Investigating the Implementation of Building Performance Simulation in Design Phase: The Case for Addis Ababa City

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A Thesis Submitted to the department of Civil Engineering Presented in Partial Fulfillment of the Requirement for the Degree of Master of Science in Civil Engineering (Specialization in Construction Engineering and Management)

SCHOOL OF CIVIL ENGINEERING AND ARCHITECTURE

OFFICE OF GRADUATE STUDIES

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

June, 2024

Adama, Ethiopia

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Office of Graduate Studies

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DECLARATION and RECOMMENDATION

I declare that this Master Thesis entitled "**Investigating the Implementation of Building Performance Simulation in Design Phase: The Case for Addis Ababa City**" is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificate in any other university. All sources of materials that are used for this Thesis have been duly acknowledged through citation. It is being submitted for the partial fulfillment for the award of the degree of Master of Science in **Civil Engineering (Specialization in Construction Engineering and Management)** at **Adama Science and Technology University** School of **Civil Engineering and Architecture**.

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I hereby certify that I have read and evaluated this Thesis entitled "**Investigating the Implementation of Building Performance Simulation in Design Phase: The Case for Addis Ababa City**" prepared under my guidance by Mr. **Belete Tilahun Worku** submitted in partial fulfillment of the requirements for the degree of Master of Science in **Civil Engineering (Specialization in Construction Engineering and Management)**. Therefore, I recommend that the candidate has fulfilled the requirements and hence he can submit the thesis to the department.

Bahiru Bewekt (PhD) ____________________ ____________________

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Approval of Board of Examiners

We, the undersigned, members of the Board of Examiners of the Thesis open defense by **Belete Tilahun Worku** have read and evaluated his Thesis entitled **“Investigating the Implementation of Building Performance Simulation in Design Phase: The Case for Addis Ababa City”** and examined the candidate. This is, therefore, to certify that the Thesis has been accepted in partial fulfillment of the requirement of the degree of Master of Science in **Construction Engineering and Management**

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ACKNOWLEDGMENTS

First and foremost, all praise, honor, and glory be to Almighty God for providing me this opportunity and giving me the strength, hope, knowledge, and perseverance to undertake and complete my research.

I would like to express my sincere thanks and deep appreciation to my advisor Dr. Bahiru Bewket Mitike (Assistant Professor) for the motivation, encouragement, inspiring and consistent guidance, and utmost cooperation throughout the duration of the research work. Above all for his critical review and feedbacks during the entire study. This thesis would not have been possible without his support and continuous guidance. It was a highly educative and memorable experience working under his supervision. I have been extremely lucky to have a supervisor who cared so much about me and my work, and who responded to my questions and queries so promptly.

I would also like to thank my research group colleagues and my friends for all their concern and supports throughout this research work.

Last but not the least, I dedicate this thesis to my parents, who devoted their life for the education of their children. My parent's priority of life for education is the key for me to reach here. You are my heroes and the source of my strength. I am grateful having a determined family. Thanks for their unconditional love and cooperation, who are the source of my happiness and the designer of the direction of my life, without which this study would not have been possible at all.

ABSTRACT

This study was conducted to Investigating the implementation of building performance simulation (BPS) during the design phase the case of Addis Ababa City with specific objectives of to analyze the extent of awareness regarding to building performance simulation (BPS) and to identify the major factors affecting the practice of BPS during design phase.

The scope of the study was limited to be focused on Investigating the implementation of building performance simulation (BPS) of some consultants' random samples in Addis Ababa City. Investigating the implementation of building performance simulation (BPS) in the design phase with providing some questionnaires and focus group discussion. The study's research design is descriptive and the research approach is mixed (qualitative and quantitative). The sample size of the study is fifty respondents of the questionnaire that are engineers, surveyors, designers, residence engineers, supervisors and project coordinators for building performance simulation (BPS) in the design phase. The sampling technique used was systematic random sampling. Hence, Survey questionnaire and interview is prepared based on reviewed literature to assess Investigating the implementation of building performance simulation (BPS) in the design phase the case of Addis Ababa City. Primary and secondary method of data collection is used from respondents and detail literature reviews respectively. Then the data collected is analyzed using statistical software package (SPSS V.26) and Microsoft excel. Results indicate Investigating the implementation of building performance simulation (BPS) in the design phase to be medium. This shows that Addis Ababa City was moderate performance on building performance simulation (BPS) therefore, it needs improvement on building performance simulation (BPS) during the design phase.

***Key words**: Performance Based Design, Building Performance Simulation, Building Information Modeling, Sustainability*

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LIST OF ACRONYMS

BEDES: Building Energy Data Exchange Specification

BP: Building Performance

BPA: Building performance Analysis

BPS: Building performance simulation

HVAC: Heat ventilation and Air Conditioning

IBPSA: International Building Performance Simulation Association

LCC: Life cycle Cost

LEED: Leadership in Energy and Environmental Design

NREL: National Renewable Energy Laboratory

PBD: Performance based design

ROI: Return on Investment

SPSS: Statistical Package for the Social Sciences

CHAPTER ONE

1. INTRODUCTION

1.1 Background of the study

The construction industry has continuously evolved from the days of building with brick and hand-made designs. Throughout the history of civilization, humans developed the tools to construct structures to fulfill a specific need or service. These structures included buildings for worship, commerce, transit, dwelling, etc. Building simulation as a discipline can be traced back to the 1960's when the US government was involved in projects to evaluate the thermal environment in fallout shelters (Solmaz, 2019a). Simulation is used before an existing system is altered or a new system built, to reduce the chances of failure to meet specifications, to eliminate unforeseen bottlenecks, to prevent under or over-utilization of resources, and to optimize system performance (268437.Pdf, n.d.)

International Building Performance Simulation Association (IBPSA) was established in 1986 as a non-profit international society of computational building performance simulation researchers, developers and practitioners, dedicated to improving the design, construction, operation, and maintenance of new and existing buildings worldwide. The building industry, without a doubt, is one of the most important industrial and economic sectors influencing the quality of life and the environment (Beausoleil-Morrison & Hensen, 2008). Each month, the Emerging Simulation Technology subcommittee poses a question submitted by an IBPSA member to recognized building professionals to get their expert perspectives (IBPSANews-32-2.Pdf, n.d.)/2022/. Significantly, the organization IBPSA has the ability through its regional structure to act globally while responding to local need. (J. Clarke, 2015a)

Building performance covers a wide variety of aspects. However, it is vitally important to realize that the primary purpose of buildings is to protect against undesirable outside conditions, sustainability, user comfort to provide healthy and includes many other cases which requires supporting by early design decision and simulation tools(J. L. M. Hensen & Lamberts, 2019a). Whether they have addressed it consciously or not, humans have been concerned with the performance of structures. The purpose and requirements these buildings have to fulfill are essential. In his book, (Wilde, 2018) defines building performance as being related to either a building as an object or a building as a construction process with three main views; engineering, process, and aesthetics. These three views concern how well a building performs, how well the construction process delivers the buildings, and the success of the building as a form for presentation or appreciation.

Computational modeling (i.e. creating a computer-based representation of a real system at a particular level of abstraction) and simulation (i.e. enacting, or implementing, or instantiating, a model to predict the (future) behavior of a real system) is one of the most powerful and widely used analysis techniques, with applications ranging from economic and climate forecasting to the testing of engineering problems (J. L. M. Hensen & Lamberts, 2019).

Since the beginning of human history, people have lived in caves and underground chambers made of stones for a variety of reasons, including protection from the elements and specific needs like shelter. Across all continents, humans have succeeded in further development and construction. The hewn rock cathedrals in Lalibela, Ethiopia (12th century AD), Chichén Itzá in Mexico (7th to 8th century AD), the Acropolis in Greece (5th century BC), the Caves of Petra in Jordan (4th century BC), and many other instances are a few examples of the numerous constructions produced. These early buildings have socioeconomic significance for their realization's effort, purpose, and contribution. For whatever purpose these structures and many other buildings were constructed, they have been made of a quality that has enabled them to last through the test of time. These buildings are labeled as early high-performance buildings (de Wilde, 2017).

With cities' increased population and urbanization, further infrastructure development is required. A research done by the United Nations Department of Economic and Social Affairs (UNDESA) in 2018 states that 55% of the world’s population resides in urban areas expected to increase to 68%. In this data, 90% of the population growth is projected in Africa and Asia. Despite the contrast of the African population (57%) living in urban cities compared to the rest of the world, the number is expected to increase in the coming decades. With this, the urban density is expected to increase as well.

The project's design stage frequently has an impact on the project's short- and long-term success as well as the functionality of the building, for better or worse. When adjustments can be made for the least amount of money, during the design phase, is the ideal moment to incorporate the best solutions for efficient, higher performing, and sustainable buildings. Performance fluctuates during the course of a building's existence, increasing gradually at the beginning and declining gradually once the facility is in use. Through restoration and maintenance, the functional performance of the building can be brought to its initial level. As time passes and these structures are exposed to the elements and the climate for an extended period of time, their performance level will rapidly deteriorate. The speed with which buildings lose their performance value depends on the design quality and construction process.

This chapter provides background information for the study and a review of the literature, which explains the research field and provides context for the problem, which in turn lead to the study's questions and objectives. The remainder of this research proposal will establish how the performance of a building in terms of crucial parameter indicators is measured and analyzed and how it can contribute to the improvement of buildings.

1.2 Statement of the Problem

The design process for buildings places a strong emphasis on the stakeholders' desired needs as well as aesthetics and the architectural component. More emphasis is placed on the building's appearance and construction during this phase. The performance requirements for building systems like plumbing, ventilation, and lighting are not given much thought during the design phase. It is more difficult to guarantee comfort, user and resident happiness, and understanding of the building's impact on the environment if a building's performance is not getting attention (Attia et al., 2012). Therefore, further research is needed to develop genuine overall environmental building design development toolkit that first of all integrates an intelligent knowledge-base, which comply with codes and rating systems, and do embrace an integrated multidisciplinary design approach including the whole design team.

Further studies can be explored on BIM case studies and comparative evaluation of BIM strategies with regard to organizational basis and types of projects.(Belay et al., 2021) In recent years, BIM has also gained a widespread acceptance across developing countries, despite its low adoption rate in developmental infrastructure projects (Ismail et al., 2017) (Olawumi and Chan, 2019). For instance, (Ismail et al., 2017) reported an improvement in overall BIM uptake across the Asian developing countries although suggested for further extended studies.

Similarly, (Murphy and Nahod, 2017) call for an in-depth investigation of BIM adoption in public construction projects for a successful BIM adoption and diffusion. Moreover, recent studies revealed that there are only very few studies conducted in sub-Saharan African countries regarding BIM adoption in public infrastructure projects (Belay et al., 2021)

While a lot has been published on the subject of simulation, the application area is often taken for granted within the IBPSA community. Yet to do meaningful simulations, one of the hardest challenges is to define the question that is to be answered (Gong et al., 2020).

Addis Ababa city is one of 40 cities in Ethiopia and ranks first in the Ethiopia population. With this speedy increase in population, there has been an increase in built space density, housing extension, infrastructure development, and industrial area restructuring in the city's (Abeje 2007; Fetene and Worku 2013). Furthermore, Addis Ababa is experiencing a clear and rapid building explosion, but it is still unclear how sustainable buildings construction will help resolve these issues. Hence, this study is intended to contribute to the existing knowledge by investigating the major factors affecting the implementation of BPS during design phase. The research focuses deeply in determining the factors affecting Building Performance Simulation during the design phase in building projects of Addis Ababa City.

1.3 Research Questions

The research will try to answer the following questions:

i. What is the extent of awareness regarding to the principle of building performance analysis/simulation?

ii. Is there practice of building performance analysis/simulation?

iii. What are the major factors affecting the practice of building performance simulation during design phase?

iv. What are the mitigate measures which solve the factors affecting the practice of building performance simulations?

1.4 Objectives of the Study

1.4.1 Main Objective

The main objective of this research is to investigating the factors affecting the implementation of building performance simulation in design phase.

1.4.2 Specific Objectives

- To analyze the extent of awareness regarding to building performance simulation (BPS) during design phase
- To study the practices of building performance simulation (BPS) during design phase
- To identify the major factors affecting the practice of BPS during design phase.
- To develop a mitigate measures for factors affecting the practice of BPS.

1.5 Significance of the study

The significance of this research is to give a general concept about Building Performance Simulation (BPS) and tend to promote Buildings Performance (BP) in the design phase to reach on high performance and sustainable building design in Addis Ababa. For the level of awareness and practices of BPS, the outcome of this study enabled building professionals and clients to gain knowledge of this new way of designing the building. Integrating BPS into design process at early design stage requires the identification of the existing factors affecting the implementation of BPS during design phase. Hence, investigating affecting factors can be input towards improving design activities by developing mitigate measures, so that professionals and clients when confronted with barriers, they can use the measures to improve the implementation of BPS in their building design process.

More importantly to find out the distinction between the preceding developments of designing in Addis Ababa City towards the modern ideas of sustainable Buildings which is additionally outlined within the MDG (Millennium Development Goal) of Ethiopia in the direction of sustainable development. Therefore, the discovering of learn about should be an evident to the city professionals. In addition, it improves the City Construction Industry (CI) in the use of integrated building design technology tools. It also promotes the efforts of key CI stakeholders; architects, designers, engineers, regulatory authorities and developers significantly in the use of BPS tools for the development of renovated high performance. The findings of this study about will additionally be used as a reference factor by way of different researchers for in addition lookup on the equal field. They can additionally use the findings as a secondary supply of information.

1.6 Scope of Study/Delimitation of the Study

The interaction between a building as a system and its functions determines a building's performance. This research was assessed the current practices and potential of building performance of building consultants during design phase. The geographical study area was bounded to Addis Ababa City. The study, investigating building performance simulations during design phase was chosen by the researcher in order to obtain reliable and valid data. Research respondent includes the consultant and the contractor in building designing and construction work. Active projects were targeted for the research.

In general, the scope of this thesis report was investigating affecting factors of building performance simulation practice during design phase of buildings as point of view of consultants in Addis Ababa which actively participate in construction(design) sector during 2023/24 were part of this study.

This research is limited to:

The infancy stage of BPS implementation, lack of similar local studies in country, limited practice of BPS with high conventional practice rises data access limitations: this refers to the fact that data gathering through the questionnaires was limited on awarded professionals. Which may limit quantity of the data collected. The other limitation of this study was other building construction phases are not included.

1.7 Organization of the Study

This research work is organized into five chapters. The following components will briefly establish how each chapter is constructed to achieve the research objective.

Chapter 1: Introduction – This chapter will include a quick introduction, a statement of the problem, general and specific objectives, a research question, scope limitations, a brief methodology, and the importance of the research.

Chapter 2: Literature Review – This chapter examines the literature on the research topic and seeks to provide a theoretical context and framework for the study.

Chapter 3: Research Methodology – The methods and approaches used to find, select, process, and analyze information are detailed. It will clarify how data was acquired or created and how it was analyzed.

Chapter 4: Result and Discussions – This chapter presents the results and findings of the research and discusses them in detail.

Chapter 5: Conclusions and Recommendations – The research closes with this chapter. It summarizes and explains the findings of the study's conclusions and suggestions.

Finally, references and appendices for the research are included at the end of this thesis.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This Chapter presents existing literature about factors affecting Building Performance Simulation (BPS) during the design phase with specific references. This literature review discusses previous research work related to the research problem and identified gaps in knowledge that form the basis of the study. Theoretical concepts associated with BPS, Sustainable Building, Building Performance criterion, Performance based design, benefits of integrating BPS into design process at early design stage and effects of BPS on buildings performance were presented from the viewpoint of several researchers. Moreover, its focus was on the design approach, Building Performance Analysis (BPA) variables that influence the practice of BPS and the measures taken to improve it. It was also illustrated and briefly discussed necessary terms and phrases. Finally, the chapter outlines different conceptual frameworks for building performances while developed by different researchers.

2.2 Definitions of Key Terms

- Sustainable Building**:** Sustainable buildings are also called green building projects which are designed, built, renovated, operated or reused in an ecological and resource efficient manner.
- Performance Indicators **(PI)** quantify building performance to represent simulation and actual measurement outcomes.
- Return on Investment (ROI) – This profitability metric is a principal tool used to evaluate how well or poorly the investment has performed in terms of the costs for the building. It is a performance measurement metric used to assess a building's efficiency or profitability.
- Sustainable Building: Sustainable buildings are also called green building projects which are designed, built, renovated, operated or reused in an ecological and resource efficient manner.

2.3 The Nature of Construction Industry

Construction comes from the word "construct," which means "to build." Building a sand castle, a fort out of pillows, or a house of cards are all examples of constructing something. In engineering terms, construction is usually associated with large structures like houses, railways, and power plants. In terms of engineering, construction is the activity of putting together different elements, using a detailed design and plan, to create a structure for a certain location. When you construct large structures, you need to have a clear plan of how you're going to do that. You also need to know the specific location. Architects and engineers design and build the structure with that location in mind (Construction: Definition & Types, 2020).

The construction industry is a project-based industry, with each project having unique features and the involvement of various parties within the life cycle of each project. It can be viewed as an organ or a whole system with integral components such as materials and the complex set of roles and relationships among various teams of workers (how the contract is planned, administered and managed), without which nothing could be achieved. The fundamental objectives are to deliver construction projects to the required quality more quickly and improve project performance. Unfortunately, practice is not that simple, as construction work has become more complex technically and administratively, and there are several challenging engineering and management problems that occur on the site (Ballard, 2005).

