ADDIS ABABA UNIVERSITY

College of Technology and Built Environment

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EXPLORING SUITABILITY OF 3D SCANNING TOOLS TO ENHANCE FACILITY MANAGEMENT PRACTICES IN ETHIOPIA:

THE CASE OF AS-BUILT MODELLING USING iOS 3D SCANNING TOOLS

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This certification attests that the thesis entitled "Exploring suitability of 3D scanning tools to enhance facility management practice in Ethiopia: The case of As-built modelling using iOS 3D scanning tools is prepared by Selamab Simeon and has been submitted in partial fulfilment of the requirements for a Master of Science degree in Construction Management, and that it adheres to the regulations of the university and conforms to the accepted standards of originality and quality.

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I verify this thesis with a title "Exploring suitability of 3D scanning tools to enhance facility management practices in Ethiopia: the case of as-built modelling using iOS 3D scanning tools" is my work. This work is not introduced anywhere.

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ABSTRACT

Facility management specifically focuses on the management of individual infrastructure or properties which involves ensuring its functionality, safety, efficiency, and overall performance by overseeing the operation, maintenance, and enhancement. In maintenance period, conventional Manual method of measurement, which works without the use of automated or computerized systems, of existing buildings is a common method used currently, these manual method approaches are subjected to human errors, since it is done through human manual collaboration which can lead to measurement inaccuracies. These inaccuracies could cause distinctness with existing condition when performing facility maintenance, repairs, or upgrades. Moreover, this method takes a lot of time and effort. When working in large and complicated facilities in particular, it can be a laborious and tiresome process to manually measure, sketch, and annotate the drawings. In this study the way of using technology aid instruments like 3D scanning usage is investigated. Moreover, it studied the perceived difference of the measurement methodologies between these conventional and 3D scanning tools. the data collection and data analysis are done by taking scanned data from existing buildings taken from Addis Ababa residential buildings. The focus group discussion is also taken to reach the challenges of implementing the 3D scanning devices in Ethiopia. It is seen using 3D scanning tools would decrease a time and an effort with more accurate results and give more detailed information with in the same consumed time than traditional measurement system. Then, after comparing two methods, this study figured out what has been the challenges for the vast applicability of this 3D scanning tools in construction sector. It gives some emphasis on which the barriers making applicability of 3D scanning tools on construction firms of Ethiopia. Some are awareness of construction sector which is a limited exposure to these technologies in academic institutions reduced awareness among professionals. And also, the budget issues that is the high cost of advanced 3D scanning tools that are workable for institutions has been a barrier for applicability of 3D scanning tools. Which means a developing country like Ethiopia could have a struggle since budget shortages. After analysing these challenges, this study develops the suitable approach for applicability of this 3D scanning tools in Ethiopia. And finally, the study sets some conclusions and future directions to improve the applicability of these tools in vast.

Key words: - Facility management, Maintenance, Existing building, As built modelling, 3D scanning, iOS device

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

ABBREVIATIONS

CHAPTER ONE

1. INTRODUCTION

Facility management is a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process, and technology. Facility management embraces the concepts of efficiency, cost-effectiveness, productivity, improvement, and employee quality of life (Richard & Roper, 2014). Nowadays the significance of facility management is far more widely recognized. Facility management recently encompasses physical and non-physical services. It generally covers the hard and soft facility services. Some of them are the maintenance of the structure, fabric, building engineering services, installations, fittings, and furnishings that form the facility. Maintenance in facility management works to prevent and deal with failure or breakdown of parts, components, systems and other elements. This maintenance process should take crucial concern, and needs plans for handling any operational impact by being prepared and updated (Atkin & Brooks, 2016).

Facility managers are the professionals most responsible for integrating people with their physical environment. As such, facility management is both a people and an environmental issue. Their role, which includes operations and compliance, involves managing people, productivity, and the associated costs. They are responsible for coordinating policies and procedures with current standards and best practises as well as legal requirements (Joseph, 2003). Facility managers should have access to complete data on the facility, including system operation and maintenance, during commissioning and before handover. Information should be supplied in digital form, wherever possible, with paper copies (Atkin & Brooks, 2016).

Facility management in existing buildings involves understanding the particular difficulties and factors involved in managing existing built and-operated. In this regard, facility managers are in charge of maintaining, maximising, and improving the performance existing buildings to satisfy the occupant needs, assure legal compliance, and maximise the efficiency of operations. And also, Facility management in existing buildings requires a proactive, strategic approach to address the unique challenges and complexities associated with maintaining and optimizing the performance of an operational facility. Facility managers play a crucial role in

the long-term success and sustainability of a building by effectively managing maintenance, energy usage, compliance, and occupant needs.

1.1 BACKGROUND

Facility managers oversee the day-to-day operations and maintenance of the building. This includes tasks such as cleaning, security, waste management, landscaping, and general upkeep. Proper management and maintenance during this phase help ensure the building continues to serve its intended purpose effectively and efficiently, which in turn helps for balanced maintenance cost after construction. Estimates show that the operational and maintenance cost is two to three times higher than the construction costs (Createmaster, 2014). As a result, there is now a considerable economic and environmental need to manage both new and existing facilities in an efficient way.

To manage programmes of repair, documentation, and maintenance more effectively, it requires 3D models of buildings. To create a semantically enhanced digital model in this situation, constructing a performing strategy based on a preliminary building survey is a vital step. Acquisition, segmentation, and modelling are the three essential processes required to develop such as built model.

1.2 PROBLEM STATEMENT

According to Creatmaster (2014) which is a company specialist in construction information hand over management, and operation and maintenance in UK, addressed that “the construction costs of building take approximately 24% of the total building costs during its lifetime and the design costs are around 3% while the rest of the costs are taken by y 73%. During the operations and maintenance phase, facility management (FM) teams, whom works for attaining useful data of a building for managing efficiently, often spend a considerable amount of time and effort” (Brodt & East, 2007).

Although conventional Manual method of measurement, which works without the use of automated or computerized systems, of existing buildings is a common method used currently, these manual method approaches are subjected to human error, since it is done through human manual collaboration which can lead to measurement inaccuracies. These inaccuracies could cause distinctness with existing condition when performing facility maintenance, repairs, or upgrades. Moreover, this method takes a lot of time and effort. When

working in large and complicated facilities in particular, it can be a laborious and tiresome process to manually measure, sketch, and annotate the drawings.

Manual drawings documents have a difficulty for several team members to share or change at once which in turn makes difficult in revising documents through times. This makes a less collaboration between facility management participants. And also archival of documents in manual drawings is the big difficulty especially when there is much documents which might cause time delays while performing maintenance. Along with this, the owners should have all the details and specifications of the equipment such as doors, windows, curtain walls, lights, and other fixtures that would be placed during the project. It is sometimes challenging to obtain the actual information for the installed equipment that reflects the as-built conditions, which aids the owners in understanding the specific condition of the existing building. This information is derived from various subcontractors and is subject to significant change during construction.

