dialog, click **Groups** and then **New**.
 - Name the new group (e.g., LEED Parameters).

6. Add a New Parameter:

- Select the newly created group and click **New** to create a new parameter.
- Name the parameter Recycled Content.
- Set the type to Text.
- Click OK to save the parameter.

Step 2: Add the Shared Parameter to a Family

1. Open the Family Editor:

- Open the family you want to add the parameter to (e.g., a wooden door family).
- If the family is not already loaded in your project, navigate to File > Open > Family and select the family file.

2. Open the Family Types Dialog:

- In the Create tab, click on Family Types.

3. Add the Shared Parameter to the Family:

- In the Family Types dialog, click Add.
- Select Shared Parameter and click Select.
- Choose the Recycled Content parameter from the shared parameter file.
- Set the parameter group to a suitable category (e.g., Materials and Finishes).
- Choose the parameter type as Instance if you want to set it individually for each instance or **Type** if it will be the same for all instances of that family type.

- Click OK to add the parameter to the family.

4. Save and Load the Family:

- Save the changes to the family.
- Click Load into Project to load the updated family into your Revit project.

Step 3: Set the Recycled Content Parameter in the Project

1. Place Family Instances in the Project:

- If not already placed, add instances of the family (e.g., wooden doors) to your project.

2. Select an Instance:

- Select a family instance in your project.

3. Edit the Parameter:

- In the Properties palette, locate the Recycled Content parameter under the category you set (e.g., Materials and Finishes).
- Enter the appropriate value for the parameter (e.g., 30% for a wooden door made with 30% recycled wood).

Step 4: Integrate the Plugin into Revit

1. Set Up a Revit Plugin Project:

- Create a new C# Class Library project in Visual Studio.
- Add references to the Revit API DLLs (RevitAPI.dll and RevitAPIUI.dll).

2. Add the Plugin Code:

- Copy the provided plugin code into your project:

```
using Autodesk.Revit.Attributes;
using Autodesk.Revit.DB;
```

```

using Autodesk.Revit.DB.Analysis;
using Autodesk.Revit.UI;
using System;
using System.Collections.Generic;
using System.Diagnostics;
using System.IO;
using System.Reflection;
using System.Threading;
using System.Windows.Media.Imaging;
using System.Xml.Serialization;

namespace MyRevitPlugin
{
    public class Class1 : IExternalApplication
    {
        public Result OnStartup(UIControlledApplication application)
        {
            RibbonPanel ribbonPanel = application.CreateRibbonPanel("BD+C");

            string thisAssemblyPath = Assembly.GetExecutingAssembly().Location;
            PushButtonData buttonData1 = new PushButtonData("cmdLEED", "LEED", thisAssemblyPath,
                "MyRevitPlugin.LEED");
            PushButtonData buttonData2 = new PushButtonData("cmdLEEDMR", "LEED MR",
                thisAssemblyPath, "MyRevitPlugin.LEEDMRPlugin");

            PushButton pushButton1 = ribbonPanel.AddItem(buttonData1) as PushButton;
            PushButton pushButton2 = ribbonPanel.AddItem(buttonData2) as PushButton;

            pushButton1.ToolTip = "LEED BD+C for Material and Resources Credit";
            pushButton2.ToolTip = "LEED MR Plugin for Recycled Content";

            Uri urlImage = new Uri(@"C:\Users\ACER\Desktop\icon.png");
            BitmapImage bitmapImage = new BitmapImage(urlImage);
            pushButton1.LargeImage = bitmapImage;
            pushButton2.LargeImage = bitmapImage;

            return Result.Succeeded;
        }

        public Result OnShutdown(UIControlledApplication application)
        {
            return Result.Succeeded;
        }
    }

    [Transaction(TransactionMode.Manual)]
    public class LEED : IExternalCommand
    {
        public Result Execute(ExternalCommandData commandData, ref string message, ElementSet
            elements)
        {
            var uiapp = commandData.Application;
            var uidoc = uiapp.ActiveUIDocument;
            var doc = uidoc.Document;

            // Post the "Create Energy Model" command

            uiapp.PostCommand(RevitCommandId.LookupPostableCommandId(PostableCommand.CreateEnergyMode
                l));
        }
    }
}

```

```

        // Delay for 2 minutes
        Thread.Sleep(2 * 60 * 1000);

        // Display message
        TaskDialog.Show("Energy Optimization", "Energy analysis model generated and system analysis
simulation completed successfully!");

        return Result.Succeeded;
    }
}

[Transaction(TransactionMode.Manual)]
public class LEEDMRPlugin : IExternalCommand
{
    public Result Execute(
        ExternalCommandData commandData,
        ref string message,
        ElementSet elements)
    {
        UIDocument uidoc = commandData.Application.ActiveUIDocument;
        Document doc = uidoc.Document;

        // Get selected elements
        ICollection<ElementId> selectedIds = uidoc.Selection.GetElementIds();
        if (selectedIds.Count == 0)
        {
            TaskDialog.Show("LEED MR Plugin", "No elements selected.");
            return Result.Cancelled;
        }

        // Iterate through selected elements
        foreach (ElementId id in selectedIds)
        {
            Element element = doc.GetElement(id);
            if (element is FamilyInstance)
            {
                FamilyInstance familyInstance = element as FamilyInstance;
                string recycledContent = GetRecycledContent(familyInstance);

                // Display element information
                TaskDialog.Show("Element Info",
                    $"Element ID: {element.Id}\n" +
                    $"Category: {element.Category.Name}\n" +
                    $"Recycled Content: {recycledContent}");
            }
        }

        return Result.Succeeded;
    }
}

private string GetRecycledContent(FamilyInstance familyInstance)
{
    foreach (Parameter param in familyInstance.Parameters)
    {
        if (param.Definition.Name.Equals("Recycled Content", StringComparison.OrdinalIgnoreCase))
        {
            return param.AsString();
        }
    }
}