The Construction Industry plays a predominant role in economy, it has high share on gross domestic product (GDP) of any developed and developing Nation. Tebeje and Teka, 2015 cited in (Tadesse Ayalew et' al., 2016) indicated that, In Ethiopia the GDP contribution of the industry has been raised to 5.6% and approaches to the sub Saharan average (6%) during 2002/2003. According to (National Bank of Ethiopia Annual report, 2015), in 2014/15, Construction industry contributed more than half (56.1 percent) to industrial sector growth and 8.5 percent to GDP growth. This implies that construction sector is currently the leading industry due to expansion in construction of roads, railways, dams and buildings. Beyond its contribution to the nation, the industry was the 6th major contributor of the continent infrastructure stock during 2002/03 following South Africa, Egypt, Morocco, Algeria and Nigeria, Tebeje and Teka, 2015 cited in (Tadesse Ayalew et' al., 2016).

2.3.1 Project Life Cycle

The project management lifecycle is a step-by-step framework of best practices used to shepherd a project from its beginning to its end. It provides project managers a structured way to create, execute, and finish a project. This project management process generally includes four phases: initiating, planning, executing, and closing. Some may also include a fifth “monitoring and controlling” phase between the executing and closing stages. By following each step, a project team increases the chance of achieving its goals (Hao, 2005).

A project life cycle is a “series of phases that a project passes through from its start to its completion.” A project phase is “a collection of logically related project activities that culminates in the completion of one or more deliverables.” A life cycle provides a basic framework for managing a project, and the phases of the chosen life cycle do not change based on the specific project work required (Construction: Definition & Types, 2020). In addition, Ritz (1994) developed a life cycle for building projects that included the conceptual stage, project definition, execution, operation, and demolition. The project life cycle, according to(Kibert, 2015), is a process of planning, building, design, use, maintenance, and destruction. But L. Shen and Tam (2002) and L. Shen, Wu, Chan, and Hao (2005) divided the project life cycle process into conception, design, construction, operation, and demolition. he various life cycle stages, required resources, and proposed principles of Sustainable Construction(Kibert, 2015)

Most projects, even those with just one phase, are typically planned and executed using what is called progressive elaboration. For this reason, the first phase of a project is the initiation phase. During this phase a business problem or opportunity is identified and a business case providing various solution options is defined. Next, a feasibility study is conducted to investigate whether each option addresses the business problem and a final recommended solution is then put forward. Once the recommended solution is approved, a project is initiated to deliver the approved solution. Terms of reference are completed outlining the objectives, scope and structure of the new project, and a project manager is appointed. The project manager begins recruiting a project team and establishes a project office environment. Approval is then sought to move into the detailed planning phase. "Within the initiation phase, the business problem or opportunity is identified, a solution is defined, a project is formed and a project team is appointed to build and deliver the solution to the customer (Construction: Definition & Types, 2020).

Develop a business case: The trigger to initiating a project is identifying a business problem or opportunity to be addressed. A business case is created to define the problem or opportunity in detail and identify a preferred solution for implementation. The business case includes; detailed description of the problem or opportunity, list of the alternative solutions available, analysis of the business benefits, costs, risks and issues, description of the preferred solution and summarized plan for implementation. An identified project sponsor then approves the business case and the required funding is allocated to proceed with a feasibility study.

Undertake a feasibility study: At any stage during or after the creation of a business case, a formal feasibility study may be commissioned. The purpose of a feasibility study is to assess the likelihood of each alternative solution option achieving the benefits outlined in the business case. The feasibility study will also investigate whether the forecast costs are reasonable, the solution is achievable, the risks are acceptable and the identified issues are avoidable.

"Establish the terms of reference: After the business case and feasibility study have been approved, a new project is formed. At this point, terms of reference are created. The terms of reference define the vision, objectives, scope and deliverables for the new project. They also describe the organization structure; and activities, resources and funding required to undertake the project. Any risks, issues, planning assumptions and constraints are also identified.

"Appoint the project team: The project team are now ready to be appointed. Although a project manager may be appointed at any stage during the life of the project, the manager will ideally be appointed prior to recruiting the project team. The project manager creates a detailed job description for each role in the project team, and recruits' people into each role based on their relevant skills and experience

"Set up a project office: The project office is the physical environment within which the team is based. Although it is usual to have one central project office, it is possible to have a virtual project office with project team members located around the world. A project office environment should include; equipment, such as office furniture, computer equipment, stationery and materials; communications infrastructure, such as telephones, computer network, e mail, Internet access, file storage, database storage and backup facilities; documentation, such as a project methodology, standards, processes, forms and registers; tools, such as accounting, project planning and risk modeling software.

"Create a project plan: The first step in the project planning phase is to document the project plan. A 'work breakdown structure' (WBS) is identified which includes a hierarchical set of phases, activities and tasks to be undertaken to complete the project (Construction: Definition & Types, 2020). After the WBS has been agreed, an assessment of the level of effort required to undertake each activity and task is made. The activities and tasks are then sequenced, resources are allocated and a detailed project schedule is formed. This project plan is the key tool used by the project manager to assess the progress of the project throughout the project life cycle.

Analysis at Design Stages

Throughout the design development stages of a building, i.e., conceptual, preliminary, and detailed/final design, the attributes of building performance analysis and its requirements differ based on the information available at each stage and evolve as much insight is gained(Jin et al., 2019). Describe the requirement of building performance analysis and attributes during conceptual design, preliminary design, and the final design, Analysis at design stages refers to the process of conducting thorough examination and evaluation of various aspects of a project or product during its design phase. This analysis is crucial for ensuring that the design meets its intended objectives, functions effectively, and aligns with the requirements and constraints of the project(Jin et al., 2019).

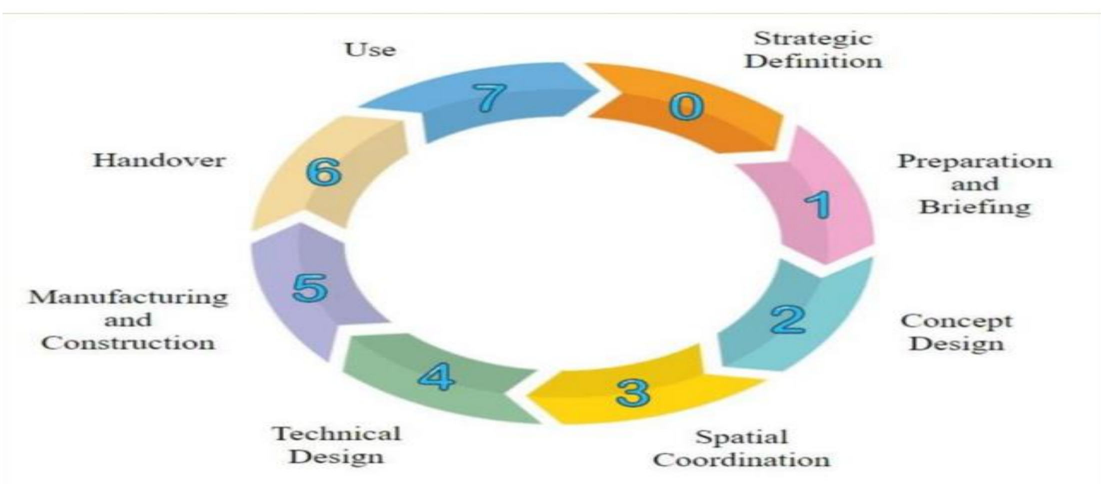

Figure 2. 1:Building lifecycle, *(Alani et al., 2020)* (Adapted from RIBA 2020)

By conducting comprehensive analysis at design stages, designers and engineers can identify potential issues early in the process, make informed decisions, and ultimately deliver a well-designed and successful end product or project.

Here are some key aspects typically addressed during analysis at design stages; functional analysis which involves identifying the primary functions the design is supposed to fulfill and ensure that the design meets the intended purpose and performs its functions effectively, the other one is requirement analysis understanding and documenting the requirements of the project or product is essential for designing a solution that meets both functional and non-functional requirements of stakeholders' needs and expectations, performance analysis also analyzing the performance of the design through simulations or other means helps identify areas for improvement and optimization and lastly ensuring that the design complies with relevant regulations, standards, and industry best practices is important for legal and safety reasons.

2.4 Concept of Building Performance Simulation

Today, the most widely used methodology to performance evaluation and analysis of building in both design and retrofit phases is simulations. Simulation is an imitation of the physical behaviors of a system(Solmaz, 2019). Identifying a system with certain number of internal variables, boundaries and external variables ensures the idealization, measurement and simplification of system's behavior in real world and the outcome is called a physical model (De Wilde, 2004). The definition of a set of relationships among the variables of the physical model results in a mathematical model, which is usually analytical in nature but sometimes involves making numerical approximations(Solmaz, 2019).

A proper definition of 'building performance' should account for the fact that there are various viewpoints of the concept: (1) an engineering view, which focuses on how well a building performs a task or function, (2) a process view, which recognizes building as a construction process rather than an object, and (3) an arts and humanities view that sees performance as presentation and communication (de Wilde, 2017). Building performance is a concept that describes, in a quantifiable way, how well a building and its systems provide the tasks and functions expected of that building. Requirements may stem from three main views: an engineering view of buildings as an object, a process view of building as a construction activity, and an arts view where performance involves the notions of form and appreciation. Important performance requirements in the engineering view pertain to building quality, resource savings, workload capacity, timeliness and readiness.

The terms modeling and simulation are sometimes interchanged, but there is a distinct difference between building modeling and building simulation. A building model is a physical or digital representation, similar to but simpler than a system it represents (Chang and Hsieh, 2020). Models describe how things work and approximate most of the features of the actual system or building as close as possible.

Simulation is the process of using a model to investigate the behavior and performance of a building system. The whole purpose of simulations is to study the characteristics of a building system by manipulating variables and evaluating a model to optimize the performance (Motawa and Carter, 2013). Simulation allows users to determine how a system responds to different inputs to understand better how it operates. Hopfe and Hensen (2011) stated that, simulation is used before an existing system is altered or a new system built, to reduce the chances of failure to meet specifications, to eliminate unforeseen bottlenecks, to prevent under or over-utilization of resources, and to optimize system performance. Moreover, J.L.M. Hensen and Lamberts, (2019) defined building performance simulation as multidisciplinary computational modeling and simulation that provides solutions close to real-world conditions. Quantifying the important aspects of a building or system's required performance is the objective of building performance simulation.

By the end of the 90s, a range of simulation applications spanned out from the research community to professional practice allowing a diverse tools landscape for a variety of users(Building Performance Simulation Tools.Pdf, n.d.). For the first time, analytical simulation power became at the fingertips of building designers (Papamichael, LaPorta et al. 1996; Tianzhen, Jinqian et al. 1997).

2.4.1 Building Performance Simulation Tools

By examining those four major changes we generally can observe that BPS tools are and will continue penetrating the building design practice. Simulation tools became recognized as design support tools within the AEC industry. In fact, simulation became an integrated element of the design process (Augenbroe 1992; Mahdavi 1998).

Building performance simulation tools were developed to reduce the complexity of the basic algorithms, the computational load, and the expected inputs from the users. Detailed simulation tools labor the development of complex mathematical models and the representation of each possible energy flow in the building (Doyle, 2008).

Today, there are many BPS tools available in the market (IBPSA, 2019). Some are mainly used in academia, while others are provided as commercial tools, but each one has its imperfections in terms of accuracy and ease of-use (Zhou et. al., 2014). The wide ranges of tools are used for specific simulation purposes and are able to analyze building performance in several performance categories such as whole building energy simulation, thermal load calculations, HVAC system selection and sizing, energy conservation measures, thermal comfort analysis, indoor air quality, weather data and climate analysis, building energy auditing and monitoring, lighting and daylighting simulation, air flow simulation, solar and photovoltaic analysis, rating and certificates, acoustic analysis, and life cycle analysis. Additionally, these tools can analyze building performance for a complex combination of geometry, building components and systems.

By examining those four major changes we generally can observe that BPS tools are and will continue penetrating the building design practice.(Building Performance Simulation Tools.Pdf, n.d.). Simulation tools became recognized as design support tools within the AEC industry. In fact, simulation became an integrated element of the design process (Augenbroe 1992; Mahdavi 1998).

2.5 Importance of Building Performance Simulation in building design

Building Performance Simulation (BPS) is of great importance in the design phase of buildings because it enables architects and engineers to evaluate and optimize building performance early in the design process. BPS provides a detailed analysis of a building's performance in terms of energy efficiency, indoor air quality, thermal comfort, and other factors. By using BPS in the design phase, architects and engineers can make informed decisions on building design, systems selection, and operation strategies to optimize building performance and reduce energy consumption.

Building Performance Simulation is a technology of considerable potential that provides the ability to quantify and compare the competing cost and performance attributes of a proposed design in a realistic manner and at relatively low effort and cost. Indeed, it is perhaps the only way to explore operational robustness at the design stage and a growing number of practitioners will understand the maxim, ‘if you can’t simulate it, don’t build it’. Moreover, during the operational phase, simulation provides a means to compare measured performance versus design intent, to test system for installation and operational faults, and to deduce effective control sequences (Negendahl, 2015)

Since its emergence in the 1970s as part of the personal computing revolution, BPS has matured slowly driven by academic enquiry and by commercial pressures in regulations driven industry. While the present generation of BPS tools have impressive capability, they remain a work in progress when viewed against the prospect of a truly powerful computational approach to design whereby arbitrarily complex models may be evolved on a task sharing basis, such models readily exchanged and understood by others, industry standard assessments automatically invoked, and seamless integration within the temporally evolving design process assured (Johari Hussein, 2011)

2.6 Building Performance Criteria

Criteria are absolute or relative values on a scale, and objective functions frequently record them to optimize unbiased for the stakeholder or decision-maker. Criteria can be contextualized in various ways, such as a preference for one design over another. Building performance criteria are needed for each of the performance requirements, such as quality requirements (how good a function must be done), resource-saving requirements (how much of a resource can be used or saved), workload capacity requirements (how much capacity is to be provided), timeliness requirements (how responsive the building is or must be), readiness requirements (under what circumstances the building must be available). For example, a criterion can be set for how much energy, water, and material is used in constructing and operating a building. These criteria define what level of performance is needed and the frame of reference for setting those values (Attia et al., 2012).

2.7 Building Performance Requirements

BPS application is driven by concerns such as energy demand reduction, climate change mitigation, environmental protection, fossil fuel replacement, security of supply and improved living standards(J. A. Clarke & Hensen, 2015). This situation has given rise to several distinct needs: support for diverse user types and applications; upward and downward extension of the application scale; the linking of energy, environment, wellbeing and productivity; the imposition of uncertainty and risk; consideration of life cycle performance; support for both design and policy objectives; and the addition of new technical domains such as micro-generation, micro-grids and demand management/response(J. A. Clarke & Hensen, 2015).

Functional Requirements are the primary requirement of buildings related with what the system must do but does not say how well the function is provided. Operational requirements, usability requirements, quality requirement how good the system performs its function, resource saving requirement how much can be used or saved and workload capacity requirements how much the system delivers regarding a function

There are also limitations which needs solutions for the performance of buildings. These are limitations to the design solution, such as applicable legislation; there may be necessary to link with other systems, reducing choice space; and there may be a space constraint for the material to be employed and also limitations that address the factors of time, location, and event; they are constraints that specify when a structure should be operational or not.

Financial or economic restrictions and the subcategories of the primary requirement types stated above play a part in performance requirements. The budget and resources allocated to a building can influence the performance achieved. Stakeholders in a particular building must have adequate finances to meet the requirements (Jalaei & Jrade, 2015).

2.8 Building Performance Indicators

Building performance can be expressed in a form of values of parameters that can be measured. Setting precise objectives and verifying explicit conformity of sustainable buildings or sustainable built environment is often very complicated and time consuming. In many cases simple indicators are needed to give guidance based on preliminary drafts and concepts when sufficient data is not available for decision making. Indicators can give information about complicated systems in a simple form supporting discussion about these issues with non-experts who need to understand them quickly. Indicators help also explaining how phenomena have changed along with time and how they have developed in relation with set objectives. An indicator can be presented as a synthetic variable, giving indications, describing or measuring the state of phenomenon or a situation. Indicators reflect cause-to-effect relationship between an action and its consequences. Indicators can also be presented as conceptual tools, expressed in clear and precise terms measuring progress towards the objective, providing a measurement unit through which modeling and monitoring can be conducted (Roshana Takim, 2002)

Scholars dealing with building performance use common terms as metrics, measures, and indicators as they seldom use measure and defined as a quantity intended to be measured. Whether metrics, performance indicators, or measures (parameters) are used, this has to be clear and straightforward for comprehension by all stakeholders. These can be straightforward, such as the illuminance or electricity consumption. In other cases, the attribute can be complex and require decomposition, such as the 'quality of the system' which is decomposed of availability, adaptability, and usability (Harputlugil and Wilde, 2022).

The UK working groups on Key Performance Indicators (KPIs) have identified 10 parameters for benchmarking projects in order to achieve a good performance in response to Egan's report (1998). However, most of these indicators, such as construction cost, construction time, defects, client satisfaction with the product and service, profitability and productivity, promote result-orientated thinking, whereas predictability of design cost and time, and predictability of construction cost and time, and safety can be regarded as process-orientated thinking. There are no suggestions for performance indicators in benchmarking projects at the project selection phase i.e., analysis stage, when the client and end-user's requirements need statements and the delivery strategy are determined (Johari Hussein, 2011)

2.9 Building Performance Quantification and Measurement

Quantification is the expression or measurement of the quantity of something where that quantity is an amount, number, or other property of something measurable. This quantification of performance will serve on how well buildings fulfill requirements. Gilb(2005) defines the measurement in the context of Systems Engineering, which is also suitable for building performance analysis(Hopfe & Hensen, 2011). Through this understanding, there are four approaches in which performance can be quantified: Physical Measurement and Testing, Computer Simulation, Expert Judgment, and Stakeholder Evaluation.