Currently in Ethiopia it can be seen a problem of a limitation of required pre-information of existing buildings, which can be an input for facility management. To mitigate these problems, facility management professionals now rely on digital tools and technologies. This study rely on practical applicability of supportive scanning tools for facility management by integrating existing buildings and facility management of buildings using iOS 3D scanning tools.

This study can contribute for current facility management process by exploring new methodologies, techniques, and technologies. This can help to improve the overall efficiency and effectiveness of building facility management processes in Ethiopia.

1.3 RESEARCH QUESTIONS

The study is expected to answer the following issues:

- ✓ What are the role/contribution of as-built 3D scan models in improving building facility management and maintenance planning in facility management?
- ✓ What are the challenges and limitations of implementing as-built 3D scan models for building facility management in Ethiopia?
- ✓ What is the suitable approach for utilizing as-built 3D scans to create models for enhancing building facility management in Ethiopia?

1.4 RESEARCH OBJECTIVE

1.4.1 GENERAL OBJECTIVE

The general objective of this study is exploring the potentials and suitability of 3D scanning technologies in enhancing building facility management practice in Ethiopia.

1.4.2 SPECIFIC OBJECTIVES

This study questioned the possible issues needs to be addressed based on the existing current problems stated in facility management process. Here is listed below the specific objectives of this study:

- ✓ To identify the effects of as-built 3D scan models compare to conventional methods for improved building facility management.
- ✓ To identify the challenges and limitations of implementing as-built 3D scan models for building facility management in Ethiopia.
- ✓ To develop a suitable approach for utilizing as-built 3D scan to create models for building facility management in Ethiopia.

1.5 SIGNIFICANCE OF THE STUDY

The facility management system in Ethiopia often lack proper documentation and facility management systems for existing buildings. The current widely used method of manual measurement in Ethiopia needs high effort and time. 3D scanning tools are valuable for retrofitting and renovating existing structures by capturing accurate measurements and data, these tools aid in the planning and implementation of modifications, additions, or upgrades. Based on this study, it elaborates how the existing buildings have a better operational management, and this gives better management for owners on their assets and to implement proactive maintenance for improved facility management than conventional method. The study demonstrated the effects of using 3D scanning technologies in creating precise and thorough digital models of buildings in efficiently and effectively. More over this study demonstrate how as built models, using recent 3D scanning tools, can be developed for the challenging existing building scenarios and effectively used to improve building management and performance.

1.6 SCOPE OF THE STUDY

This scope of this study is focused on how scanning tool technology is used in facility management by developing as-built models so as to optimize the efficiency of facility management practice in Ethiopia existing buildings. It focusses on comparing 3D scanning tools specified to iOS devices with the manual method of data collection for building facility management. This involves conducting comparison to assess the differences in data accuracy, completeness, and the time required to capture and process data using each method.

CHAPTER TWO

2. LITREATURE REVIEW

2.1 OVER VIEW OF FACILITY MANAGEMENT

The private sector is relatively new to the business and management discipline of facility management, or FM for short, although it has long been practiced in the public sector as plant administration, public works, or post engineering (Cotts, et al., 2010).

Facility Management is explained as the efficient integration of support activities within the business environment which is essential to the successful performance of any organization (Facilities Management association in UK, 2021).

According to International Facility Management Association in explaining facility management, defines as a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology. In other word, IFMA states that a facility management organization's business perspective requires a variety of interdisciplinary functions by stating lower operating costs, more energy efficiency, support for sustainability, and higher-quality buildings as the ultimate goals of facility management.

FM works to integrate the interface between what people do and where they do it (David & Edward, 2008). Thus, FM touches on elements of human resources, process engineering, ergonomics, architecture, and interior design. Besides, planning, maintenance, and provision of the assets for both big and small that assist employees in their efforts at work are essential elements of FM (Teicholz, 2004).

2.2 DEVELOPMENT OF FACILITY MANAGEMENT

The development of Facility Management (FM) as a profession has changed over time as the demands and difficulties of managing complex constructed environments changed over time, the field of facility management (FM) developed to fulfil those needs (David & Edward, 2008).

The early stages of FM as a distinct discipline emerged in the late 20th century. Initially, facility management activities were often integrated within other roles, such as building engineering or operations. The focus was primarily on building maintenance and operational activities (Teicholz, 2004). Then, in the 1980s and 1990s, FM became to be acknowledged as an area of specialisation. To advance FM and offer resources for interaction and education, professional associations like the International Facility Management Association (IFMA) and the British Institute of Facilities Management (BIFM, now known as the Institute of Workplace and Facilities Management, or IWFM) were formed (David & Edward, 2008).

The dynamic nature of FM through time has aware the importance of strategic points in supporting their core business objectives, so FM has changed the focus from a tactical function to a more strategic one. The emphasis switched to improving workplace efficiency and employee well-being, optimising space utilisation, and coordinating facility management goals with organisational goals (Peter & David, 2003).

The development and integration of technology have significantly influenced the practice of FM. Computerized Maintenance Management Systems (CMMS), Integrated Workplace Management Systems (IWMS), Building Information Modelling (BIM), Internet of Things (IoT), and data analytics have transformed how facilities are managed, monitored, and maintained.

FM has increasingly embraced collaboration and partnerships with external service providers. Outsourcing certain FM functions, such as cleaning, security, or maintenance, has become common practice. FM professionals now play a critical role in managing these partnerships, ensuring service quality, and focusing on core competencies. The field of FM continues to evolve rapidly, necessitating on-going learning and professional development. FM professionals are encouraged to stay updated with industry advancements, new technologies, and emerging trends through conferences, workshops, certifications, and networking

opportunities (Booty, 2009). Overall, the development of Facility Management has seen a shift from a primarily operational focus to a strategic, technology-driven, and user-centric discipline. FM professionals now play a vital role in optimizing facility performance, supporting organizational objectives, and creating sustainable and engaging work environments.

2.3 BUILDING FACILITY MANAGEMENT

Building facility management (BFM) specifically focuses on the management of individual buildings or properties which involves ensuring its functionality, safety, efficiency, and overall performance by overseeing the operation, maintenance, and enhancement of a building. And also it aims to guarantee the provision of properly operating building systems and components that are properly maintained as well as environments and situations that promote high-quality instruction and communication (Atkin, Brian; Brooks, Adrian, 2009).