```

```

    }
    return "N/A";
}
}
}

namespace LeedCertification
{
    public class LeedPanel : IExternalApplication
    {
        public Result OnStartup(UIControlledApplication application)
        {
            string assemblyPath =
@"C:\REVITLEED\LeedCertification\LeedCertification\bin\Debug\LeedCertification.dll";
            RibbonPanel leedPanel = application.CreateRibbonPanel("LEED Certification");

            PulldownButtonData pData = new PulldownButtonData("MRPrerequisites", "MR Prerequisites");
            PulldownButton pButton = leedPanel.AddItem(pData) as PulldownButton;

            AddPushButton(pButton, "MRp1 Rating System", "LeedCertification.MRp1RatingSystem",
assemblyPath);
            AddPushButton(pButton, "MRp1 Template", "LeedCertification.MRp1Template", assemblyPath);

            // Repeat for other LEED categories as needed...
            return Result.Succeeded;
        }

        private void AddPushButton(PulldownButton pButton, string buttonText, string className, string
path)
        {
            PushButtonData buttonData = new PushButtonData(buttonText, buttonText, path, className);
            pButton.AddPushButton(buttonData);
        }

        public Result OnShutdown(UIControlledApplication application)
        {
            return Result.Succeeded;
        }
    }

    public class MRp1RatingSystem : IExternalCommand
    {
        public Result Execute(ExternalCommandData commandData, ref string message, ElementSet
elements)
        {
            Process.Start(@"C:\REVITLEED\LEEDTemplates\MR\MRp1RatingSystem.pdf");
            return Result.Succeeded;
        }
    }

    // Additional classes for other PDFs...
}

namespace ZipDistCalculator
{
    public class ZipCode
    {
        public string Code { get; set; }
        public string State { get; set; }
    }
}

```

```

public double Latitude { get; set; }
public double Longitude { get; set; }

public static List<ZipCode> LoadData(string path)
{
    if (!File.Exists(path)) throw new FileNotFoundException("ZipCodeData.xml not found.");

    using (StreamReader reader = new StreamReader(path))
    {
        XmlSerializer serializer = new XmlSerializer(typeof(List<ZipCode>));
        return (List<ZipCode>)serializer.Deserialize(reader);
    }
}

public static double CalculateDistance(ZipCode zip1, ZipCode zip2)
{
    double radians(double angle) => angle * Math.PI / 180;
    double dLat = radians(zip2.Latitude - zip1.Latitude);
    double dLon = radians(zip2.Longitude - zip1.Longitude);
    double a = Math.Sin(dLat / 2) * Math.Sin(dLat / 2) +
        Math.Cos(radians(zip1.Latitude)) * Math.Cos(radians(zip2.Latitude)) *
        Math.Sin(dLon / 2) * Math.Sin(dLon / 2);
    double c = 2 * Math.Atan2(Math.Sqrt(a), Math.Sqrt(1 - a));
    const double EarthRadiusKm = 6371;
    return EarthRadiusKm * c;
}
}
}

```

3. Build the Project:

- Build the project in Visual Studio to create the DLL file.

4. Deploy the Plugin:

- Copy the compiled DLL file to the Revit **Addins** folder, typically located at **C:\ProgramData\Autodesk\Revit\Addins\<RevitVersion>**.

5. Create an Add-In Manifest File:

- Create a .addin file to register the plugin with Revit. The file should look like this:

```

<?xml version="1.0" encoding="utf-8" standalone="no"?>
<RevitAddIns>
  <AddIn Type="Application">
    <Name>LEED MR Plugin</Name>
    <Assembly>C:\Path\To\Your\Dll\MyRevitPlugin.dll</Assembly>
    <AddInId>12345678-1234-1234-1234-123456789012</AddInId>
    <VendorId>VENDOR_ID</VendorId>
    <VendorDescription>Your Company</VendorDescription>
  </AddIn>
</RevitAddIns>

```

6. Restart Revit:

- Restart Revit to load the new plugin.

Step 5: Execute the LEEDMRPlugin

1. Open a Revit Project:

- Open your Revit project where you have placed the family instances with the "Recycled Content" parameter.

2. Select Family Instances:

- Select one or more family instances in your project.

3. Run the Plugin:

- Click on the "LEED MR" button in the "BD+C" ribbon panel.
- The plugin will iterate through the selected elements, check if they are FamilyInstance elements, and display their "Recycled Content" values.

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