According to Wong and Jan (2003), building performance is a framework, through the comprehensive use of both objective and subjective field evaluations in all performance areas simultaneously, serve to understand the critical balance needed to simultaneously ensure all building performance mandates. The mandate refers to building performance approaches that help to optimize building lifecycle, management of people and process related space, asset, and efficient supply of resources (Preiser, 2005). As indicated by Kian et al. (2001), taking into account the mandate during the process of building performance evaluation helps managers to ensure that at the end of the measurement process building does not bring any negative effect users. To come up with a building performance framework one must first identify different strategies and techniques that will be used in measuring building. The aim of identifying these strategies is to help managers to avoid forgetting crucial building components that may result into poorly functioning building with high maintenance cost. Identified strategies and techniques are then to be linked with structural and non-structural building facilities in order to come up with a reliable building performance measurement decision (J. Hensen et al., 2004)

Measurement of building performance is done through collecting users' response on environmental and psychological satisfaction that is brought by the quality of services necessary for the operations of building facilities and assets as provided by Lavy (et. al, 2010). Supported by Preiser and Vischer (2005), measuring this type of performance will help managers to see whether the non-financial impact related to building facilities on users do support the core business objectives and user's expectations(Roshana Takim, 2002).

2.10 Performance-Based Design

The performance-based design process explicitly evaluates how building systems are likely to perform under a variety of conditions associated with potential hazard events. The process takes into consideration the uncertainties inherent in quantifying the frequency and magnitude of potential events and assessing the actual responses of building systems and the potential effects of the performance of these systems on the functionality of buildings. Identifying the performance capability of a facility is an integral part of the design process and guides the many design decisions that must be made (J. A. Clarke & Hensen, 2015)

Performance-based design starts with selecting design criteria articulated through one or more performance objectives. Each performance objective is a statement of the acceptable risk of incurring different levels of damage and the consequential losses that occur as a result of this damage. Losses can be associated with structural or nonstructural damage, and can be expressed in the form of casualties, direct economic costs, and loss of service costs. Loss of service costs may be the most important loss component to consider, especially for critical facilities such as schools (Yezioro et al., 2008)

Performance-based design is an evolving concept. The term as currently used has multiple definitions and three are presented below:

- A design approach that meets the life safety and building performance intents of the traditional code while providing designers and building officials with a more systematic way to evaluate alternative design options currently available in codes. In this regard, performance-based design facilitates innovation and makes it easier for designers to propose new building systems not covered by existing code provisions.
- A design approach that identifies and selects a performance level from several performance level options. Some provisions in the current version of the International Building Code (IBC) are sometimes called performance-based because they incorporate distinctions between performance goals for different building uses. These performance options are conceived to achieve higher-than-code-minimum design requirements.
- A design approach that provides designers with tools to achieve specific performance objectives such that the performance of a structure can be reliably predicted. In the hazards area, this approach has been highly developed for seismic design although considerable research is still necessary to ensure the requisite reliability and predictability that would allow a performance-based code to be possible (J. Hensen & Lamberts, 2019)

Today, the most widely used methodology to performance evaluation and analysis of building in both design and retrofit phases is simulations. Simulation is an imitation of the physical behaviors of a system. Identifying a system with certain number of internal variables, boundaries and external variables ensures the idealization, measurement and simplification of system’s behavior in real world and the outcome is called a physical model (Solmaz, 2019). The definition of a set of relationships among the variables of the physical model results in a mathematical model, which is usually analytical in nature but sometimes involves making numerical approximations. Building performance simulation tools were developed to reduce the complexity of the basic algorithms, the computational load, and the expected inputs from the users. Detailed simulation tools labors the development of complex mathematical models and the representation of the each possible energy flow in the building (Motawa and Carter, 2013).

2.11 Current State of BPS Practice

The current state of Building Performance Simulation (BPS) can be examined from various perspectives, including the available software, research trends, and industry standards. There is a wide range of BPS software available, ranging from commercial software to open-source software. Some of the widely used commercial software includes Energy Plus, IES VE, and Design Builder, while open-source software such as Open Studio and request is also gaining popularity. While each software has its strengths and limitations, they all provide the ability to model a building's performance and analyze its energy efficiency. Research in the field of BPS is continually evolving, and current research trends focus on improving the accuracy and usability of BPS software. Recent research has been focused on integrating machine learning and artificial intelligence techniques into BPS software to improve its performance and reduce the time required for simulations. Other research trends include the use of sensor data to calibrate and validate models and the development of new algorithms for more accurate and efficient simulations.

The use of BPS software is becoming increasingly widespread in the building industry, and industry standards are emerging to ensure consistency and accuracy in the use of these tools. Some of the emerging industry standards include ASHRAE Standard 209, which establishes minimum requirements for building performance simulation modeling, and ISO 52000, which provides guidelines for energy performance calculations. Overall, the current state of BPS is robust, with a wide range of software available and continued research efforts aimed at improving its accuracy and usability. As industry standards continue to emerge, the use of BPS in building design and construction is likely to become even more widespread.

2.11.1 Integrating BPS in to design process at early design

Integrating building performance simulation (BPS) into the design process at an early stage is essential for optimizing building performance and minimizing the need for costly redesigns later in the project lifecycle. Here are some strategies for effectively integrating BPS at the early design stage. BPS tools and software are focused on improving the accuracy and efficiency of simulations, reducing costs, and making BPS more accessible to a wider range of users. By integrating BIM data, cloud-based simulation, real-time simulation, and automated model generation tools, BPS can become even more accurate and useful in building design and construction(Motawa and Carter, 2013).

2.11.2 Case Study 1: The Edge Building, Amsterdam, Netherlands

The Edge Building, located in Amsterdam, is considered to be one of the most sustainable buildings in the world. BPS was used extensively in the design and construction of the building to optimize energy efficiency, indoor comfort, and occupant well-being. The project team used BPS to analyze various design strategies such as passive solar heating, natural ventilation, and daylighting(Motawa and Carter, 2013). The BPS analysis helped the project team to optimize the building's energy performance and to achieve a high level of indoor comfort for occupants. The Edge Building has received numerous awards for its sustainability features and is considered a successful example of BPS adoption in building design. https://en.wikipedia.org/.

2.11.3 Case Study 2: The Tower at PNC Plaza, Pittsburgh, USA

The Tower at PNC Plaza is a LEED Platinum certified building located in Pittsburgh, USA. BPS was used extensively in the design and construction of the building to optimize energy performance and indoor comfort. The project team used BPS to analyze various design strategies such as natural ventilation, daylighting, and efficient HVAC systems. The BPS analysis helped the project team to optimize the building's energy performance and to achieve a high level of indoor comfort for occupants. The Tower at PNC Plaza has received numerous awards for its sustainability features and is considered a successful example of BPS adoption in building design. https://www.archdaily.com.

2.11.4 Case Study 3: Unity University Administration Building, Addis Ababa, Ethiopia

The Unity University Administration Building, located in Addis Ababa, Ethiopia, is a green building that has achieved LEED Gold certification. BPS was used in the design and construction of the building to optimize energy efficiency and indoor comfort. The project team used BPS to analyze various design strategies such as natural ventilation, daylighting, and efficient HVAC systems. The BPS analysis helped the project team to optimize the building's energy performance and to achieve a high level of indoor comfort for occupants. The Unity University Administration Building is considered a successful example of BPS adoption in Ethiopia. uuninfo@ethionet.et.

2.11.5 Case Study 4: Ethiopia Commodity Exchange Headquarters, Addis Ababa, Ethiopia

The Ethiopia Commodity Exchange Headquarters, located in Addis Ababa, Ethiopia, is a green building that has achieved LEED Gold certification. BPS was used extensively in the design and construction of the building to optimize energy efficiency and indoor comfort. The project team used BPS to analyze various design strategies such as natural ventilation, daylighting, and efficient HVAC systems. The BPS analysis helped the project team to optimize the building's energy performance and to achieve a high level of indoor comfort for occupants. The Ethiopia Commodity Exchange Headquarters is considered a successful example of BPS adoption in Ethiopia. http://www.ecx.com.et/.

In conclusion, the above case studies highlight the successful adoption of Building Performance Simulation (BPS) in building design across the world, including Addis Ababa, Ethiopia. The use of BPS has helped the project teams to optimize energy efficiency, indoor comfort, and occupant well-being, leading to high-performing and sustainable buildings. These successful examples can serve as a model for other architects, engineers, and building professionals to adopt BPS in their building design process.

2.12 Building Performance Simulation Gap

A concept one must be careful about is when some buildings do not fully perform as intended, which creates a discrepancy between simulated or predicted performance and measured performance. This is called a performance gap. This is a significant issue and challenge in quantifying building performance through simulation. A few problems that lead to this issue include model uncertainties and training deficiencies. These discrepancies can occur in various areas, including energy usage, thermal comfort, lighting, acoustics, tenant behavior, and actual building use, which may differ from what the design team anticipated. This has a considerable impact on the building's performance(J. Hensen & Lamberts, 2019).

The concept of building performance and its practice in the Ethiopian context is a non-existential practice. Despite the potential boom in the development of large-scale construction projects and the possible proven benefits of building performance assessment, its potential is left unsatisfied as a thorough and systematic approach in carrying out performance assessment and sustainability of buildings design stages is far off as it is beset with a vague understanding of the concept and potential unfulfilled use of bootlegged simulation tools(J. Hensen & Lamberts, 2019).

The practices in the developing world are characterized by diligent efforts and approaches to improve buildings' performance and assure sustainable building development. Legislative frameworks such as the Energy Performance of Buildings Directive by the European Commission and the Environmental Protection Agency (EPA) Building Performance Standards Policy Toolkit in the United States are enforced to improve energy performance and benchmark and reduce energy use and greenhouse effect gas emissions. Many of research and development on the concept has helped the AEC industry in their respective countries better understand building performance analysis. Buildings are assessed for sustainability through performance-based design, lifecycle assessment, rating systems, and certification schemes Preiser and Vischer (2005).

According to the detailed literature review stated in this chapter, one can realize the potential unexploited benefits in consideration of building performance analysis in building design stages. Building performance analysis and simulation practices are very important to address the environmental, economic and the built environment challenges. In contrast, these practices have not been adopted into mainstream local practices except for a few academic studies conducted to improve the performance aspects of the building with regards to thermal and user comfort and energy-efficient design. Other than these studies, there has not been comprehensive research on building performance analysis and simulation practices in the country. An underlying cause is linked to education and training, as there has not been developed to ensure the industry access professionals to integrate different aspects and analysis methods(Roshana Takim, 2002).

Taking up the task to advance the practice of building performance analysis should not be the sole responsibility of consultants as academic and government institutes should join efforts. Professionals have not fully familiarized themselves with these concepts to fully benefit from them. Therefore, the local consulting firms have a long way to go in exercising and incorporating building performance analysis and simulation tools in their design to bring reliable and applicable results. This research aims to examine local consultants' current practice regarding building performance analysis and the extent of use in simulation tools. Then with the conceptual gaps identified in this section between literature and practice, needs possible solution(Roshana Takim, 2002).

2.13 Challenges with Building Performance Simulation

The present challenge is to ensure that BPS tools evolve to adequately represent the built environment and its myriad supply technologies in terms of their performance, impact and cost. Attaining multi-functional tools, and embedding these within the design process, is a non-trivial task.(J. Clarke, 2015)

(Motawa & Carter, 2013)There are still some problems in using BPS/BIM for sustainable design. For example, using BPS/BIM for energy analysis currently relies on estimated values for loads, air flows and heat transfer for simulation which may result in unreliable estimates(Harputlugil & Wilde, 2022). The dynamic interaction between systems, environment, building, equipment, and people can bring about a high level of health, comfort, and productivity through building performance simulation (J. Hensen et al., 2004).

The authors disclose a few challenges and solutions to each of the corresponding points despite its challenges.

2.13.1 Quality assurance

The study mentions the importance of sufficient domain knowledge of buildings and systems paired with verified and validated software. Furthermore, it is essential to use a correct simulation methodology and solve the right equation as accurately as possible. The parameter values registered in the model and which model to use are vital. Develop standardized procedures and protocols for conducting building performance simulation to ensure consistency and reliability, establish quality control measures, such as peer reviews and model validation checks, to verify the accuracy and integrity of simulation results and Document simulation methodologies, assumptions, and validation procedures to facilitate transparency and reproducibility(J. Hensen et al., 2004).

2.13.2 Scope expansion

The researchers disclosed the limitations to building performance simulation in building design projects and the seldom use of building performance simulation for supporting early design phases and alternative design generation. The development of computing and technology and the significant contribution by developers have provided several platforms that have solved the barriers of building performance simulation. However, having sufficient domain knowledge of building systems and appropriate utilization of verified software is prevalent. They mentioned that solving this issue would utilize building simulation for conceptual design and design optimization.

Most recently, Hong, T., Langevin, J., and Sun, K. (2018) has surveyed the several studies pointing out the challenging issues in BPS tools, and by summarizing and making in-depth analysis, they demonstrated key challenges for future BPS development.

As Hong, T., Langevin, J., and Sun, the main challenges that cover several existing and emerging areas of BPS are presented in ten categories. The first one is finding out the performance gap between predicted building performance during design stage and actual energy performance of the building during life cycle in order to achieve performance goals, the second one is modeling and accurately simulating human-building interactions, which affect significantly both building energy use and thermal comfort level, in order to represent expected occupant’s behavioral interaction with buildings and their effects on simulated building energy flows in design stage, and also to ensure control schemes for building operations to optimize building energy use and occupant thermal comfort simultaneously in building operation stage.

Improving the modeling capabilities of the performance simulation tools to accurately represent the actual performance of the model, and decreasing the discrepancies between simulated energy using thermal model data and the actual measured data is the third, the fourth one is improving the applicability of building energy simulation during building operation, control and retrofit phases to identify and evaluate the most effective energy saving solutions for the building, the next is ensuring modeling of operational faults such as control faults, sensor offset, equipment performance degradation (Cheung et. al., 2015), to estimate of the severity common faults and hence to provide decision making in a timely manner.

Supporting the design of Net-zero-energy-buildings (NZEB), modeling passive and advanced control strategies, and quantitative evaluation and optimization of design alternatives. Moreover, enabling the simulation of renewable energy generation and on-site energy generation of buildings that are able to adjust electricity demand based on grid needs, supporting the simulation of city/urban scale building energy performance to aid urban planning, and to achieve energy and environmental goals, the eight one is supporting a quantitative evaluation of energy use and CO_2 emissions at national and regional scales, and making future projections.

Modeling the adoption of building energy efficiency technologies, and ensuring decision-making for research and technology development, and identifying the impact of adoption of new building technologies and lastly supporting decision-making process across the building life cycle by ensuring the integration of four dimensions: data, domain, simulation tool and workflow mentioned as key challenges of BPS(J. Hensen et al., 2004).

In summary, some of the challenges faced with building performance are that buildings are one of products compared to other industries with many stakeholders, necessitating a great deal of effort to achieve common performance goals and objectives. Furthermore, due to the various categories of buildings, such as residential buildings, commercial buildings, hotels, hospitals, and so on, developing a universally applicable list of performance attributes all buildings are expected to fulfill is very difficult. Relevant characteristics of performance for a given building are case specific. A one-size-fits-all strategy will not be a suitable approach to ensuring building performance. The study of building performance analysis varies and is a complex subject due to these aspects(J. Hensen et al., 2004).

2.13.3 Building Performance Simulation affecting factors

Building performance simulation (BPS) is a powerful tool used in architecture, engineering, and construction to evaluate and optimize the performance of buildings in various aspects such as energy consumption, thermal comfort, daylighting, indoor air quality, and overall environmental impact Hong, T., Langevin, J., and Sun, K. (2018). Several factors can affect the accuracy and reliability of building performance simulations. These factors are categorized in four major categories. Namely; organizational factors, technical factors, economic factors and regulatory factors.

2.13.3.1 Organizational Factors

Organizational factors related with organizational working culture. The organizational culture of a firm can impact the adoption of BPS. Firms that value sustainability and environmental performance are more likely to adopt BPS in their design process. Likewise, resources such as time, money, and staff are necessary for the successful adoption of BPS. Organizations that do not have the resources to support BPS may be less likely to adopt the tool. Another reason for the lack of expertise is the limited availability of training and education programs. Many architecture and engineering programs do not include building performance simulation in their curriculums. Therefore, architects and engineers often have to rely on continuing education courses or self-teaching to acquire the necessary skills(J. Hensen et al., 2004).

Another significant challenge in building performance simulation is the availability and quality of data. Building performance simulation requires accurate data inputs, including building geometry, construction materials, occupancy patterns, lighting schedules, and weather data. The lack of data or low-quality data can lead to inaccurate simulation results, which can have significant consequences on the building's performance. The data collection process can be time-consuming and expensive, which may discourage some building owners or designers from investing in the necessary data. Additionally, some data, such as weather data, can be difficult to obtain or may not be available for a specific location. This can be a particular problem for projects in remote or underdeveloped areas where weather stations or other data sources may not be available(Motawa & Carter, 2013).