Building facility management maintains a building attractive, clean, hygienic, and safe by identifying and correcting facility needs and deficiencies through routine reviews of current systems and system components. It also makes sure availability of adequate funds and other resources available to fulfil shown facility maintenance requirements (Atkin, Brian; Brooks, Adrian, 2009)

Enduring interests in facility management include building services engineering installations in particular and maintenance of facilities at all (Booty, 2009). In fact, building maintenance management gave rise to facility management in several countries, and senior managers continue to set a high priority on it. Determining the compatible option or combination of options for the provision of maintenance-related services adheres to the organization's key procedures and corporate objectives is one of the tasks of maintenance management. Regarding this, it is crucial to understand the extent of maintenance requirements and the capability and capacity required to deliver appropriate services to end-users (Atkin & Brooks, 2016).

2.3.1 CLASSIFICATION OF BUILDING FACILITY MANAGEMENT

Building facility management can be classified as hard and soft building facility management. It is based to define the scope of responsibility within facility management and

the distinction between the physical and non-physical elements of facility management (Barrie & Peter, 2007).

A) HARD BUILDING FACILITY MANAGEMENT

Hard building facility management refers to the tangible and physical aspects of managing a building or facility (Baldry, 2003). It encompasses a wide range of responsibilities to ensure the proper functioning, safety, and efficiency of the building (Barrie & Peter, 2007). Some examples of hard facility management activities include Maintenance and repair of building systems (HVAC, electrical, plumbing, etc.), inspections and testing of fire protection systems, repairs and upkeep of structural elements (walls, roofs, floors, etc.), maintenance of elevators, escalators, and other mechanical systems, landscaping and outdoor maintenance, energy management and optimization of building systems, and security systems installation and maintenance. By effectively managing these hard facility management aspects, building owners and facility managers can ensure the longevity, safety, and optimal performance of the building's physical infrastructure and systems.

B) SOFT BUILDING FACILITY MANAGEMENT

Soft building facility management encompasses the intangible aspects of managing a building or facility (Atkin, Brian; Brooks, Adrian, 2009). Soft facility management focuses on creating a comfortable, productive, and satisfying environment for occupants by managing services, processes, and interactions functions that contribute to the overall functioning and well-being of the occupants within the facility. (Atkin, Brian; Brooks, Adrian, 2009)Some examples of hard facility management activities includes Cleaning and janitorial services, reception and front desk services, security personnel and access control, space planning and allocation, vendor and contract management, help desk and customer service support, health and safety policies and procedures, tenant or occupant satisfaction surveys, sustainability and environmental initiatives, and event management and coordination.

Generally, Effective facility management requires a balance between managing the physical infrastructure and systems (hard) and providing support services and a conducive environment for occupants (soft). also, it’s important to note that hard and soft facility management are interconnected and complementary. Both aspects are necessary for effective facility management. Hard facility management ensures the physical infrastructure is well-

maintained and functioning optimally, while soft facility management focuses on providing the necessary services and support to enhance the overall experience and productivity within the facility.

2.3.1 MAINTENANCE STRATEGY AND POLICY

The maintenance strategy, which is used for setting maintenance policy and operational responses, depends heavily on planning. A well-defined maintenance strategy supports the organization's business objectives; whereas a poorly defined strategy, or none at all, could have significant adverse safety, legal and commercial consequences. The ability to fulfil sustainability, environmental and corporate social responsibility commitments and targets is also dependent upon a clear maintenance strategy. A maintenance strategy should be prepared that meets current and likely future needs, as well as taking account of the facility's capacity to deliver the services demanded of it. The strategy should be reviewed at least annually to ensure that it aligns with business objectives (Atkin & Brooks, 2016).

The creation of operational plans in accordance with the maintenance strategy should be supported by a policy. The policy should specify the extent and steps to be taken in order to achieve business goals and how those connect to the maintenance goals specified in the facility management plan (Brian & Wood, 2009).

The best value principle should be included in the policy to safeguard the facility's resource and asset values. In addition to considering performance and functional suitability—which includes facility use, change of use, and the impact of any alterations or conversion work on the life cycles of existing materials, components, and building services engineering installations.it should cover anticipated future requirements for the facility, including the organization's sustainable space provision. It should also consider the timing of alterations, conversions, or refurbishment work. in order to minimize any disturbance brought on by a component or part failing (Atkin & Brooks, 2016).

2.3.2 MAINTENANCE AND REPAIR FOR BUILDINGS

Determining the effects of reducing maintenance and repair can usually be challenging. it may take years to notice any effects, since physical evidence is typically not immediately apparent. Furthermore, facility managers typically lack the documentation necessary to

support their requests and are unable to articulate the precise effects of underfunding. Yet the costs to correct the effects of long-term underfunding often exceed the cost of the M&R that would have precluded those deficiencies. Besides there are principles and concepts that ensure a cohesive approach to M&R which tries to fill needs at corporate level (Richard & Roper, 2014).

MAINTENANCE: - the effort required to preserve a fixed asset's initial expected useful life. It is the maintenance of equipment and property. Although it does not increase the value of the property or equipment or prolong its life, maintenance comprises routine or sporadic inspection, adjustment, lubrication, cleaning, painting, part replacement, minor repairs, and other operations to prolong service and prevent unplanned breakdown (Richard & Roper, 2014).

REPAIR: - endeavor to return worn-out or damaged property to its typical state of operation. To put it simply, maintenance is preventive, whereas repairs are curative. There are two types of repairs: small and big. Minor repairs are related to maintenance tasks that take no more than one or two workdays to complete. Small fixes don't significantly increase the equipment's or property's value or lifespan. Major repairs are those that take more than two workdays to complete or that are beyond the scope of the current maintenance staff. Major repairs are frequently described as those that can extend the life of equipment or property without raising its value. For repair services, they typically need to be contracted.

REPLACEMENT OF BUILDING-RELATED COMPONENTS OR SYSTEMS: - replacing a piece of plant equipment or a permanent investment. It is the process of exchanging or replacing a fixed asset with another that can serve the same purpose (Brian & Wood, 2009). The need for a replacement could result from damage, wear and tear, or obsolescence. Generally speaking, replacement entails a fully identifiable item, as opposed to repair (Barrie & Peter, 2007).

2.3.3 CLASSIFICATION OF BUILDING MAINTENANCE

There are different types of building maintenance that are typically categorized based on the nature and purpose of the maintenance activities. Here are some common types of building maintenance.

PREVENTIVE MAINTENANCE: It involves planned and regular inspections, cleaning, and servicing of building systems and equipment to prevent potential failures or issues. It

seeks to detect and resolve issues at an early stage, lowering the likelihood of significant malfunctions and long-term maintenance expenses (Palmer, 2019).

CORRECTIVE MAINTENANCE: sometimes referred to as reactive or breakdown maintenance, is carried out in reaction to unanticipated problems or equipment breakdowns. In order to reduce downtime and interruptions, it seeks to promptly return the building's systems or equipment to operational condition (Levit, 2003)

PREDICTIVE MAINTENANCE: Predictive maintenance involves using advanced techniques and condition monitoring tools to assess the performance and health of building systems and equipment. By predicting possible breakdowns or deterioration, it makes it possible to plan maintenance tasks ahead of time using data-driven insights (Mobley, 2003).

ROUTINE MAINTENANCE: Routine maintenance refers regular and frequent tasks that are carried out to maintain the building's condition. It includes activities such as cleaning, lubrication, filter replacement, and minor repairs to maintain the functionality, aesthetics, and cleanliness of the building (Booty, 2009).

PLANNED MAINTENANCE: Planned maintenance refers to scheduled maintenance activities that are performed based on predetermined intervals or specific conditions. It involves routine inspections, servicing, and repairs to ensure the continued performance and reliability of building systems and equipment (Levitt, 2013).

2.3.4 BENCHMARKING OF MAINTENANCE & REPAIRS

M&R benchmarking has grown in popularity. This has been influenced by the quality management movement and is mostly focused on efficiency issues. Finding specific areas to study, assessing performance in these areas, finding other businesses to compare the department's performance to, comparing the department's performance to its benchmarking partners, and determining who has the best practices and how to implement them within the department are all steps in the benchmarking process. The professional associations have assisted in this regard. The Building Owners and Managers Association (BOMA) publishes the Experience Report annually. The International Facility Management Association (IFMA) publishes Benchmark Report tri-annually. It has created and disseminated the Strategic Assessment mechanism, a benchmarking mechanism that evaluates M&R among other things. The model comprises a suggested standard as well as fifteen benchmarks that colleges

and universities can use to compare their maintenance programs to others (Facilities Management association in UK, 2021).

The management should define goals and objectives to improve M&R after the benchmarks have been set and the implementation processes are operational. Resource allocation is a step in this process. Progress should be monitored by the benchmarking process in order to assign blame, reward achievement, and identify failures early (Richard & Roper, 2014).

2.4 PROBLEMS FACING CURRENT BUILDING FACILITY MANAGEMENT PROCESS

Although FM is a continually changing (improving) field, its involvement and its practice on construction management is less. It needs to employ important techniques continually through time. So, the involvement of expertise in this field should be encouraged and employed in different levels of management in order to have improved decision-making system through interaction (collaboration) (Baldry, 2003).

Adopting external contacts such as insurance firms, specialists on building control and other local business with exchanged ideas help in maintaining changes constant in FM process (David & Edward, 2008). One problem which has an impact for continuous FM process change is discouraging the possible cooperation between FM process and involvement of future strategic planning with in management of the organization.

The involvement of facility managers in strategic planning are influenced by the management structure of the organization. The management level of the Facility managers makes it difficult for their involvement of corporate decision-making system of the organization. Consequently, this less collaboration also brings less power in significant decisions. One reason for this practice is a belief of taking facility managers involvement as an expendable process. So as to compromise this belief, organizations rather would take a short-term managerial decision plans. For instance, issues related with maintenance plans including budget and time would be raised in times of hardship. This organizational understanding is built from unreal realization of that a continuous changing process which makes an organization not plans too far in the future. Despite a property needs to plan well before the situation become critical (Baldry, 2003).

Thus, it should be encouraged to consider critical (crucial) issues of high quality, proactive and effective cost services to keep credibility with their owner of the facility, instead of being stacked to the reactive mode of management. Strategic plans involvement should aim for effective and efficient facility management that fit objectives of the organizations for better business core aspect through times of future. This strategic planning process should involve clear objectives, external and internal factors, and their implementation methods of the organizational goals (Baldry, 2003).

2.5 BUILDING FACILITY MANAGEMENT IN ETHIOPIA

The field of facility management is developing in Ethiopia as the value of good facility management techniques in maximizing the sustainability and performance of buildings and facilities becomes more widely acknowledged. One important thing to remember is that Ethiopia has recently had tremendous infrastructure and economic expansion. This growth has resulted in the construction of various types of buildings and facilities, including commercial complexes, residential buildings, hospitals, educational institutions, and government facilities. And also, facility management guidelines, rules, and standards are provided by the Ministry of Urban Development and Construction and other pertinent governmental organizations. Association's plays a crucial role for development of FM. Professional associations and organizations dedicated to facility management are emerging in Ethiopia. These associations seek to advance professional growth, best practises in facility management, and knowledge exchange. They offer platforms for national facility management experts to network and collaborate. And also, Educational institutions in Ethiopia are beginning to offer facility management programs and courses to meet the growing demand for skilled facility management professionals. These programs give students the information and abilities they need to manage buildings and facilities efficiently. Ethiopia is increasingly focusing on sustainable and green building practices. Facility management plays a crucial role in implementing sustainable initiatives, such as energy efficiency measures.

Although there is substantial change in facility management process, Facility management in Ethiopia faces some challenges, including limited awareness and understanding of its importance, inadequate resources and funding, and a shortage of skilled professionals. However, efforts are being made to address these challenges and promote the growth of

facility management practices in the country. As the field of facility management continues to develop in Ethiopia, emphasis on professionalism, sustainability, technological advancements, and collaboration contribute for effective and efficient management of buildings and facilities in the country.

2.6 EXISTING BUILDINGS FACILITY MANAGEMENT

Facility managers depend mostly on as-built data to comprehend what was constructed at a facility and what was installed to ensure optimal job performance. In taking a measurement or dimensional survey of existing properties, it needs attention of accuracy of taking existing available information. A dimensional survey is typically required if the old building's blueprints are unavailable or erroneous. Accuracy is crucial, but the fundamentals of measuring existing buildings are simple to understand. Care must be taken while taking and verifying dimensions of an existing building to ensure accurate results because even a minor measurement inaccuracy can lead to a lot of problems (Douglas & Noy, 2011).

"As-built" refers to the final documentation of a building or structure that accurately represents its physical condition after construction or modifications have been completed. As-built measurements are typically taken to compare the actual construction or modifications against the initial design plans or to create accurate records for future reference. These measurements capture the precise dimensions, locations, and specifications of various components of the building.

2.7 METHODS OF AS BUILT MEASUREMENT

To perform as-built measurements for an existing building, there are two different methods can be used: -

A) Manual method of measurement, and

B) 3D scanning tools measurement

2.7.1 MANUAL MEASUREMENT

This manual measurement can use measuring tools such as a tape measure, laser distance meters, or total stations to record dimensions, heights, and distances of various building elements. This method is primarily widely utilised globally. For a variety of reasons, the building and management processes in developing nations continue to rely heavily on human

resources and traditional tools. It is most likely not practical or practicable to deploy 3D scanning technologies in such areas.