Building performance simulation tools are an essential aspect of the simulation process, but they can also present several challenges. The primary challenge is selecting the appropriate tool for a particular project, as there are many different tools available, each with its own strengths and weaknesses. Some tools are better suited for specific types of buildings or simulation goals, and the selection process can be complicated, especially for non-experts. Another challenge is the computational power required for building performance simulations. Simulation models can be computationally intensive, and the required hardware and software infrastructure can be expensive. This can be a barrier for smaller firms or projects with limited budgets(Motawa & Carter, 2013).

Building performance simulation is often a time-sensitive process that must be completed within specific project schedules. However, the simulation process can be lengthy and time-consuming, especially for complex projects. This can make it challenging for designers and building owners to incorporate the results of the simulations into their decision-making process effectively.

One of the significant challenges with project schedules is that simulations often require data from several sources, including weather data, occupancy patterns, and building geometry, among others. Collecting and processing this data can be time-consuming and may cause delays in the simulation process. Additionally, the complexity of the simulations themselves can also add to the time required to complete the project(Motawa & Carter, 2013).

2.13.3.2 Technical Factors

The lack of expertise in building performance simulation is a significant challenge for designers and architects. Building performance simulation requires specialized knowledge in different areas, including HVAC systems, building envelopes, lighting, and acoustics. The lack of expertise can lead to improper modeling assumptions, incorrect data inputs, or unrealistic results. BPS is a complex tool that requires specialized knowledge and training to use effectively. The complexity of the tool can impact its adoption by architects and engineers. One of the reasons for the lack of expertise is the complexity of the simulation software. Most building performance simulation software requires a certain level of technical knowledge, and it is not always easy for non-experts to use. Additionally, the software is constantly evolving, requiring users to keep up-to-date with the latest versions and features(Motawa & Carter, 2013).

The availability of BPS software can impact its adoption. Limited availability of software can make it difficult for architects and engineers to access and use the tool. BPS must be compatible with other design tools used in the design process. Incompatibility can make it difficult for architects and engineers to incorporate BPS into their design process(Motawa & Carter, 2013).

Another challenge with simulation tools is the complexity of the software. Building performance simulation tools can be challenging to use, requiring specialized knowledge and technical expertise. Even with user-friendly interfaces and tutorials, the complexity of the tools can be overwhelming, and it may take some time for users to become proficient in their use.

2.13.3.3 Economic Factors

The cost of BPS can be a significant challenge, especially for smaller projects or those with limited budgets. The cost of simulation software, hardware, and the time required to perform the simulations can quickly add up and become prohibitively expensive. One of the main factors that contribute to the cost of BPS is the complexity of the project. The more complex the project, the more time and resources will be required to complete the simulations. Additionally, the cost of simulation software and hardware can vary significantly depending on the type and level of complexity required. The return on investment (ROI) of BPS must be considered when adopting the tool. If the ROI is not clear, organizations may be less likely to adopt BPS(Negendahl, 2015).

2.13.3.4 Regulatory Factors

Building codes and standards can impact the adoption of BPS. Stay informed about local building codes, energy standards, and certification programs to ensure compliance. If codes and standards require the use of BPS, organizations may be more likely to adopt the tool. Engage with regulatory authorities or third-party certifiers to clarify requirements and seek guidance as needed. Green building certifications such as LEED or BREEAM can also impact the adoption of BPS. Organizations seeking certification may be more likely to adopt the tool. Proactively incorporate simulation into the design process to identify and address regulatory requirements early(Negendahl, 2015).

In conclusion, the adoption of Building Performance Simulation (BPS) in building design can be influenced by several factors. These factors can impact both the willingness of architects and engineers to adopt the tool and the ability of organizations to support its use. Organizational factors such as organizational culture, resources, and training can impact the adoption of BPS. Technical factors such as the complexity of the tool, availability of software, and compatibility with design tools can also impact its adoption. Economic factors such as cost and ROI, and regulatory factors such as building codes and green building certifications can also impact the adoption of BPS(Negendahl, 2015)

2.14 Mitigate Measures of BPS tools

To address the lack of expertise, building performance simulation software companies have started to develop more user-friendly interfaces and tutorials to help non-experts use their software. Additionally, there are now more training and education programs available to help architects and engineers learn about building performance simulation. Industry organizations have also started to provide resources and training to help their members improve their skills in building performance simulation(J. L. M. Hensen & Lamberts, 2019)..

To address the challenge of data availability, there are several strategies that designers and building owners can employ. First, they can work to gather as much relevant data as possible, including utilizing sensors and other monitoring tools to track building performance. Additionally, they can work with data providers and experts to help ensure that the data they do have is accurate and high-quality(J. L. M. Hensen & Lamberts, 2019)..

There are also efforts to make data more accessible and standardized. Organizations such as the Building Energy Data Exchange Specification (BEDES) and the National Renewable Energy Laboratory (NREL) are working to develop common data standards and tools that can help simplify the data collection and analysis process. Finally, some building performance simulation software includes built-in data libraries, which can help users ensure that they are using accurate and relevant data in their simulations(J. L. M. Hensen & Lamberts, 2019)..

To address the challenges of simulation tools, there are several strategies that designers and building owners can employ. First, they can work with experts or consultants who have experience in selecting and using simulation tools to help identify the best tool for their specific project. Additionally, they can work to improve their own technical expertise by taking training courses or participating in continuing education programs(J. L. M. Hensen & Lamberts, 2019)..

Another strategy is to utilize cloud-based simulation services that allow users to access simulation tools and computing resources on demand. These services can be more cost-effective than investing in their own computing infrastructure, and they can help ensure that users have access to the latest simulation tools and technology.

Finally, designers and building owners can work to ensure that they are using appropriate modeling assumptions and simplifications when using simulation tools. This can help reduce the complexity of the simulations and make them more manageable, even for non-experts.

To address these challenges, designers and building owners can employ several strategies. First, they can work to ensure that they have access to all of the data required for the simulations as early as possible. This can help ensure that there is adequate time to process the data and incorporate it into the simulation models.

Another strategy is to use simplified simulation models, which can help reduce the time required to complete the simulations. These simplified models can be less accurate than more complex models, but they can still provide valuable information that can be used to inform design decisions.

Finally, designers and building owners can work to streamline the simulation process itself by using simulation tools that are designed to be faster and more efficient. These tools can help reduce the time required to complete simulations and can help ensure that the results are available when they are needed(J. L. M. Hensen & Lamberts, 2019)..

In summary, the challenge of project schedules in building performance simulation can be addressed by ensuring that all required data is available as early as possible, using simplified simulation models where appropriate, and using simulation tools that are designed to be fast and efficient. By addressing these challenges, designers and building owners can ensure that they are able to incorporate the results of simulations effectively into their decision-making process.

To address the challenge of cost, designers and building owners can employ several strategies. One approach is to use simplified simulation models that require less processing power and are less expensive to run. These models may not be as accurate as more complex models, but they can still provide valuable insights into building performance.

Another approach is to use open-source simulation software, which can be a cost-effective alternative to commercial software. Open-source software is typically free to use and can provide similar functionality to commercial software in some cases. However, open-source software may require a higher level of expertise to use effectively.

Finally, designers and building owners can work to reduce the time required to perform simulations, which can help reduce costs. This can be achieved through strategies such as using simplified models, optimizing simulation settings, and streamlining the simulation process.

In conclusion, the cost of building performance simulation can be a significant challenge, but there are strategies that designers and building owners can use to reduce the cost of the simulations. These strategies include using simplified models, open-source software, and optimizing the simulation process to reduce the time required to complete the simulations

Designers can take steps to mitigate these factors and ensure that the simulation results are accurate. This can include using accurate input data, validating the simulation results with actual building performance data, using software that has been validated by independent organizations, and performing sensitivity analyses to identify the factors that have the greatest impact on the simulation results(J. L. M. Hensen & Lamberts, 2019)..

In summary, BPS can provide valuable information for building design, but designers must be aware of the factors that can affect the accuracy of the simulation results. These factors include input data accuracy, assumptions and simplifications, uncertainty in performance data, weather data accuracy, modeling complexity, human error, and simulation software. Designers can take steps to mitigate these factors and ensure that the simulation results are accurate(J. L. M. Hensen & Lamberts, 2019)..

2.15 Summary (Gap)

At the design stage, Building Performance Analysis (BPA) allows for the evaluation of the building's performance and the variables that influence it. Building designers and other stakeholders can gain crucial information for making decisions about buildings by simulating a building's performance by seeing how the building will respond to excitation in a virtual environment. However, a frequent practice in Ethiopia suggests that in the project's design phase, more attention is paid to the building's aesthetics and construction than to how it will fulfill its specified functions and performance standards. Despite structures' extended lifespans, analysis of how they will function and fulfill their intended purpose is rare. It is obvious that there is a mismatch and underlying lack of understanding of the foundations of building performance simulation. In addition, because Building Information Modeling (BIM) techniques in Addis Ababa City consultants are still in their infancy, it is currently not foreseeable how to profit from BIM-based Building Performance Simulation (BPS) of buildings. This research proposes to study the current practices of building performance simulation in consultants in Addis Ababa city. The research design suggests using a questionnaire to gather data. It extracts information from consultants regarding their method of design, their instruments, their use of BPS tools, their consideration of uncertainties in their design, and their sustainability strategies. The research proposal's final goal is to determine the level of knowledge and practice, as well as difficulties encountered by consultants with using the tools for BPA and simulation during the design phase. This will be done based on research findings discovered through data analysis. The conclusion and recommendation will be demonstrated at the end of the study (Abeje 2007; Fetene and Worku 2013).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Introduction

The techniques and strategies by which the study's objectives were attained are explained and justified in this research portion. The steps taken to collect all relevant data are described in full. It also details the study's research instruments and strategy. Finally, it discusses sample size, data gathering methods, and the data analysis procedure.

3.2. Description of the Study Area

The study area of this research were in Addis Ababa City, the capital city of Ethiopia and Africa. The city has about 5.7 mil. residents living in 11 sub cities, whose life was based on trade, governmental and non-governmental workers, agriculture and labor work. In the city there are a lot of factories, financial institutions, cultural and religion institutions, regional and federal government offices, embassies, African Union headquarter and other many international offices.

3.3. Research Design

Research designs were plan and the procedures for research that span the decisions from broad assumptions to detailed methods of data collection and analysis. This plan involves several decisions, and they need not be taken in the order in which they make sense to me and the order of their presentation here. The overall decision involves which design should be used to study a topic. Informing this decision should be the worldview assumptions the researcher brings to the study; procedures of inquiry (called strategies); and specific methods of data collection, analysis, and interpretation. The selection of a research design was also based on the nature of the research problem or issue being addressed, the researchers' personal experiences, and the audiences for the study.

There are three types of designs are advanced: qualitative, quantitative, and mixed methods. Often the distinction between qualitative and quantitative research was framed in terms of using words (qualitative) rather than numbers (quantitative), or using closed-ended questions (quantitative hypotheses) rather than open-ended questions (qualitative interview questions).

Mixed methods research is an approach to inquiry that combines or associates both qualitative and quantitative forms. A mixed methods design is useful when either the quantitative or qualitative approach by itself is inadequate to best understand a research problem or the strengths of both quantitative and qualitative research can provide the best understanding. For example, a researcher may want to both generalize the findings to a population as well as develop a detailed view of the meaning of a phenomenon or concept for individuals. Therefore, this research was used mixed research method as the research approach or design.

3.4. Sources of Data

This study was used both primary and secondary sources of data.

3.4.1. Primary Source of Data

The data gathered through questionnaires and focus group discussion with stakeholders were used as the primary sources of data.

3.4.2. Secondary Data

Publications, literatures, journals, books, documents and research in building performance simulation and analysis were used as secondary sources of data.

3.5. Population, Sample Size and Sampling Techniques

3.5.1. Population

The research population was contractors and consultants from Addis Ababa in 2015/ E.C. It consists of 50 consultants. Therefore, 50 consultants were the target populations of the study.

3.5.2. Sample Size and Sampling Techniques

The population size of this study was known and therefore, Krejcie and Morgan formula (Krejcie and Morgan, 1970) was used to calculate the sample size for this study. Accordingly, the flowing formula was used to calculate the sample size (n) of this study.

$$n = \frac{\chi\, 2Np(1\ -\ p)}{e2(N-1) + X2P(1-P)}$$

Where, n = sample size,

N = population size;

e = acceptable error of sample size, 0.05;

χ^2= Chi-square;

df= 1 and reliability level 95% (X^2 = 3.841);

p = the population proportions (assumed to be 0.3 or 30%).

i. **Consultants Sample Size**

Table 3. 1**:** Consultants population

Year		**Levels of Consultants**			
	Consultants' grade	**1**	**2**	**3**	**Total**
2015 E.C	Number of consultants	28	8	14	50

Source: Addis Ababa Building Permit and Control Authority Office

$$n = \frac{3.841*50*0.3(1-0.3)}{(0.05)2*(50-1)+3.841(0.3)(1-0.3)}$$

$$n = 44$$

According to Table 3.1, the total population of consultants were 50 and out of these the calculated sample size was 44. Therefore, the sample size (n) for this study was calculated to be 44 that were almost 88% of the total population and these were very appropriate sample size for this study. Accordingly, these 44 samples were participants of this study to whom questionnaire was distributed.

To select out the 44 participants of the study a Systematic random sampling method was implemented. Systematic random sampling is a type of probability sampling in which the researcher randomly selects a subset of participants from a population. In this sampling method, each member of the population has a chance of being selected.

Systematic random method is the most straightforward of all the probability sampling methods, since it only involves a single random selection and requires little advance knowledge about the population. Because it uses randomization, any research performed on this sample should have high internal and external validity, and be at a lower risk for research biases like sampling bias and selection bias. Simple random sampling is used to make statistical inferences about a population. It helps ensure high internal validity: randomization is the best method to reduce the impact of potential confounding variables.

In addition, with a large enough sample size, a Systematic random sample has high external validity: it represents the characteristics of the larger population. Each sample (n) was selected systematically.

3.6. Data Collection Instruments

The data collection instruments planned to be used for this study were closed ended questionnaire and focus group discussion to gather primary data resources.

3.6.1. Questionnaire

Questionnaire is the simplest and time saving method to collect data effectively from a huge number of respondents. When properly constructing a questionnaire as a scientific instrument to obtaining the data from large number of individuals. Therefore, the questionnaire prepared for this study contains about 44 closed ended items prepared in Likert scale form. It has 44 major thematic areas that matches with the basic research questions. It is prepared in English language, and 44 copies will be prepared and disseminated to the 44 respondents.

3.6.2. Focus group discussion

Effective facilitation of a discussion involves the recognition and employment of different perspectives and different skills to create an inclusive environment. In order to do so, it was important to consider the features of effective discussions, and conditions that promote small group interaction and engagement. A well-facilitated discussion allows the participant to explore new ideas while recognizing and valuing the contributions of others.

Accordingly, the focus group discussion will be conducted with selected 4 professionals. That is, the total participant of the focus group discussion was 8 in two groups, and these participants do not participate in any other means of data collection. The discussion will be conducted in Amharic and the ideas will be recorded properly, using language experts it will be translated to English for analysis purpose.

3.7. Validity and Reliability

There are two main standards that was used to measure the study level of quality. These are validity and reliability.

3.7.1. Validity

Pilot testing of the research instrument was conducted using staff working in building construction Projects in Addis Ababa. Ten respondents were randomly selected and given the questionnaire to respond it. After one day the same participants were requested to respond to the same questionnaires but without prior notification in order to ascertain any variation in responses of the first and the second test. Content validity which was employed by this study was a measure of the degree to which data collected using a particular instrument represents a specific domain or content of a particular concept. Expert opinion was requested to comment on the representativeness and suitability of questions and give suggestions or corrections to be made to the structure of the research tools. After the test pilot questionnaire, the final questionnaire was developed by using a literature review and observations.

3.7.2. Reliability

The researcher intends to select a pilot group of 10 individuals from the target population to test the reliability of the research questionnaire. In order to test the reliability of the questionnaire and internal consistency of the items by using Cronbach's Alpha value test. The alpha value ranges between 0 and 1 with reliability increasing with the increase in value. Coefficient of 0.7 is a commonly accepted rule of thumb that indicates acceptable reliability. The pilot data was not being included in the actual study. The alpha value calculated for the data collected from the pilot test resulted in 0.78, and this indicated that there was a good internal consistency of the items in the questionnaire. Therefore, the questionnaire has acceptable reliability and ready to distribute to the sample of the study.

3.8. Method of Data Analysis

After collecting the necessary data different analysis methods were used according to the type of the data that were collected. Descriptive method was used to analyze the data and interpret the results in quantitative and qualitative ways. The data retrieved was collected, compiled, and analyzed using both Microsoft Excel and SPSS (for descriptive and inferential statistical analysis) as this research follows a descriptive statistics method. The analysis of ideas and opinions from focus group discussion was done by analytical reasoning and logic to find patterns and correlations. or analysis trends to acquired data.

The descriptive analysis made use of frequencies, mean, standard deviation, maximum and minimum values. Inferential statistics involved independent sample t-test to see the difference between the responses of the two groups (contractors and consultants) and the significance of the results for interpretation and conceptual generalization.

In order to be able to select the appropriate method of analysis, the level of measurement must be understood. In these respects, participants were asked to indicate the level of BPS awareness, its practice, factors and mitigate measures or research variables by ranking them as 1, 2, 3, 4, and 5 in ascending order. The numbers assigned to the important ones (1, 2, 3, 4, and 5) do not indicate the interval, but it was to indicate their agreed level.

The mean score (MS) and average mean score (CMS) were used for the analysis of the data. The mean score comparison technique was commonly used to analyze and compare levels of quantitative measures (Zaidotal and Bagheri, 2009). This study also applied this technique.

The mean score (MS) of BPS awareness, its practice, factors and mitigate measures were computed to identify their level and to analyzing their effects by using the following expression:

$$MS = \frac{\sum(f \times s)}{N}$$

Where: MS = Mean score

f = frequency of response for each score

S = score given to each factor (1 to 5)

N = Total number of responses for each factor

According to Zaidotal and Bagheri (2009), mean score values are classified into three ranges. Mean score comparison basis for five point Likert scale instrument mean score < 3.00 is Low, mean score between 3.00-4.00 is Moderate and mean score > 4.00 is high.

3.9. Ethical Consideration

For this study, data collection should be ethical and it should respect individuals and sites. Obtaining permission before starting to collect data is not only a part of the informed consent process but is also an ethical practice. Protecting the anonymity of individuals by assigning numbers to returned instruments and keeping the identity of individuals confidential offers privacy to participants. During data collection, the researcher must view the data as confidential and not share it with other participants or individuals outside of the research.

The researcher will respect the wishes of individuals who choose not to participate in the study. Even when they consent to participate, people may back out or not show up for an observation or interview. Attempts to reschedule may be futile and the researcher may select another person for data collection rather than forcing an individual to participate. Observing in a classroom, for example, may disturb learning by distracting teachers and students, especially when you observe them closely and write down observations about their behavior on checklists.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter provides explanations to the issues related to the distribution of the questionnaire, collection of responses and subsequent analysis of the data acquired through the responses of professionals who are working for the consultants involved in the designing building projects in Addis Ababa. The main goal of this study is to investigate the factors that affect Building performance simulation during design phase of building projects that are required to be given due attention in future building design projects in Addis Ababa. The descriptive statistical analysis results are presented in tables and charts in the following sections.

4.2 Basic Information and results of the Respondents

This part is primarily concerned with presenting the study's findings derived from the data gathered through questionnaires. To be clear, the results were presented in accordance with and in addressing the fundamental research questions. It is preferable to examine the questionnaires' ability to meet the goal and aim before analyzing the final outcome. To assess the achievement, the researcher piloted ten (10) questionnaires to a group of stakeholders and examined the results to see if the study questionnaires could meet the goal. The responses indicated that the developed questionnaires were capable of achieving the intended purpose.

4.2.1 Rate of response

For the actual survey the responders were members of consultants or/and their representatives. In reference to chapter 3.4 sampling techniques, the researcher circulated questionnaires to selected experts in consultant's organizations who are willing to respond and who are held accountable for delivering honest information. A total of 44 key staff members have been incorporated into these investigations. According to the research stated intent in chapter three, a total of 44 questionnaires were distributed to targeted respondents which comprise of 44 for consultants, wherein the sample of the questionnaire is attached herewith in the Appendix-I. From the total 44 targeted respondents 43 returned the questionnaires duly completed. Table 4.1 illustrates the summary questionnaires response rate.

Table 4. 1: Summary of overall survey response Rate

Questionnaire Distributed	Questionnaire Returned	Percentage (%)
44	43	98

Consultants were return 98% of their response. This was significant for the purpose of validating the research results. The respondents were averagely good in responding to the questionnaires, as well as all were compiled within a reasonable time space.

4.2.2. Respondents Educational Subject Matter Back Ground

Table 4.2 show the respondents' profession subject matter. The profession of the respondents included architects, civil engineers, urban engineers, construction technology and management, mechanical engineers, sanitary engineers, electrical engineers and surveyors with the roles of designers, residence engineers, supervisors and project coordinators. From the total respondent's architects were led by 41.9%, civil engineer respondents were 18.6%, professionals with different subjects in the field responds with 23.3% and electrical engineer respondents were 16.3% from the total respondents. The percentage distribution of the various professionals indicates that the majority of the questionnaires were completed directly by professionals involved in building designing and construction projects

Table 4. 2: Summary Respondents Educational Subject Matter

Occupation of respondents	Frequency	Percent	Valid Percent	Cumulative Percent
Architect	18	41.9	41.9	41.9
Civil engineer	8	18.6	18.6	60.5
Electrical engineer	7	16.3	16.3	76.7
Others	10	23.3	23.3	100
Total	43	100	100	

4.2.3 Academic Level of Respondents

The purpose of section was to know the educational and professional capability of respondents to undertake the work. The questionnaire was completed by respondents who were involved/involving in building designing and construction projects.

The survey result shows that 55.8% of the respondents have a BSc degree educational qualification and the rest 44.2% have a MSc degree educational qualification as shown in Table 4.3. The percentage distribution of respondent's educational level indicates that the majority of the questionnaires were completed directly by skilled professionals involved in building designing and construction projects. The survey also shows that it was well represented by better-qualified professionals in building designing and construction Projects and these groups of respondents are expected to have plenty of knowledge on the subject matter.

Table 4. 3: Summary of overall Academic Level of Respondents

Educational level of respondents	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
Bachelor	24	55.8	55.8	55.8
Masters	19	44.2	44.2	100
Total	43	100	100	

4.2.4 Respondents Work Experience

The range of experience years of the respondents is presented here in the table below. Professionals share approximately the same ratio were 0-5 and 6-10 years of experience are the majority. The least number was with 11-15 years of experience. Professionals with >15 years of experience.

Out of the 43 respondents, both 0-5 and 6-10 years are take 27.9% of the respondents equally, 20.9% had taken by 11 to 15 years of experience and 23.3% had taken by professionals above

15 years of experience in Building Design and construction projects. Table 4.4 shows personal work experience of professionals.

Table 4. 4: Summary of overall survey response level

Work experience of respondents	**Frequency**	**Percent**	**Valid Percent**	**Cumulative Percent**
0-5	12	27.9	27.9	27.9
6 up to 10	12	27.9	27.9	55.8
11 up to 15	9	20.9	20.9	76.7
>15	10	23.3	23.3	100
Total	43	100	100	

4.3 Awareness of Building Performance Simulation During Design Phase

The first specific objective of the study, as stated in chapter one of this document, was to analyze the awareness level regarding on building performance simulation (BPS) during design phase of building projects by professionals of the field that actively participates in consultant's organizations on designing buildings. Respondents were asked to indicate their level of awareness regarding on BPS as 'Very high', 'High', 'Medium', 'Low' or 'Very low'. Professionals in designing field of building projects need to be aware of the concept of building performance simulation and apply its principles for the success of sustainable building performances.

The mean value of consultants shows that the ability to select appropriate software for identified task with the total average mean value of 2.35, training or seminar opportunities on simulation software with the total average mean value of 2.49, familiarity with all BPS tools with the total average mean value of 2.65 and professional development training opportunities on BPS with the total average mean value of 2.79 were the major BPS awareness gaps.

Table 4. 5: Group Statistics of Awareness of Consultants on BPS

Descriptive Statistics of BPS Awareness			
Items	Mean	Std. Deviation	Rank
Relationship of my educational back ground to BPS.	3.4	0.66	1
BPS can provide energy saving design option.	3.37	0.489	2
Knowledge about effects of BPS on building performance.	3.28	0.701	3
BPS can analyze life cycle cost of a building.	3.23	0.684	4
My interest in using BPS tools.	3.16	0.721	5
Awareness on BPS evaluates indoor environmental quality. (thermal comfort, ventilation, acoustics & lighting)	3.16	0.531	6
Understanding of Construction organizations about BPS.	3.12	0.731	7
Knowledge about benefits of BPS for building performance.	3.07	0.593	8
My concept of BPS in the field of work.	3.05	0.754	9
Understanding about BPS fits into design process optimizes building performance at early design stages.	3.02	0.707	10
Access to BPS software	2.93	0.768	11
My knowledge about methodology of BPS tools.	2.84	0.785	12
Professional development training opportunities on BPS.	2.79	0.638	13
My familiarity with all BPS tools.	2.65	0.65	14
Training or seminar opportunities on simulation software.	2.49	0.668	15
Ability to select appropriate software for identified task.	2.35	0.482	16

In the other hand the ‘Relationship of my educational back ground to BPS’ was the highest total average mean value of 3.4, ‘BPS can provide energy saving design option’ with the total average mean value of 3.37 ranked secondly, ‘Knowledge about effects of BPS on building performance’ with the total average mean value of 3.28 ranked thirdly and ‘BPS can analyze life cycle cost of a building’ were identified fourthly as opportunity to the implementation of BPS.

More generally, from the questionnaire survey of this research the group statistics for level of Total Awareness (TA) was discovered and agreed on the concept of BPS by all respondents on medium level with the total average mean value of 2.99.

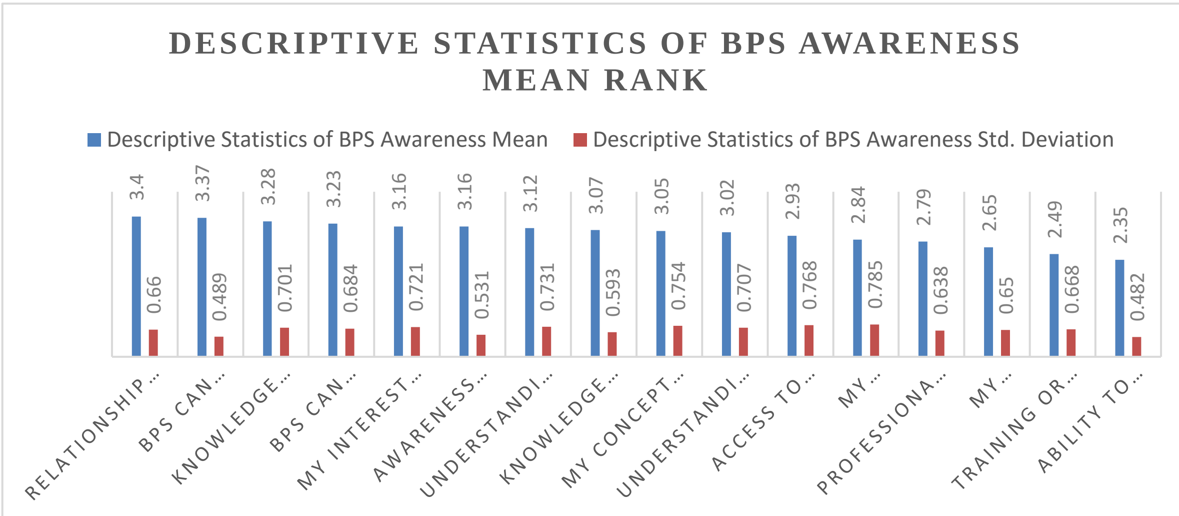

Figure 4. 1: Level of BPS Awareness Rank

4.4 Current Practice of Building Performance Simulation (BPS) During Design Phase

As mentioned in chapter one of this publication, the second specific objective of the research was to study the practices of BPS during design phase in Addis Ababa City. Table 4.6 showed the mean value for the level of BPS practices during design phase by the point of view of consultants in Addis Ababa. The result indicated that consideration of ‘following target oriented design approach’ with the average mean value of 3.16 was the highest ranked parameter, create list of user needs for a building at the design stage with the average mean value of 3.12 was the secondly ranked parameter, the thirdly ranked parameter for practice of BPS during design phase was ‘use fault preventive design approach, with the average mean value of 3.09.

Table 4. 6: Group Statistics of Practice of Consultants on BPS

Descriptive Statistics of BPS Practice			
Items	Mean	Std. Deviation	Rank
I'm following target oriented design approach.	3.16	0.574	1
I create list of user needs for a building at the design stage.	3.12	0.762	2
I use fault preventive design approach.	3.09	0.75	3
My collaboration with design team.	3.02	0.74	4
I participate in design team meetings.	2.98	0.771	5
I use BPS tools to identify energy saving design options.	2.88	0.762	6
I discuss and evaluate findings with the stakeholders and decision makers of the building projects.	2.84	0.814	7
I use BPS software tools to analyze life cycle cost of a building by different design options.	2.84`	0.754	8
I set performance criteria in a quantitative value of a set of physical factors to serve as a performance indicator.	2.81	0.627	9
I interpret simulation results and translate them in to actionable design decision.	2.77	0.751	10
I use BPS tools to evaluate indoor environmental quality.	2.74	0.658	11
I integrate BPS into design process at early design stage.	2.74	0.727	12
I transform list of user needs into qualitatively expressed physical terms of performance requirements.	2.72	0.701	13
I use simulation tools to prove the fulfillment of performance requirements explicitly.	2.67	0.644	14
I use BPS software tools with effective confidence.	2.53	0.702	15
I use appropriate BPS software tools during designing.	2.3	0.513	16

In the other hand use appropriate BPS software tools during designing with the average mean value of 2.3, use BPS software tools with effective confidence with the average mean value of 2.53, use simulation tools to prove the fulfillment of performance requirements explicitly with the average mean value of 2.67, transform list of user needs into qualitatively expressed physical terms of performance requirements with the average mean value of 2.72, integrate BPS into design process at early design stage with the average mean value of 2.74, interpret simulation results and translate them in to actionable design decision with the average mean value of 2.77, setting performance criteria in a quantitative value of a set of physical factors to serve as a performance indicator with the average mean value of 2.82 were the least practiced BPS activities during design phase.

The group statistics for level of Total Practice (TP) analyzed from the questionnaire survey of this research was discovered with the total average mean value of 2.82. This implies that all of the respondents agreed on the level BPS practice in the City was at medium level.

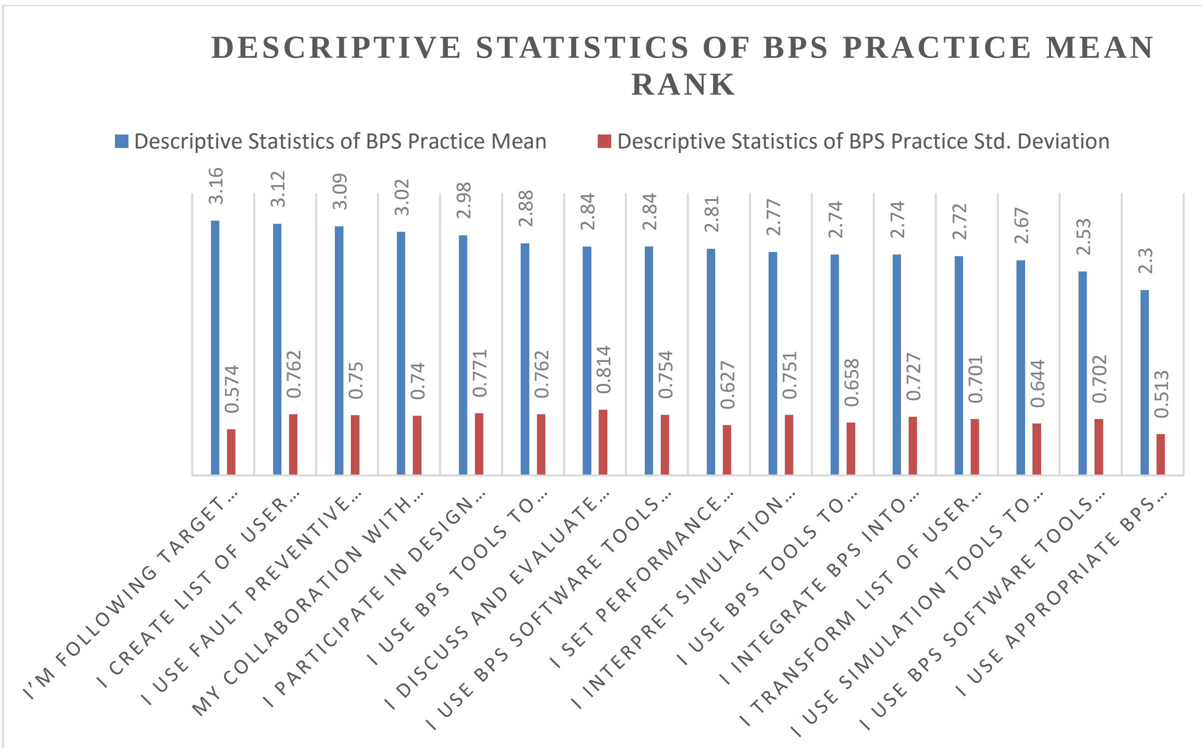

Figure 4. 2: Level of BPS Practice Rank

4.5 Factors Affecting the Implementation of BPS During Design Phase

As stated under chapter one of this document, the third specific objective of the research was identifying the major factors that affecting the practice of BPS during design phase in Addis Ababa City from the consultant’s viewpoint. In the questionnaire survey, the respondents were asked to rate the degree of contribution of the variables drawn from the literature review.

Furthermore, the respondents were also asked to add other variables or factors that could be a factor which affect the implementation of BPS.

Limited researchers have studied on factors affecting the implementation of BPS during design phase and addresses huge numbers of variables regarding on affecting factors in the designing and constructing building construction industry. The ultimate challenge for the building sector is to achieve a zero-carbon built environment by designing and developing high-performance buildings with indoor environments optimized for health, comfort and/or productivity(J. L. M. Hensen & Lamberts, 2019). According to the authors, only 1 % of the then 392 tools listed on the U.S. Department of Energy homepage [26] can be categorized as pre-design informative(Østergård et al., 2016). Development and application of building performance simulation started in the 1960s(J. L. M. Hensen & Lamberts, 2019).