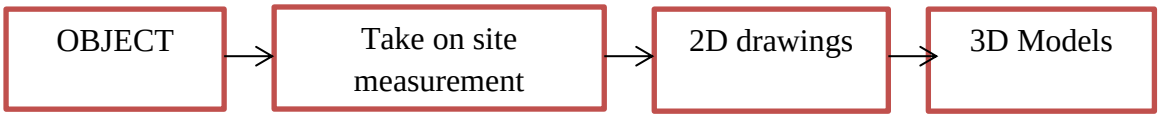
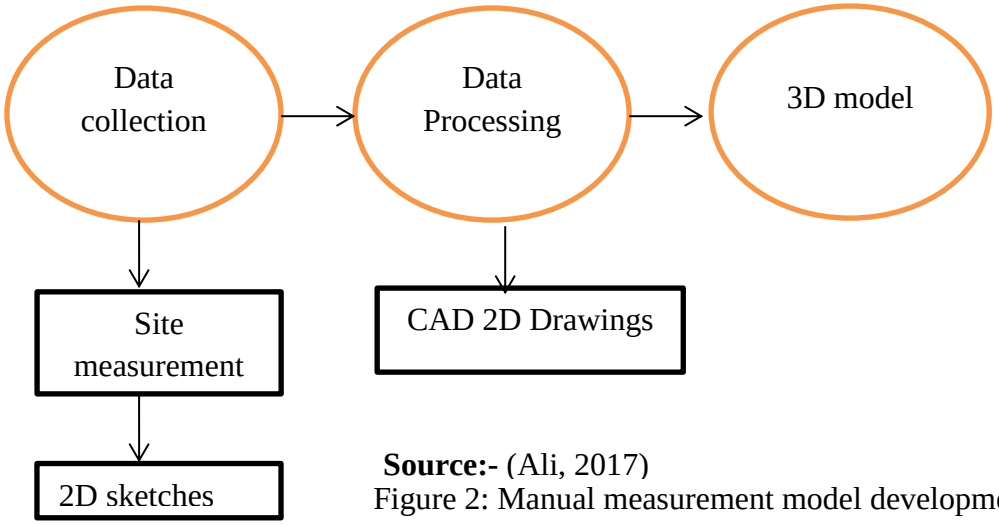


Figure 1: manual measurement work flow

Source: - (Ali, 2017)

It appears that using the manual measuring methodology to perform models is not a simple or effective method. For an existing building, the 2D designs or previously created drawings need to include all of the information. Given that one needs to measure the distance between each wall, the beams between them, the size of the columns, the windows, the doors, and every object that is placed in or a part of the building, taking all these measurements from the laser metre or metre tape would take more time and human labour. This approach involves three phases:

1. Data collection (On site measurement),
2. Data processing (Sketch, 2D drawings), and Modelling (3D model).



Source:- (Ali, 2017)

Figure 2: Manual measurement model development approach

2.7.2 3D SCANNING TOOLS

The process of gathering data about a physical object's surface by generating a point cloud that depicts the object's surface as a three-dimensional digital duplicate is known as 3D scanning (Creaform., 2014). The gathered information contributes in creating a basis for the creation of digital, three-dimensional models that may be applied to a wide range of interpretive scenarios. The primary characteristics of the 3D scanning solution are its capacity

to meet the necessary standards for accuracy and data clarity as well as efficiently record digital descriptions of the objects.

A 3D scanner is a non-contact, non-destructive digital tool that precisely captures the geometry of a physical object using a light line or laser. Quicker and simpler implementations of 3D scanning technologies and other virtual technologies have been made feasible by the rapid advancements in the communication between three-dimensional (3D) software and hardware. This has allowed for the acquisition and reconstruction of various objects. The utilization of 3D modeling and animation from cloud data capture has increased as a result of advancements in 3D scanning (Abdi, et al., 2009).

Better than traditional construction methods, the 3D models include important information about building projects that is essential for building modelling procedures. Nowadays, a wide variety of 3D scanning devices and technologies are available, each one coming with its own limitations, and advantages. While 3D scanners are becoming more and more common in many businesses, the use of 3D scanned data to create 3D models is less common in education than 3D modelling (Abdi, et al., 2009).

2.7.2.1 3D SCANNING TOOLS IN BUILDING CONSTRUCTION

The construction industry is in a state of constant change, as it evolves from weak productivity driven by poor management and outdated methods, to adopting new building technologies.

Significant technology advancements in recent years have made it possible to create intricate three-dimensional (3D) models that accurately depict the "as-built condition" of buildings (Laguela, et al., 2014). Reality capture is the process of gathering the greatest and most accurate information regarding actual conditions, sometimes referred to as the "as-built" or "as-is condition." One method of capturing reality is 3D scanning. There are numerous justifications for collecting project data in the actual world, such as: tracking development during the building project's phases and using the facility for maintenance (Shalabi & Yelda, 2016).

Since owners require as-built models with more precise data, gathering data for as-built modeling in the construction industry is one of the most crucial applications. As-built can be created using a variety of technologies and methods, including range-based technology, non-range-based (visual-based) technology, and manual survey (traditional).

The capability of LiDAR as a tool to collect a large amount of accurate 3D data has been investigated and applied using the existing technologies (Laguela, et al., 2014). Therefore, there is much work needed to improve the accuracy of the current practices considering cost and time in construction.

2.7.2.2 TYPES OF 3D SCANNING TOOLS

There are numerous methods for obtaining a 3D-scan representation of a physical thing, including contact scanning, which employs a portable probe pressed up against the object's surface to gather position data, photogrammetry, which calculates three-dimensional positions based on images, and on the other hand, laser and structured light are non-contact scanners. Structured light lasers cast a pattern onto the object's surface, and the laser uses the reflected light from the laser scanner to collect surface data (Abdil, 2009). Scanning technology is connected to other system factors, including the acquisition distance, the acquisition rate and the data resolution/accuracy.

3D scanning tools are used to capture the physical shape and dimensions of real-world objects or environments and convert them into digital 3D models. These tools employ various technologies and techniques to capture accurate and detailed data. Laser scanning tool and Photogrammetry are some commonly used 3D scanning tools.

LASER SCANNING TOOL

3D laser scanning is a non-contact, non-destructive technique for data collection that can be used for digital modification, archiving, and the quick and precise generation of three-dimensional images. Despite being created in the 1960s, laser scanning wasn't applied to structural surveying until the late 1990s (Joncic & Zachar, 2017). In within a few minutes, a 3D laser scanner can collect millions of closely spaced measurements of a target object by emitting a narrow laser beam. After compiling and organising these scanned measurements into compressed point cloud databases, the item can be processed to create a 3D dense representation (wang, et al., 2019).

Surveying, manufacturing inspection, and building construction quality control are just a few of the many applications for laser scanning, one of the most popular 3D imaging methods. A centralized technique for gathering, recording, and analysing three-dimensional data on the

as-constructed condition of infrastructure and buildings, laser scanning devices are currently included into many built environment applications (Diaz-vilarino, et al., 2018).