Table 4.7 showed the mean value of factors affecting the implementation of BPS during design phase. The result indicated that consideration of Limited time given for design stage with the mean value of 4.67 was ranked firstly, Lack of data accuracy and availability with the mean value of 4.65 was ranked secondly, Lack of skilled and experienced professionals involve in data input, model calibration and result interpretation with the mean value of 4.58 ranked thirdly, High cost of software and expertise with the mean value of 4.51 was ranked fourthly, Stakeholders awareness about BPS with the mean value 4.49 was ranked fifthly, Lack of design team collaboration (Interdisciplinary coordination) with the mean value 4.47 was ranked sixthly, Client requirements (expectations) with the mean value 4.42 was ranked seventhly, Scale and complexity of the project and Lack of obligatory building regulations on BPS ranked on the eighth and ninth level with the mean value of 4.4 and 4.35 respectively.

Table 4. 7: Group Statistics of Factors Affecting BPS Implementation

Descriptive Statistics of BPS Affecting Factors			
Items	Mean	Std. Deviation	Rank
Limited time given for design stage	4.67	0.474	1
Lack of data accuracy and availability	4.65	0.482	2
Lack of skilled and experienced professionals involve in data input, model calibration and result interpretation.	4.58	0.499	3
High cost of software and expertise	4.51	0.506	4
Stakeholders awareness about BPS	4.49	0.506	5
Lack of design team collaboration (Interdisciplinary coordination)	4.47	0.505	6
Client requirements (expectations)	4.42	0.499	7
Scale and complexity of the project	4.4	0.495	8
Lack of obligatory building regulations on BPS	4.35	0.482	9
Lack of conducting sensitivity analysis	4.28	0.454	10
Shortage of Cost-effective alternatives	4.26	0.581	11
Uncertainties associated with simulation outcomes	4.19	0.546	12
Lack of Construction Industry organizations support	4.16	0.754	13
Lack of incorporating feedbacks from stakeholders	4.14	0.915	14
Absence of Government incentives	4.13	0.905	15
Limited educational opportunities	4.12	0.731	16
Software capacity limitations	4	0.756	17
Limited access to BPS software	3.98	0.859	18
Lack of clear communication with stakeholders	3.95	0.615	19

On contrary variables of the least affecting the implementation of BPS during design phase were; Lack of clear communication with stakeholders with the mean value of 3.95 ranked lastly, Limited access to BPS software with the mean value of 3.98 Software capacity limitations with the mean value of 4.0, Limited educational opportunities with the mean value of 4.12.

The group statistics for level of Total Factor (TF) analyzed from the questionnaire survey of this research was discovered with the total average mean value of 4.3. This implies that all of the respondents agreed on all of factors in the City was at sever level.

Figure 4.3 shows that, even if those variables under the least statement their mean value was not far away with those sever affecting variables.

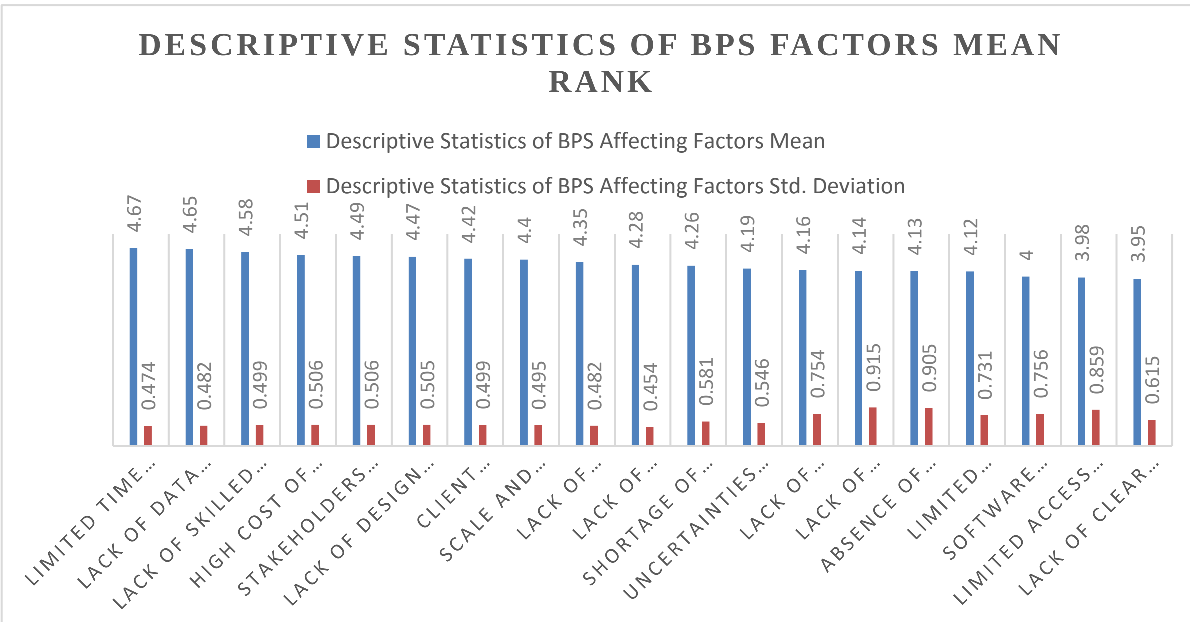

Figure 4. 3: Level of BPS affecting Rank

4.6 Mitigate measures for Poor Performance practice of BPS during design phase

The last specific objective of the research was to develop a mitigate measures for factors affecting the practice of BPS during design phase in Addis Ababa City from the contractors and consultants point of view.

Table 4.8 showed the average mean value of mitigate measures for the implementation of BPS during design phase on the point of view of consultants in Addis Ababa. The result indicate that consideration of Collect quality data at early design stage with the mean value of 4.81 was the highest ranked mitigate measure, Providing training opportunities for stakeholders about benefits of BPS through different methods, such as case studies and demonstrations with the mean value of 4.7 was the secondly ranked mitigate measure.

Table 4. 8: Group Statistics of Mitigate Measures for Consultants

Descriptive Statistics of Mitigate Measures for BPS			
Items	Mean	Std. Dev.	Rank
Collect quality data at early design stage	4.81	0.394	1
Providing training opportunities for stakeholders about benefits of BPS through different methods, such as case studies and demonstrations.	4.7	0.465	2
Introducing and practicing obligatory building regulations to incorporate BPS into the design process proactively.	4.63	0.489	3
Accessing educational opportunities and skilled professionals.	4.6	0.495	4
Allocating sufficient budget during design phase	4.58	0.499	5
Make clear communication and understand stakeholders.	4.56	0.505	6
Break down complex projects into manageable components for simulation analysis.	4.55	0.505	7
Allocating sufficient time at design stage	4.54	0.505	8
Government incentives for BPS implementation	4.53	0.505	9
Explore open-source or low cost simulation software alternatives.	4.52	0.506	10
Prioritize simulation efforts on critical aspects of the design to optimize cost effectiveness.	4.51	0.506	11
Providing adequate organizational support in upgrading software infrastructures.	4.5	0.631	12
Construction industry organizations support in upgrading hardware and software infrastructures	4.49	0.506	13
Create collaboration between design team members	4.47	0.631	14
Allocate the right personnel based on scale and complexity of the project.	4.46	0.629	15
Evaluate multiple simulation software options to identify the most suitable tool.	4.44	0.502	16
Incorporating feedbacks from stakeholders improve simulation accuracy.	4.4	0.623	17
Implement performance benchmark simulation results against industry standards	4.37	0.482	18
Conducting sensitivity analysis to identify uncertainties and incorporate the result improves simulation accuracy.	4.35	0.715	19
Implement knowledge sharing/transfer/ initiatives.	4.34	0.606	20
Utilizing collaborative tools for design team	4.33	0.715	21

The thirdly ranked mitigate measure for the implementation of BPS during design phase was Introducing and practicing obligatory building regulations to incorporate BPS into the design process proactively with the average mean value of 4.63, Accessing educational opportunities and skilled professionals with the average mean value of 4.6 ranked fourthly, Allocating sufficient budget during design phase and Make clear communication and understand stakeholders takes the fifth and the sixth order with the mean value of 4.58 and 4.56 respectively.

On contrary variables of the least mitigate measure to the implementation of BPS during design phase were; Utilizing collaborative tools for design team with the mean value of 4.33 ranked lastly, Implement knowledge sharing/transfer/ initiatives with the mean value of 4.34, Conducting sensitivity analysis to identify uncertainties and incorporate the result improves simulation accuracy with the mean value of 4.35, Implement performance benchmark simulation results against industry standards with the mean value of 4.37 and Incorporating feedbacks from stakeholders improve simulation accuracy with the mean value of 4.4 were the least mitigate measure for the implementation of BPS during design phase.

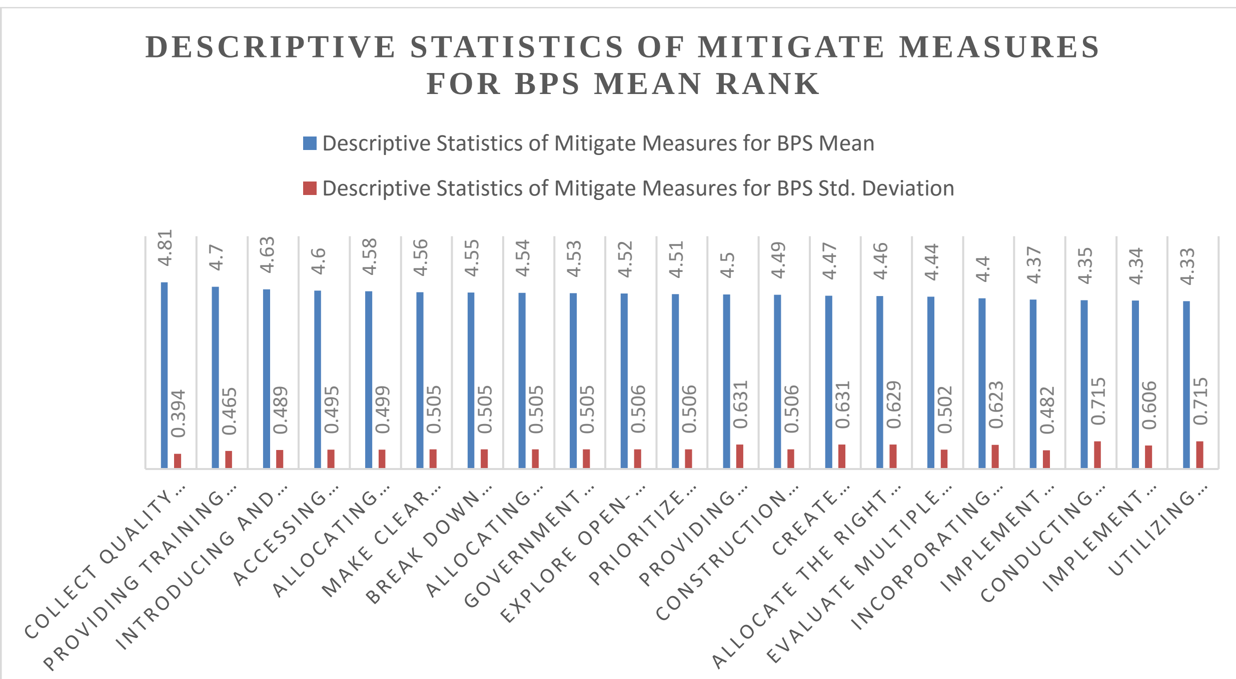

Figure 4. 4:BPS Mitigate Measures Rank

Figure 4.4 show that those variables under the least statement their value of average mean value not far away with those active measure variables. So that they need equivalent consideration to overcome the affecting factors of BPS during design phase.

The group statistics for level of Total Mitigate Measures (TM) analyzed from the questionnaire survey of this research was discovered with the total average mean value of 4.5. This implies that all of the respondents agreed on all of mitigate measures.

4.7 Focus group discussion

Focus group discussion was used to collect qualitative primary data. There are three leading questions are ready for discussions which identify the level of awareness of BPS during design phase, the current BPS practice of professionals, affecting factors and benefits of BPS related questions were arranged. It was organized in different two groups and participants were selected from design team members participating in building design with different professions. These professionals do not participate in any other means of data collection and eight in number. Their personal back ground was stated in the following table.

Table 4. 9*:* personal back ground OF Group Discussion Professionals

Profession	**Group One**	**Group Two**	**Total**
Architect	1	1	2
Civil Engineer	1	1	2
Urban Engineer	-	1	1
Electrical Engineer	1	1	2
Surveyor	1	-	1
Total	4	4	8

These were group discussion questions, description of the questions and summary of the group discussion participants' suggestions.

1. How can you enhance your utilization of BPS in your design process to optimize BP, address sustainability goals, and overcome potential challenges?

This question encouraged the team to consider ways to improve their awareness, practice, understanding of factors influencing simulation implementation, and implementation of mitigate measures. It also fostered collaboration and brainstorming to identify practical strategies and solutions for integrating building performance simulation effectively into their design workflow.

Accordingly, the participants of the group discussion forwarded their own suggestion regarding the utilization of BPS in design phase. Building performance simulation early in the design process, allows for interactive analysis and adjustments to be made when design phase changes were less costly. For example, one of the participants said that "in building design phase, majority of consultants did not use building performance simulation tools to produce renovated alternative designs and the best possible solutions for challenges in the area".

Moreover, the participants agreed on that BPS utilization increase their awareness to the benefits of data accuracy to insure accurate input data for simulations. This includes building geometry, occupancy patterns, HVAC systems, and weather data. Inaccurate data can lead to misleading results, choose appropriate simulation tools from various software options available, each with its own strengths and capabilities that suit the project requirements and complexity.

2. How can you modernize your approach to BPS to ensure it becomes an integral part of your design process, leading to more sustainable and efficient building designs?

This question prompted the design team to reflect on their current practices and explored opportunities for improvement in integrating simulation tools and methodologies into their workflow.

The participants of group discussion said that opportunities for improvement in integrating simulation tools and methodologies into their workflow to incorporate simulation at the early stages of design for influence decision from the start and also by embracing these strategies and modernizing the approach to building performance simulation, design teams can ensure that it becomes an integral part of the design process, leading to more sustainable and efficient building designs.

3. How can BPS help you to achieve your project goals and objectives, such as BP, reducing energy costs, enhancing occupant comfort, and demonstrating sustainability leadership?

This question engaged stakeholders in understanding the potential benefits of BPS for their project and encouraged them to consider how simulation can support their specific needs and priorities. It also opened the door for discussion on the value proposition of simulation and its alignment with their project vision.

Most of the participants of this group discussion agreed that BPS opened the door for discussion on the value proposition of simulation and its alignment with their project vision to the value of building performance simulation as a versatile tool that supports the achievement of project goals related to energy efficiency, occupant comfort, and sustainability. They also said that, by providing insights into the performance of design alternatives and guiding decision-making throughout the design process, BPS empowers project teams to deliver high-performance buildings that meet the needs of occupants while minimizing environmental impact.

4.8 Summary of the Findings

This section of the study provides an overview of the data analysis, as well as findings and discussions. The findings are based on questionnaire responses from Addis Ababa City active building construction projects.

According to the finding of this study, lack of awareness about BPS was observed due to the traditional practice of BPS and consultants to the design stage. Making new strategies to encourage performance based simulated building designs and construction, such as granting design approval and building permits at half price for BPS is recommended.

The findings of this study have the potential to contribute to the development of sustainable building practices by promoting the adoption of BPS in the design phase. By optimizing building performance and reducing energy consumption, the research aims to enhance the environmental sustainability of buildings and improve the quality of life for building occupants. Additionally, the study aimed to provide insights and recommendations for improving the accuracy and reliability of BPS, which could contribute to the development of more advanced and effective BPS tools.

Regarding the challenges to PBS, The result of the study indicated that consideration of limited time given for design stage, lack of data accuracy and availability, lack of skilled and experienced professionals, high cost of software and expertise, stakeholders awareness about BPS, lack of design team collaboration (Interdisciplinary coordination), client requirements (expectations), scale and complexity of the project and lack of obligatory building regulations on BPS were the potential challenges.

The study result indicated that, consideration of collect quality data at early design stage with the highest ranked mitigate measure, providing training opportunities for stakeholders about benefits of BPS through different methods, such as case studies and demonstrations, the thirdly ranked mitigate measure for the implementation of BPS during design phase was introducing and practicing obligatory building regulations to incorporate BPS into the design process proactively, accessing educational opportunities and skilled professionals, allocating sufficient budget during design phase and make clear communication and understanding were the mitigating factors.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents conclusions of the study resulting from findings, secondly deals with recommendations based on findings and lastly concerned with concepts that might require further studies. The findings of this research categorized into four sections dealing with the level of awareness of consultants on Building Performance Simulation (BPS) during design phase, BPS current practice of field professionals during design phase, the factors affecting the practice of BPS during design phase and the mitigate measures taken to overcome the factors and to improve the buildings performance through design.

5.2 Conclusions

The research findings show that factors affecting the implementation of BPS by consultants and contractors in Addis Ababa leaves much to be desired. The results suggest that the consideration of building performance during the design stage is not widely practiced.