The surface geometry of target objects can be accurately and efficiently captured by 3D point cloud data from 3D laser scanners, which can also quickly and accurately record the 3D geometries of objects connected to construction (Wang & Kim, 2014).

Laser scanners mainly use one of three different principles for measurements: triangulation, time-of-flight (ToF), or phase-comparison. Even though all of these methods produce a 3D point cloud, the range and accuracy of registered values vary between these methods (Clive, et al., 2018). Typically, laser scanners operated by ToF or phase are used in the recording of building exteriors and interiors. There are three main laser scanning types: -

A) TERRESTRIAL LASER SCANNING (TLS)

One of the most popular techniques for obtaining as-built information on existing buildings is TLS. Terrestrial laser scanners (TLS) are often installed on a tripod and are positioned either directly on the ground or on a platform that is placed on the ground (wang, et al., 2019). A terrestrial laser scanner automatically records millions of 3D points to capture the geometry and textual information of an existing building (Murphy & Conor, 2017). These days, a wide range of TLS with varying range and pulse frequencies are available. The majority of TLS are long-range devices utilized for 3D documentation of expansive landscape areas or intricate structures.

B) AIRBORNE LASER SCANNING (LIDAR)

Airborne laser scanning is a scanning method for gathering information about the earth's surface characteristics and items. Because it can map topographic height and the height of objects on the surface with high vertical and horizontal accuracy, as well as over wide areas, it is a valuable source of data for environmental studies. An active remote sensing technique that can quickly gather data from a large region is airborne laser scanning (George, 2010).

C) HANDHELD (PORTABLE) LASER SCANNING

Handheld Laser Scanning is a cutting-edge surveying technique that uses laser systems (Lidar) in a portable, manageable gadget. It is a method that uses a portable device with a laser scanner to record three-dimensional (3D) information about things or settings. In order to calculate distances and create a 3D point cloud representation, laser beams are emitted and

directed towards the target surface. The scanner then records the time it takes for the laser beams to return (Toru, et al., 2015).

Handheld scanners have been used more frequently in recent years. Their portability is their primary benefit. Despite the fact that the majority of handheld scanners rely on structured light technology, the use of laser portable scanners is clearly growing. With the use of calibration targets attached to the object being scanned, the majority of handheld laser scanners use the triangulation method.

2.7.2.3 ADVANTAGES AND DISADVANTAGES OF LS IN BUILDING CONSTRUCTION

In addition to using laser scanners for existing buildings, such as for as-built creation, studies currently plan to employ them for construction. According to (Arayci, 2004) listed advantages and disadvantages of this Laser scanning technology which are shown in the table below

Table 2.1: advantages and disadvantages of LS

ADVANTAGE	**DISADVANTAGE**
Applicable to all 2D and 3D surface	Some systems do not work in sun or rain
Rapid 3D data collection	Large 3D data sets require post-processing to produce a useable output
Very effective due to large volumes of data collected at a predictable precision (Clive, et al., 2018).	Difficulty in extracting the edges examples from indistinct data clouds (Stefano & Roberto, 2018).
Ideal for all 3D modelling and visualisation purposes (Stefano & Roberto, 2018).	Output requires manipulation to achieve acceptable recording quality (Stefano & Roberto, 2018).
3D position and surface reflectance generated can be viewed as an image	No common data exchange format currently in use
Rapidly developing survey technology	Difficult to stay up-to-date with developments

Extensive world-wide research and development currently undertaken	Hardware expensive and sophisticated software required to process data

Source:- (Arayci, 2004)

PHOTOGRAMMETRY

Photogrammetry is a technique used to capture 3D data by analysing multiple 2D images of an object or environment. It involves the process of extracting geometric information from photographs and using it to create a 3D model (Karl & Sabry, 2016). Photogrammetry software packages that were used for the reconstruction of the 3D object are: -

AGISOFT METASHAPE: -Agisoft Metashape is a standalone software program that processes digital photos photogrammetrically and produces 3D spatial data for usage in GIS applications, recording of cultural heritage, visual effects creation, and indirect measurements of things at different scales.

REALITY CAPTURE: - Reality Capture is a photogrammetry software that enables the creation of high-quality 3D models from a set of photographs. It offers advanced algorithms for image alignment, dense reconstruction, mesh generation, texture mapping, and other photogrammetric processes.

PIX4D:- Pix4D is a comprehensive photogrammetry software solution that specializes in aerial and drone-based image processing. It allows users to process large datasets captured from drones or other aerial platforms and generate accurate 3D models, and point clouds.

PHOTO MODELLER: - Photo Modeller is a versatile photogrammetry software that offers a range of features for 3D modelling and measurements. It can be used for various applications, including architecture, engineering, archaeology, and more. It provides tools for camera calibration, image matching, dense point cloud generation, and mesh creation.

MESH ROOM: - Mesh room is an open-source photogrammetry software developed by Alice Vision. It uses a node-based approach for processing images and generating 3D models. Mesh room utilizes advanced computer vision algorithms and offers a user-friendly interface for generating accurate 3D reconstructions.

2.8 IOS MOBILE 3D SCANNING DEVICE

An iOS mobile 3D scanning device is a hardware accessory or an integrated feature in certain iPhone models that enables users to capture three-dimensional (3D) data using their iOS devices (Gerald & Ramash, 2017).These devices utilize advanced depth-sensing technologies, such as LiDAR (Light Detection and Ranging), structured light, or time-of-flight, to accurately measure distances and capture depth information. It enables users to create precise 3D models that represent the real-world environment with high accuracy. By scanning the space or object from multiple angles, the device captures depth information, geometry, and texture, allowing for the creation of a detailed digital representation (David, 2016). Together with advancements in sensor technology, smartphones' widespread use now creates new opportunities for scientific applications and low-cost, crowdsourced observations for mapping surface changes (Jaud, et al., 2019) .

2.8.1 FEATURES OF IPHONE PRO MAX DEVICES

The iPhone Pro between versions 11 - 15 is equipped with a 12 MP camera system that contains three different cameras (1x telephoto, 1x wide, and 1x ultra wide camera), a flashlight and a LiDAR sensor on the backside of the phone.

The 3D models created using an iOS mobile 3D scanning device for as-built purposes can be used for a variety of applications. Some common uses include:

Architecture and Construction: - Architects, engineers, and construction professionals can capture as-built conditions of existing structures and use the 3D models for design, renovation, or retrofitting purposes. The models help in visualizing and analysing the space accurately (Alexander, 2015).

Facility Management: - Facility managers can use the 3D models to document and manage the spatial layout of buildings, including measurements, room details, and asset locations. It aids in space planning, maintenance, and facility operations.