1. Organizations should prioritize raising stakeholder awareness, integrating simulation into standard design processes, comprehending the factors influencing its implementation, and putting targeted mitigation measures in place to effectively address barriers in order to optimize the benefits of building performance simulation. Organizations may fully utilize the potential of building performance simulation to design more sustainable, health-conscious, and efficient buildings of the future by implementing a thorough and integrated approach.
2. In the current time practice, the majority of consultants in Addis Ababa had only a cursory experience with and comprehension of building performance simulation and analysis. They do not thoroughly analyze the building's performance throughout the design phase, even in spite of targeted efforts to enhance a particular building's sustainability performance element. One of the primary causes was the prescriptive approach used in the majority of Addis Ababa projects. Instead of using a goal-oriented performance-simulated design, it is generally acceptable to use deemed-to-satisfy

solutions for building design. Moreover, in building design projects, consultants do not use building performance simulation tools to produce alternative designs and the best possible solutions.

3. The current factors to the implementation of BPS, investigate how BPS can be integrated into the design process most effectively, examine the attitudes of architects and engineers towards BPS, how these affect its implementation, and identify ways to improve the accuracy and reliability of BPS to increase its application early in the design phase process.
4. A useful technique for improving design choices, increasing building performance and guaranteeing sustainability in the built environment is building performance simulation. However, a number of elements must come together for it to be implemented successfully, such as BPS awareness, its practice, identifying affecting factors, and develop modifying measures. These activities need time and patience; consultants also need the easiest way of designing: therefore, developing BPS modifying measures do not practice by consultants.

5.3 Recommendations

Building's life cycle: from planning to design, construction, operation, maintenance, renovation, and demolition. These responsibilities should be performed deliberately. All these should have answered during design phase. The following recommendations are suggested to practice BPS during design phase, building permit time and construction sites in Addis Ababa City and Sub Cities building projects:

1. Improve awareness of stakeholders on the benefits of using Building Performance Simulation early in the design process by introducing BPS is a powerful tool that can be used in the design stage to maximize building performance, minimize the impact of buildings on the environment, and enhance the comfort and well-being of building occupants.
2. Consultants recommended to acquire renovated design approach of building projects in Addis Ababa. The city is currently experiencing massive construction projects with a wide footprint and a multi-decade lifespan, a plan for the long term performance of these buildings needs to be taken into consideration. Numerous studies have demonstrated

how buildings affect land usage and ecology, global greenhouse gas emissions, and overall energy use. More ideal solutions must be looked for, even though they may be difficult and time consuming, in order to enhance building performance and assess how well designed, constructed, and operated structures will serve their intended purposes.

3. Education and training programs for building professionals is needed to improve the understanding of affecting factors and benefits of implementing BPS tools on buildings performance by visualizing; how the building will react in response to excitation in a virtual environment. Through seminars and workshops, stakeholders in the construction industry should become more knowledgeable about BPS. The Ministry of Education must include specialized courses and modules in textbooks for all generations, from elementary school to higher education institutions, in order to encourage BPS practices. Therefore, professionals should aware on BPS and practice it for better building performance by overcoming affecting factors.
4. It is recommended for the government and organizations to acknowledge and encourage the industry by providing incentives to designers who prioritize the analysis of how a building will function and meet performance standards by actively incorporating BPS tools into the design phase. Furthermore, the agency responsible for building ratings recommended that buildings that were accurately designed and built with excellent performance be acknowledged and certified. These improves the practice of BPS at early stage of design process. To this end, the recommendation submitted in this research is poised to assist building professionals in implementing BPS practices in their building design process.

5.4 Future Research Suggestions

BPS remains a relatively untouched subject in Addis Ababa construction industry context. This study tried to identify critical factors affecting the implementation of integrate BPS into design process at early design stage of project life cycle with mitigate measures for Building Permit Office specifically for Addis Ababa City and its Sub Cities. Further to this, as a researcher recommend the following study areas; detailed investigation of the Implementation of BPS During Design Phase with Case Studies, the Impact of Proper Design on Building Performance, studying BPS for high seismic value area Buildings, studying Factors Affecting the Implementation of design aid software for Highway, Expressway, Railway, Bridge, Dam (separately or in one category).

References

268437.pdf. (2015). Retrieved December 24, 2022, from https://dl.acm.org/doi/pdf/10.1145/268437.268440

Alani, Y., Dawood, N., Rodriguez, S., & Dawood, H. (2020). *Whole Life Cycle Construction Information Flow using Semantic Web Technologies: A Case for Infrastructure Projects*. 141–155. https://doi.org/10.46421/2706-6568.37.2020.paper011

Attia, S., Hensen, J. L. M., Beltrán, L., & De Herde, A. (2012). Selection criteria for building performance simulation tools: Contrasting architects' and engineers' needs. *Journal of Building Performance Simulation*, *5*(3), 155–169. https://doi.org/10.1080/19401493.2010.549573

Attia, S., Hensen, J. L. M., Beltrán, L., & De Herde, A. (2012). Selection criteria for building performance simulation tools: Contrasting architects' and engineers' needs. *Journal of Building Performance Simulation*, *5*(3), 155–169. https://doi.org/10.1080/19401493.2010.549573

Beausoleil-Morrison, I., & Hensen, J. L. M. (2008). Editorial. *Journal of Building Performance Simulation*, *1*(1), 1–1. https://doi.org/10.1080/19401490801963065

Belay, S., Goedert, J., Woldesenbet, A., & Rokooei, S. (2021). Enhancing BIM implementation in the Ethiopian public construction sector: An empirical study. *Cogent Engineering*, *8*(1), 1886476. https://doi.org/10.1080/23311916.2021.1886476

Building Performance Simulation Tools.pdf. (2015).

Chang, Y.-T., & Hsieh, S.-H. (2020). A review of Building Information Modeling research for green building design through building performance analysis. *Journal of Information Technology in Construction*, *25*, 1–40. https://doi.org/10.36680/j.itcon.2020.001

Clarke, J. (2015). A vision for building performance simulation: A position paper prepared on behalf of the IBPSA Board. *Journal of Building Performance Simulation*, *8*(2), 39–43. https://doi.org/10.1080/19401493.2015.1007699

Clarke, J. (2015). A vision for building performance simulation: A position paper prepared on behalf of the IBPSA Board. *Journal of Building Performance Simulation*, *8*(2), 39–43. https://doi.org/10.1080/19401493.2015.1007699

Clarke, J. A., & Hensen, J. L. M. (2015). Integrated building performance simulation: Progress, prospects and requirements. *Building and Environment*, *91*, 294–306. https://doi.org/10.1016/j.buildenv.2015.04.002

de Wilde, P. (2017a, August 7). *The Concept of Building Performance in Building Performance Simulation – a Critical Review*. 2017 Building Simulation Conference. https://doi.org/10.26868/25222708.2017.270

de Wilde, P. (2017, August 7). *The Concept of Building Performance in Building Performance Simulation – a Critical Review*. 2017 Building Simulation Conference. https://doi.org/10.26868/25222708.2017.270

Gong, P., Li, X., Wang, J., Bai, Y., Chen, B., Hu, T., Liu, X., Xu, B., Yang, J., Zhang, W., & Zhou, Y. (2020). Annual maps of global artificial impervious area (GAIA) between 1985 and 2018. *Remote Sensing of Environment*, *236*, 111510. https://doi.org/10.1016/j.rse.2019.111510

Harputlugil, G. U., & Wilde, P. D. (2022). The role of simulation in design of high-performance buildings in Turkey. *CLIMA 2022 Conference*, 2022: CLIMA 2022 The 14th REHVA HVAC World Congress. https://doi.org/10.34641/CLIMA.2022.66

Hensen, J., Djunaedy, E., & Radoševi, M. (2004). *BUILDING PERFORMANCE SIMULATION FOR BETTER DESIGN: SOME ISSUES AND SOLUTIONS*.

Hensen, J., Djunaedy, E., & Radoševi, M. (2004). *BUILDING PERFORMANCE SIMULATION FOR BETTER DESIGN: SOME ISSUES AND SOLUTIONS*.

Hensen, J. L. M., & Lamberts, R. (2019). Building performance simulation – challenges and opportunities. In J. L. M. Hensen & R. Lamberts (Eds.), *Building Performance Simulation for Design and Operation* (2nd ed., pp. 1–10). Routledge. https://doi.org/10.1201/9780429402296-1

Hensen, J. L. M., & Lamberts, R. (2019). Building performance simulation – challenges and opportunities. In J. L. M. Hensen & R. Lamberts (Eds.), *Building Performance Simulation for Design and Operation* (2nd ed., pp. 1–10). Routledge. https://doi.org/10.1201/9780429402296-1

Hensen, J. L. M., & Lamberts, R. (2019). Building performance simulation – challenges and opportunities. In J. L. M. Hensen & R. Lamberts (Eds.), *Building Performance Simulation for Design and Operation* (2nd ed., pp. 1–10). Routledge. https://doi.org/10.1201/9780429402296-1

Hensen, J., & Lamberts, R. (Eds.). (2019). *Building performance simulation for design and operation* (Second edition). Routledge.

Hopfe, C. J., & Hensen, J. L. M. (2011). Uncertainty analysis in building performance simulation for design support. *Energy and Buildings*, *43*(10), 2798–2805. https://doi.org/10.1016/j.enbuild.2011.06.034

IBPSANews-32-2.pdf. (2012). Retrieved December 26, 2022, from http://www.ibpsa.org/Newsletter/IBPSANews-32-2.pdf

Ismail, N. A. A., Chiozzi, M., & Drogemuller, R. (2017). *An overview of BIM uptake in Asian developing countries*. 080008. https://doi.org/10.1063/1.5011596

Jalaei, F., & Jrade, A. (2015). Integrating building information modeling (BIM) and LEED system at the conceptual design stage of sustainable buildings. *Sustainable Cities and Society*, *18*, 95–107. https://doi.org/10.1016/j.scs.2015.06.007

Jin, Z., Gambatese, J., Liu, D., & Dharmapalan, V. (2019). Using 4D BIM to assess construction risks during the design phase. *Engineering, Construction and Architectural Management*, *26*(11), 2637–2654. https://doi.org/10.1108/ECAM-09-2018-0379

Johari Hussein. (2011). *Assessment of Building Performance Measurement Tanzania*.

Kibert, C. J. (2011). *Sustainable Construction at the Start of the 21st Century*.

Motawa, I., & Carter, K. (2013). Sustainable BIM-based Evaluation of Buildings. *Procedia - Social and Behavioral Sciences*, *74*, 419–428. https://doi.org/10.1016/j.sbspro.2013.03.015

Murphy, M. E., & Nahod, M.-M. (2017). Stakeholder competency in evaluating the environmental impacts of infrastructure projects using BIM. *Engineering, Construction and Architectural Management*, *24*(5), 718–735. https://doi.org/10.1108/ECAM-07-2015-0106

Negendahl, K. (2015). Building performance simulation in the early design stage: An introduction to integrated dynamic models. *Automation in Construction*, *54*, 39–53. https://doi.org/10.1016/j.autcon.2015.03.002

Olawumi, T. O., & Chan, D. W. M. (2019). Development of a benchmarking model for BIM implementation in developing countries. *Benchmarking: An International Journal*, *26*(4), 1210–1232. https://doi.org/10.1108/BIJ-05-2018-0138

Østergård, T., Jensen, R. L., & Maagaard, S. E. (2016). Building simulations supporting decision making in early design – A review. *Renewable and Sustainable Energy Reviews*, *61*, 187–201. https://doi.org/10.1016/j.rser.2016.03.045

Roshana Takim, A. A. (2002). *PERFORMANCE INDICATORS FOR SUCCESSFUL CONSTRUCTION PROJECT PERFORMANCE*.

Solmaz, A. S. (2019). *A CRITICAL REVIEW ON BUILDING PERFORMANCE SIMULATION TOOLS*. *12*(2).

Solmaz, A. S. (2019). *A CRITICAL REVIEW ON BUILDING PERFORMANCE SIMULATION TOOLS*. *12*(2).

Wilde, P. de. (2018). *Building Performance Analysis*. John Wiley & Sons.

Yezioro, A., Dong, B., & Leite, F. (2008). An applied artificial intelligence approach towards assessing building performance simulation tools. *Energy and Buildings*, *40*(4), 612–620. https://doi.org/10.1016/j.enbuild.2007.04.014

APPENDIX

I: QUESTIONNAIRE SURVEY

ADAMA SCIENCE AND TECHNOLOGY UNIVERSITY

SCHOOL OF CIVIL AND ARCHITECTURAL ENGINEERING

DEPARTMENT OF CIVIL ENGINEERING

MASTER OF SCIENCE IN CONSTRUCTION ENGINEERING AND MANAGEMENT

Dear respondent,

The aim of this survey is to study the practices of building performance analysis/simulation at Design Phase in Addis Ababa with investigating the major affecting factors and to develop mitigate measures for factors affecting the practice of building performance simulation in Addis Ababa. In order to accomplish these objectives, it is crucial to conduct this questionnaire which is required to be filled with relevant facts as much as possible. Your genuine, honest and prompt response to the questionnaire will have contribution to the success of the research. I would like to confirm that all the data included in this questionnaire will be used only for academic purpose.

Thank you for your great contribution!

Researcher's information:

Name: Belete Tilahun

Phone: +251-915766824/+251-911270782

E-Mail: beletetilahun33@gmail.com

General Instruction

- For any additional option or explanation, you are kindly requested to write briefly on the space provided

Section-I Personal and Organizational Profile of Respondent

1. Please select your occupation from the table and mark "√" under your alternatives.

Architect	**Civil Engineer**	**Electrical Engineer**	**Mechanical Engineer**	**Others (Please specify)**

2. Please select your highest **educational level** and mark "√" under your alternatives.

College Diploma	**Bachelor's Degree**	**Master's Degree**	**Doctorate Degree**	**Others (Please specify)**

3. Please select the **type of organization** you involve in and mark "√" under your alternatives.

Consultants	**Others (Please specify)**

4. Please select your **work experience** in relation to designing projects and/or construction process and mark "√" under your alternatives.

0-5 Years	**6-10 Years**	**11-15 Years**	**>15 Years**

5. Please specify your **category** as per Ethiopian Construction Authority and mark "√" under your alternatives.

Grade 1	**Grade 2**	**Grade 3**	**Others (Please specify)**

Section-II Items regarding extent of awareness on Building Performance Simulation (BPS)

Please rate the following items based on your level of awareness regarding BPS and mark "√"at your selection.

SN.	Items	Very high	High	Medium	Low	Very low
1	Relationship of my educational back ground to BPS.					
2	Professional development training opportunities on BPS.					
3	Training or seminar opportunities on simulation software.					
4	Understanding of Construction organizations about BPS.					
5	My concept of BPS in the field of work.					
6	Access to BPS software					
7	My interest in using BPS tools.					
8	My familiarity with all BPS tools.					
9	Ability to select appropriate software for identified task.					
10	My knowledge about methodology of BPS tools.					
11	BPS can provide energy saving design option.					
12	Awareness on BPS evaluates indoor environmental quality. (thermal comfort, ventilation, acoustics & lighting)					
13	BPS can analyze life cycle cost of a building.					
14	Knowledge about benefits of BPS for building performance.					

15	Understanding about BPS fits into design process optimizes building performance at early design stages.					
16	Knowledge about effects of BPS on building performance.					

Section-III Items Regarding the Practices of BPS

Please rate the following items about your practices of BPS and mark √" at your selection.

SN.	Items	Always	Frequently	Sometimes	Rarely	Never
1	My collaboration with design team.					
2	I participate in design team meetings.					
3	I use appropriate BPS software tools during designing.					
4	I use BPS software tools with effective confidence.					
5	I'm following target oriented design approach.					
6	I create list of user needs for a building at the design stage.					
7	I transform list of user needs into qualitatively expressed physical terms of performance requirements.					
8	I integrate BPS into design process at early design stage.					
9	I use BPS tools to evaluate indoor environmental quality.					
10	I set performance criteria in a quantitative value of a set of physical factors to serve as a performance indicator.					
11	I use BPS tools to identify energy saving design options.					

12	I use BPS software tools to analyze life cycle cost of a building by different design options.					
13	I interpret simulation results and translate them in to actionable design decision.					
14	I use simulation tools to prove the fulfillment of performance requirements explicitly.					
15	I discuss and evaluate findings with the stakeholders and decision makers of the building projects.					
16	I use fault preventive design approach.					

Section-IV Items regarding factors affecting the implementation of BPS

Please rate the following factors affecting the implementation of BPS and mark "√"at your selection.

SN.	**Item**	**Strongly agree**	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**
1	Stakeholders awareness about BPS					
2	Limited educational opportunities					
3	Lack of skilled and experienced professionals involve in data input, model calibration and result interpretation.					
4	Lack of Construction Industry organizations support					
5	Absence of Government incentives					
6	Lack of obligatory building regulations on BPS					
7	Limited access to BPS software					
8	High cost of software and expertise					
9	Software capacity limitations					

10	Shortage of Cost-effective alternatives					
11	Limited time given for design stage					
12	Scale and complexity of the project					
13	Lack of data accuracy and availability					
14	Client requirements (expectations)					
15	Lack of clear communication with stakeholders					
16	Lack of incorporating feedbacks from stakeholders					
17	Lack of conducting sensitivity analysis					
18	Uncertainties associated with simulation outcomes					
19	Lack of design team collaboration (Interdisciplinary coordination)					

Section-V Items regarding mitigating measures

Please rate the following mitigating measures that can improve the implementation of BPS During Design Phase and mark "√"at your selection.

SN.	**Item**	**Strongly agree**	**Agree**	**Undecided**	**Disagree**	**Strongly disagree**
1	Accessing educational opportunities and skilled professionals.					
2	Providing training opportunities for stakeholders about benefits of BPS through different methods, such as case studies and demonstrations.					