Historical Preservation: - 3D scanning of historical sites or artefacts using an iOS mobile device helps in accurately documenting and preserving cultural heritage. Virtual tours, restoration projects, and research can all benefit from the intricate models. (Stefano & Roberto, 2018).

Real Estate and Property Documentation: - Real estate professionals can capture 3D models of properties to create immersive virtual tours or showcase the space to potential buyers or tenants.

2.8.2 IOS 3D SCANNER PROCESS

An Apple iPhone with a built-in LiDAR scanner and the free "3D Scanner App" from the Apple App Store are needed for this procedure. To expand the scanning area, a selfie stick is an optional accessory. For transferring data between an iPhone and a non-Apple device (like a Windows computer), credentials to access a cloud service (e.g. Dropbox, Google Drive, OneDrive, iCloud) are required (Gregor, 2010) .

In such approach, the job would be carried out in four major steps: Initialization (Purpose, site analysis, pre-scanning arrangements), scanning, registering point cloud Data, and Modelling. So generally, the processes involved in this process are Data acquisition, Data processing, and Modelling

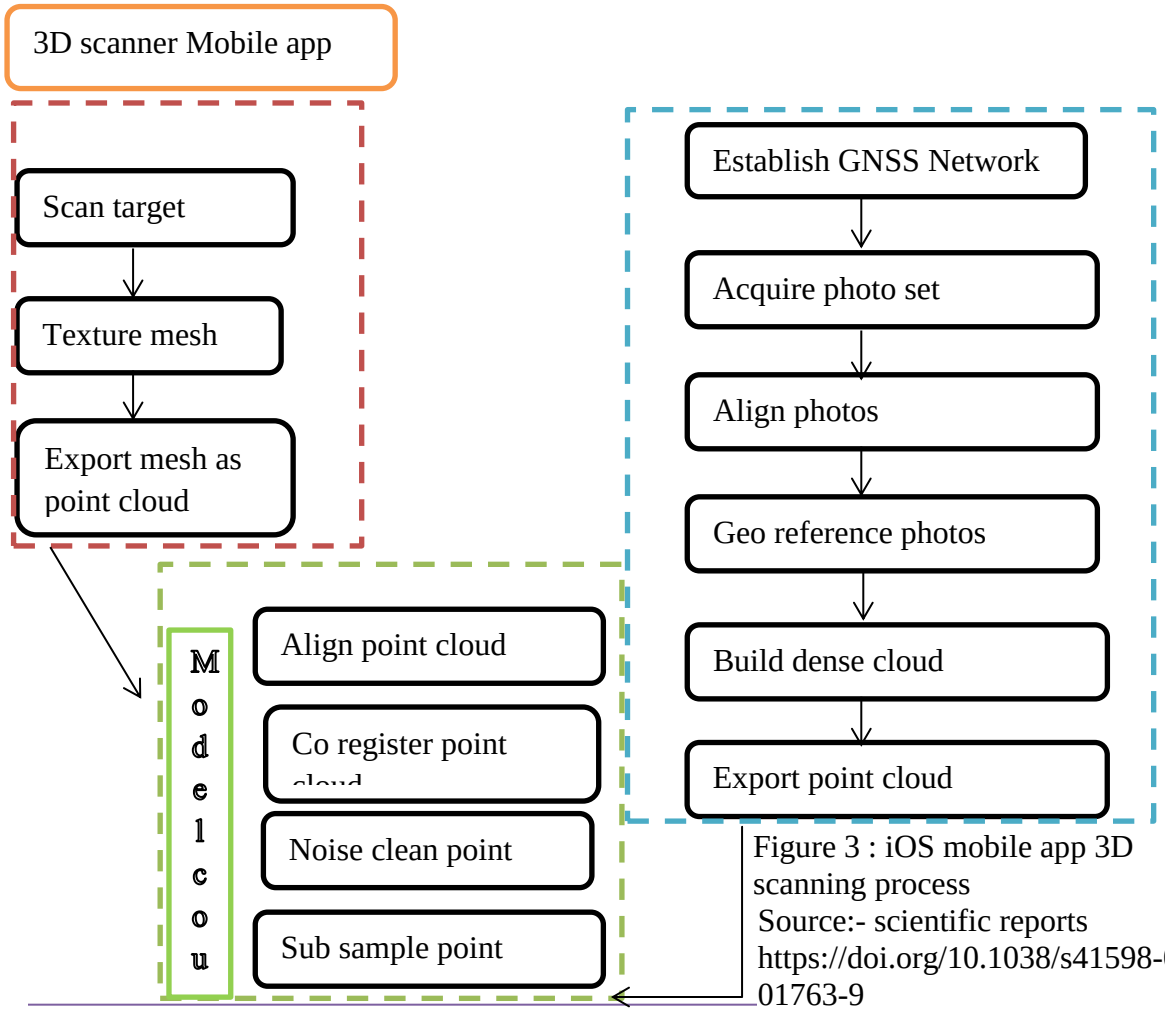


Figure 3 : iOS mobile app 3D scanning process
Source:- scientific reports https://doi.org/10.1038/s41598-021-01763-9

2.9 COMPARISON BETWEEN MANUAL MEASUREMENT AND CURRENT 3D SCANNING TECHNOLOGY

Table 2.2 : Comparison between manual measurement and current 3D scanning technology

Parameter	Manual measurement	3D Scanning technologies	Source
Process	Measurements, involves physically measuring, are taken manually by individuals on-site using tools like tape measures, rulers, and laser distance meters.	Utilize advanced sensors and cameras on iOS devices to capture detailed 3D point cloud data of the built environment.	(Häusler & Zhang, 2016)
Accuracy	The accuracy of manual measurements depends on the skills and precision of the person performing the measurements. Human errors and limitations can affect the accuracy and consistency of the recorded data.	It can provide highly accurate measurements and spatial data.	(Gregor, 2010)
Time	Manual measurement can be time-consuming, especially for complex or large-scale buildings. It requires significant effort to measure and document all relevant details accurately.	It significantly reduces the time required for data collection. With a few scans, a comprehensive 3D representation of the space can be captured, including dimensions, shapes, and surface details.	(Häusler & Zhang, 2016)
Detail level	Manual measurement may capture basic dimensions and features but can lack comprehensive information	It captures detailed data about the building, including walls, floors, ceilings, furniture, and	(Häusler & Zhang, 2016)

	about intricate building elements, systems, and spatial relationships.	other objects, resulting in a comprehensive representation of the space	
Integration	Data collected through manual measurement needs to be manually entered into digital systems, which can introduce further errors and require additional time and effort.	Scanning as-built technologies provide digital output in the form of 3D point cloud data or mesh models that can be easily integrated into various software applications and workflows for analysis, visualization, and collaboration.	(Zhang, 2018)

2.10 RESEARCH GAP IDENTIFICATION

This literature review covered the overall existed process related to building facility management in existing buildings. And it oversees the advancement of current building facility management practices in related with integration of facility management with existing 3D scanning tools.