3	Construction industry organizations support in upgrading hardware and software infrastructures					
4	Providing adequate organizational support in upgrading software infrastructures.					
5	Government incentives for BPS implementation					
6	Introducing and practicing obligatory building regulations to incorporate BPS into the design process proactively.					
7	Evaluate multiple simulation software options to identify the most suitable tool.					
8	Prioritize simulation efforts on critical aspects of the design to optimize cost effectiveness.					
9	Explore open-source or low cost simulation software alternatives.					
10	Allocating sufficient time at design stage					
11	Break down complex projects into manageable components for simulation analysis.					
12	Allocate the right personnel based on scale and complexity of the project.					
13	Allocating sufficient budget during design phase					
14	Collect quality data at early design stage					
15	Make clear communication and understand stakeholders.					
16	Incorporating feedbacks from stakeholders improve simulation accuracy.					

17	Conducting sensitivity analysis to identify uncertainties and incorporate the result improves simulation accuracy.					
18	Create collaboration between design team members					
19	Utilizing collaborative tools for design team					
20	Implement knowledge sharing/transfer/ initiatives.					
21	Implement performance benchmark simulation results against industry standards					

Section-VI Additional Questions

1. Are you aware of on Building Performance Simulation (BPS) concepts?
   mark "√" in front of your selection blank space.
   a) Yes _____
   b) No ______
2. If your answer on the above question number 1 of **section VI** is "Yes" please, show me your level of awareness.
   mark "√" in front of your selection blank space.
   a) Very Low ___________
   b) Low ___________
   c) Medium ___________
   d) High ___________
   e) Very High ___________
3. Which one is the most affecting factor of your decision in using BPS tools in a design building project?
   a) Lack of expertise
   b) Training opportunities
   c) Availability of accurate data
   d) Client requirements (expectations)
   e) Budget constraints (Cost)

f) Project schedule (Complexity)

g) Building regulations

h) Other (please specify) ____

4. Are there any additional factors that you think which affects the implementation of BPS during design phase?

   Please select one of the two and put "√" in the blank space.

   A. Yes _____

   B. No _____

5. If your answer on the above question number 4 of **section VI** is "Yes" please list down the factors affects the implementation of BPS.

   ____

   ____

   ____

   ____

   ____

6. Please, list down the mitigate measures for factors you identified on question number 5 of **section VI** Questionnaire

   ____

   ____

   ____

   ____

   ____

" Thank you very much for your time and helpful insight, it was greatly appreciated'

II. SPSS RESULT OUTPUT

```
FREQUENCIES VARIABLES=Occupation EduLevel TypeofOrg Experiance
Catagory/ORDER=ANALYSIS.
```

Frequencies

Notes

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Comments		
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Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data.
Syntax		FREQUENCIES VARIABLES=Occupation EduLevel TypeofOrg Experiance Catagory /ORDER=ANALYSIS.
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Consultant.sav
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Statistics

		Occupation of respondents	Educational level of respondents	Type of organization of respondents	Work experience of respondents	Category of respondents
N	Valid	43	43	43	43	43
	Missing	0	0	0	0	0

Frequency Table

Occupation of respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Architect	18	41.9	41.9	41.9
	Civil engineer	8	18.6	18.6	60.5
	Electrical engineer	7	16.3	16.3	76.7
	Others	10	23.3	23.3	100.0
	Total	43	100.0	100.0	

Educational level of respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Bachlor	24	55.8	55.8	55.8
	Masters	19	44.2	44.2	100.0
	Total	43	100.0	100.0	

Type of organization of respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Consultants	43	100.0	100.0	100.0

Work experience of respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0-5	12	27.9	27.9	27.9
	6-10	12	27.9	27.9	55.8
	11-15	9	20.9	20.9	76.7
	>15	10	23.3	23.3	100.0
	Total	43	100.0	100.0	

Catagory of respondents

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Grade 1	13	30.2	30.2	30.2
	Grade 2	12	27.9	27.9	58.1
	Grade 3	18	41.9	41.9	100.0
	Total	43	100.0	100.0	

```
DESCRIPTIVES VARIABLES=Awareness1 Awareness2 Awareness3 Awareness4
Awareness5 Awareness6 Awareness7 Awareness8 Awareness9 Awareness10
Awareness11 Awareness12 Awareness13 Awareness14 Awareness15 Awareness16
/STATISTICS=MEAN STDDEV/SORT=MEAN (D.
```

Descriptives

Notes

Output Created		05-JUN-2024 16:40:29
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	Cases Used	All non-missing data are used.
Syntax		DESCRIPTIVES VARIABLES=Awareness1 Awareness2 Awareness3 Awareness4 Awareness5 Awareness6 Awareness7 Awareness8 Awareness9 Awareness10 Awareness11 Awareness12 Awareness13 Awareness14 Awareness15 Awareness16 /STATISTICS=MEAN STDDEV /SORT=MEAN (D).
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

```
[DataSet1] C:\Users\BAB AL SAFA\OneDrive\Desktop\Analysis\Analysis
Consultant.sav
```

Descriptive Statistics

	N	Mean	Std. Deviation
Relationship of my educational back ground to BPS.	43	3.40	.660
BPS can provide energy saving design option.	43	3.37	.489
Knowledge about effects of BPS on building performance.	43	3.28	.701
BPS can analyze life cycle cost of a building.	43	3.23	.684
My interest in using BPS tools.	43	3.16	.721
Awareness on BPS evaluates indoor environmental quality. (thermal comfort, ventilation, acoustics & lighting)	43	3.16	.531
Understanding of Construction organizations about BPS.	43	3.12	.731
Knowledge about benefits of BPS for building performance.	43	3.07	.593
My concept of BPS in the field of work.	43	3.05	.754
Understanding about BPS fits into design process optimizes building performance at early design stages.	43	3.02	.707
Access to BPS software	43	2.93	.768
My knowledge about methodology of BPS tools.	43	2.84	.785
Professional development training opportunities on BPS.	43	2.79	.638
My familiarity with all BPS tools.	43	2.65	.650
Training or seminar opportunities on simulation software.	43	2.49	.668
Ability to select appropriate software for identified task.	43	2.35	.482
Valid N (listwise)	43		

```
DESCRIPTIVES VARIABLES=Practice1 Practice2 Practice3 Practice4 Practice5
Practice6 Practice7 Practice8 Practice9 Practice10 Practice11 Practice12
Practice13 Practice14 Practice15 Practice16
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```

Descriptives

Notes

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Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	All non-missing data are used.
Syntax		DESCRIPTIVES VARIABLES=Practice1 Practice2 Practice3 Practice4 Practice5 Practice6 Practice7 Practice8 Practice9 Practice10 Practice11 Practice12 Practice13 Practice14 Practice15 Practice16 /STATISTICS=MEAN STDDEV /SORT=MEAN (D).
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

```
[DataSet1] C:\Users\BAB AL SAFA\OneDrive\Desktop\Analysis\Analysis
Consultant.sav
```

Descriptive Statistics

	N	Mean	Std. Deviation
I'm following target oriented design approach.	43	3.16	.574
I create list of user needs for a building at the design stage.	43	3.12	.762
I use fault preventive design approach.	43	3.09	.750
My collaboration with design team.	43	3.02	.740
I participate in design team meetings.	43	2.98	.771
I use BPS tools to identify energy saving design options.	43	2.88	.762
I discuss and evaluate findings with the stakeholders and decision makers of the building projects.	43	2.84	.814
I use BPS software tools to analyze life cycle cost of a building by different design options.	43	2.84	.754
I set performance criteria in a quantitative value of a set of physical factors to serve as a performance indicator.	43	2.81	.627
I interpret simulation results and translate them in to actionable design decision.	43	2.77	.751
I use BPS tools to evaluate indoor environmental quality.	43	2.74	.658
I integrate BPS into design process at early design stage.	43	2.74	.727
I transform list of user needs into qualitatively expressed physical terms of performance requirements.	43	2.72	.701
I use simulation tools to prove the fulfillment of performance requirements explicitly.	43	2.67	.644
I use BPS software tools with effective confidence.	43	2.53	.702
I use appropriate BPS software tools during designing.	43	2.30	.513
Valid N (listwise)	43		

```
DESCRIPTIVES VARIABLES=Factors1 Factors2 Factors3 Factors4 Factors5
Factors6 Factors7 Factors8 Factors9 Factors10 Factors11 Factors12 Factors13
Factors14 Factors15 Factors16
  /STATISTICS=MEAN STDDEV/SORT=MEAN (D).
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Notes

Output Created		05-JUN-2024 16:43:12
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Syntax		DESCRIPTIVES VARIABLES=Factors1 Factors2 Factors3 Factors4 Factors5 Factors6 Factors7 Factors8 Factors9 Factors10 Factors11 Factors12 Factors13 Factors14 Factors15 Factors16 /STATISTICS=MEAN STDDEV/SORT=MEAN (D).
Resources	Processor Time	00:00:00.00
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```
DESCRIPTIVES VARIABLES=Factors1 Factors2 Factors3 Factors4 Factors5
Factors6 Factors7 Factors8 Factors9 Factors10 Factors11 Factors12 Factors13
Factors14 Factors15 Factors16 Factors17 Factors18 Factors19
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```

Descriptives

Notes

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	Cases Used	All non-missing data are used.
Syntax		DESCRIPTIVES VARIABLES=Factors1 Factors2 Factors3 Factors4 Factors5 Factors6 Factors7 Factors8 Factors9 Factors10 Factors11 Factors12 Factors13 Factors14 Factors15 Factors16 Factors17 Factors18 Factors19 /STATISTICS=MEAN STDDEV/SORT=MEAN (D).
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.01

```
[DataSet1] C:\Users\BAB AL SAFA\OneDrive\Desktop\Analysis\Analysis Consultant.sav
```

Descriptive Statistics

	N	Mean	Std. Deviation
Limited time given for design stage	43	4.67	.474
Lack of data accuracy and availability	43	4.65	.482
Lack of skilled and experienced professionals involve in data input, model calibration and result interpretation.	43	4.58	.499
High cost of software and expertise	43	4.51	.506
Stakeholders awareness about BPS	43	4.49	.506
Lack of design team collaboration (Interdisciplinary coordination)	43	4.47	.505
Client requirements (expectations)	43	4.42	.499
Scale and complexity of the project	43	4.40	.495
Lack of obligatory building regulations on BPS	43	4.35	.482
Lack of conducting sensitivity analysis	43	4.28	.454
Shortage of Cost-effective alternatives	43	4.26	.581
Uncertainties associated with simulation outcomes	43	4.19	.546
Lack of Construction Industry organizations support	43	4.16	.754
Lack of incorporating feedbacks from stakeholders	43	4.14	.915
Absence of Government incentives	43	4.12	.905
Limited educational opportunities	43	4.12	.731
Software capacity limitations	43	4.00	.756
Limited access to BPS software	43	3.98	.859
Lack of clear communication with stakeholders	43	3.95	.615
Valid N (listwise)	43		

```
DESCRIPTIVES VARIABLES=Measure1 Measure2 Measure3 Measure4 Measure5
Measure6 Measure7 Measure8 Measure9 Measure10 Measure11 Measure12 Measure13
Measure14 Measure15 Measure16 Measure17 Measure18 Measure19 Measure20
Measure21
  /STATISTICS=MEAN STDDEV/SORT=MEAN (D).
```

Descriptives

Notes

Output Created		05-JUN-2024 16:52:12
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Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	All non-missing data are used.
Syntax		DESCRIPTIVES VARIABLES=Measure1 Measure2 Measure3 Measure4 Measure5 Measure6 Measure7 Measure8 Measure9 Measure10 Measure11 Measure12 Measure13 Measure14 Measure15 Measure16 Measure17 Measure18 Measure19 Measure20 Measure21 /STATISTICS=MEAN STDDEV/SORT=MEAN (D).
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.01

```
[DataSet1] C:\Users\BAB AL SAFA\OneDrive\Desktop\Analysis\Analysis
Consultant.sav
```

Descriptive Statistics

	N	Mean	Std. Deviation
Collect quality data at early design stage	43	4.81	.394
Providing training opportunities for stakeholders about benefits of BPS through different methods, such as case studies and demonstrations.	43	4.70	.465
Introducing and practicing obligatory building regulations to incorporate BPS into the design process proactively.	43	4.63	.489
Accessing educational opportunities and skilled professionals.	43	4.60	.495
Allocating sufficient budget during design phase	43	4.58	.499
Make clear communication and understand stakeholders.	43	4.53	.505
Break down complex projects into manageable components for simulation analysis.	43	4.53	.505
Allocating sufficient time at design stage	43	4.53	.505
Government incentives for BPS implementation	43	4.53	.505
Explore open-source or low cost simulation software alternatives.	43	4.51	.506
Prioritize simulation efforts on critical aspects of the design to optimize cost effectiveness.	43	4.51	.506
Providing adequate organizational support in upgrading software infrastructures.	43	4.51	.631
Construction industry organizations support in upgrading hardware and software infrastructures	43	4.49	.506
Create collaboration between design team members	43	4.47	.631
Allocate the right personnel based on scale and complexity of the project.	43	4.44	.629
Evaluate multiple simulation software options to identify the most suitable tool.	43	4.44	.502
Incorporating feedbacks from stakeholders improve simulation accuracy.	43	4.40	.623
Implement performance benchmark simulation results against industry standards	43	4.35	.482
Conducting sensitivity analysis to identify uncertainties and incorporate the result improves simulation accuracy.	43	4.33	.715
Implement knowledge sharing/transfer/ initiatives.	43	4.33	.606
Utilizing collaborative tools for design team	43	4.33	.715
Valid N (listwise)	43		

```
GET
  FILE='C:\Users\BAB AL SAFA\OneDrive\Desktop\Analysis\Consultant\Analysis
Consultant.sav'.

DATASET NAME DataSet1 WINDOW=FRONT.
COMPUTE TA=Awareness1 + Awareness2 + Awareness3 + Awareness4 + Awareness5 +
Awareness6 + Awareness7 + Awareness8 + Awareness9 + Awareness10 +
Awareness11 + Awareness12 + Awareness13 + Awareness14 + Awareness15 +
Awareness16.
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EXECUTE.
DESCRIPTIVES VARIABLES=TA/STATISTICS=MEAN STDDEV.
```

Descriptives

Notes

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	Cases Used	All non-missing data are used.
Syntax		DESCRIPTIVES VARIABLES=TA/STATISTICS=MEAN STDDEV.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

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[DataSet1] C:\Users\BAB AL
SAFA\OneDrive\Desktop\Analysis\Consultant\Analysis Consultant.sav
```

Descriptive Statistics

	N	Mean	Std. Deviation
TA	43	47.9070	5.22272
Valid N (listwise)	43		

Notes

Output Created		07-JUN-2024 15:23:39
Comments		
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	Cases Used	All non-missing data are used.
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Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

```
COMPUTE TP=Practice1 + Practice2 + Practice3 + Practice4 + Practice5 +
Practice6 + Practice7 + Practice8 + Practice9 + Practice10 + Practice11 +
Practice12 + Practice13 + Practice14 + Practice15 + Practice16.
EXECUTE.
DESCRIPTIVES VARIABLES=TP/STATISTICS=MEAN STDDEV.
```

Descriptives

Notes

Output Created		07-JUN-2024 15:27:12
Comments		
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Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
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Syntax		DESCRIPTIVES VARIABLES=TP/STATISTICS=MEAN STDDEV.
Resources	Processor Time	00:00:00.02
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[DataSet1] C:\Users\BAB AL
SAFA\OneDrive\Desktop\Analysis\Consultant\Analysis Consultant.sav
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Descriptive Statistics

	N	Mean	Std. Deviation
TP	43	45.2326	7.02661
Valid N (listwise)	43		

```
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+ Factors7 + Factors8 + Factors9 + Factors10 + Factors11 + Factors12 +
Factors13 + Factors14 + Factors15 + Factors16 + Factors17 + Factors18 +
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EXECUTE.
DESCRIPTIVES VARIABLES=TF/STATISTICS=MEAN STDDEV.
```

Descriptives

Notes

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Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	All non-missing data are used.
Syntax		DESCRIPTIVES VARIABLES=TF/STATISTICS=MEAN STDDEV.
Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.01

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[DataSet1] C:\Users\BAB AL
SAFA\OneDrive\Desktop\Analysis\Consultant\Analysis Consultant.sav
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Descriptive Statistics

	N	Mean	Std. Deviation
TF	43	81.7209	4.79248
Valid N (listwise)	43		

```
COMPUTE TM=Measure1 + Measure2 + Measure3 + Measure4 + Measure5 + Measure6
+ Measure7 + Measure8 + Measure9 + Measure10 + Measure11 + Measure12 +
```

```
Measure13 + Measure14 + Measure15 + Measure16 + Measure17 + Measure18 +
Measure19 + Measure20 + Measure21.
EXECUTE.
DESCRIPTIVES VARIABLES=TM/STATISTICS=MEAN STDDEV.
```

Descriptives

Notes

Output Created		07-JUN-2024 15:35:41
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	N of Rows in Working Data File	43
Missing Value Handling	Definition of Missing	User defined missing values are treated as missing.
	Cases Used	All non-missing data are used.
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Resources	Processor Time	00:00:00.00
	Elapsed Time	00:00:00.00

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[DataSet1] C:\Users\BAB AL
SAFA\OneDrive\Desktop\Analysis\Consultant\Analysis Consultant.sav
```

Descriptive Statistics

	N	Mean	Std. Deviation
TM	43	94.5581	6.33322
Valid N (listwise)	43		