The field of building facility management is continuously evolving. Research conducted on building facility management plays a crucial role in advancing the field, new technologies, industry standards, and best practices emerge regularly, shaping the way facilities are managed and operated. The current system of Ethiopians measurement method is widely the traditional method of measurement.

While research in the field of 3D scan in existing facilities has made significant progress, there may still be further opportunities for exploration and advancements. The ongoing development of techniques, and software tools continues to enhance the accuracy, efficiency, and usability of the as-built scans.

Existing literature on 3D scanning tools in building facility management predominantly focuses on developed countries, where advanced infrastructure and resources of scanning

tools are readily available. Despite the growing adoption of 3D scanning technology in facility management practices, there is a lack of comprehensive research and understanding regarding to examining the applicability, effectiveness the specific challenges and opportunities associated with implementing 3D scanning tools for facility management process in Ethiopia.

Thus, this thesis attempted to study the contribution of these 3D scan tools in improving building facility management than the current conventional method of measurement while exploring the challenges on implementing these 3D scan tools for building facility management in Ethiopia by applying iOS 3D scanning tools so as to develop the suitable approach for applicability in Ethiopia.

Research paper Review	**Identified Gaps**
A case study on use of 3D scanning for reverse engineering and quality control (Mohid, et al., 2021).	Focused on demonstrate the methodologies and technologies used for Reverse engineering & quality control of products and investigate what possibilities, limitations, and challenges exists when applying 3D scanning technologies
Industrial perspectives of 3D scanning: Features, roles and it's analytical applications (Robin & Hirpa, 2021).	Focused on its contribution for manufacturing industry.
Application of 3D laser scanning technology in engineering field (Hu & Linghui, 2020).	Limited on laser scanning device
3D laser scanners: History and applications (Edl, 2018).	Limited on describing the whole path of 3D laser scanner history and applicability
Application of 3D Laser scanning technology using Laser Radar system to error Analysis in the curtain wall construction (Wan, 2022).	Limited on laser radar system and curtain wall construction
Scan-to-BIM for facility management: A	Focuses on the integration of scanning

case study of an existing office building in Vietnam (Nam, et al., 2024).	devices with BIM
A Case study of 3D scanning techniques in civil engineering using the terrestrial Laser scanning technique (Artur, et al., 2023).	Focuses on comparing the image acquisition capabilities of different devices, which has practical significance for the acquisition of measurement techniques.

Table 3:-Research Gap identification

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1 GENERAL ON RESEARCH METHODOLOGY

Research methodology is a way to systematically solve the research problem to acquire new knowledge or insights in a particular field of study. It may be understood as a science of studying how research is done scientifically. Inside it studies the various steps that are generally adopted by a researcher in studying his research problem along with the logic behind them since the methodology may differ from problem to problem (Kothari, 2004). It involves the overall framework and techniques used to design, implement, and analyse research studies.

A research design is a plan, structure and strategy of investigation so conceived as to obtain answers to research questions or problems (Kumar, 2011). In other words, The logical process that connects the factual facts of a study to the research question and, eventually, to the conclusion is known as research design. Following the formulation of a research question, scientists need to select a research strategy, gather and examine the data, and make some conclusions (Marczyk, et al., 2005).

A research design is a set of procedures that a researcher uses to answer questions in a legitimate, objective, accurate, and cost-effective manner. It includes deciding which study design to employ and how to get data from your sources. How you plan to choose your sources, analyse the data you gather, and present your findings (Kumar, 2011).

3.2 RESEARCH APPLICATION

This study needs to select the most appropriate type based on the research questions, objectives, available resources, and the nature of the research problem investigating. As this study aims to identify the effects 3D scanning tools for existing buildings, it focuses on solving specific practical problems or addressing practical challenges. It aims to apply existing knowledge and theories to find practical solutions and improve real-world situations. Applied research often involves the development of new technologies, processes, or interventions.

3.3 RESEARCH APPROACH

This study integrates the qualitative and quantitative findings to provide a comprehensive understanding of the effects of as-built 3D scan models. Identify patterns, correlations, and relationships between challenges, limitations, and performance metrics.

The quantitative approach entails the creation of quantitative data that may be rigorously and formally submitted to quantitative analysis. This research methodology can be further divided into three subcategories: simulation, experimentation, and inference.

In an experimental approach, the research setting is considerably more controlled, and some factors are changed to see how they affect other variables. Using a simulation approach, a simulated environment is created in which pertinent data and information can be produced. This makes it possible to see, under controlled circumstances, how a system (or its sub-system) behaves dynamically. Additionally, this simulation method can be helpful in creating models to comprehend future circumstances (Kothari, 2004).

Subjective evaluation of attitudes, beliefs, and actions is the focus of qualitative research methods. In such a scenario, the researcher's perceptions and insights determine the research. Research using this method produces data that are either non-quantitative or that are not rigorously analysed quantitatively (Kothari, 2004). Generally, the techniques of focus group interviews, projective techniques and depth interviews are used.

3.4 SOURCE OF DATA

Triangulation method is used as the source of data in this study. Which means it have both primary data and secondary data so as to conduct this study.

The source of data for:-

Objective 1:- To identify the effects of as-built 3D scan models compare to traditional methods for improved building facility management..

- ✓ **Primary data: -** The as built 3D scan model of specific existing G+0 building is the primary data in identifying the effects of as-built 3D scan models for improved building facility management and performance of existing buildings. This data is collected using iPhone 12 pro max mobile phone. And the manual measurement of the same building is taken.

Objective 2:- To identify the challenges and limitations of implementing as-built 3D scan models for building facility management in Ethiopia.

- ✓ **Secondary data: -** a review of literatures which are published books, academic journals, articles and research papers published in the field of the study area often contain relevant studies, methodologies, and findings related to as-built 3D scan model. the qualitative interview taken from construction firms like consultants, contractors, and facility management institutes. A questionnaire, which involves experts interview and questionnaire in building facility management is the secondary data sources for this study. These sources can provide theoretical frameworks, case studies, best practices, and insights that can inform and support the study.

Objective 3:- developing a suitable approach for utilizing as-built 3D scan to create models for enhancing building facility management in Ethiopia.

- ✓ **Secondary data: -** a review of literatures, questionnaire and qualitative interviews done for objective two above would be the inputs for attaining this objective.

3.5 DATA SOURCE SELECTION

The selection of data source should capture and answer the necessary information for described research questions and scope of the paper. So, the data source for the primary data of as built 3D scan model for achieving objective one corresponds to the specific G+0 building in Addis Ababa. And the interviews for objective two and three has covered the institutions in Addis Ababa which has facility management team.

3.6 DATA COLLECTION METHODS

In collecting data for an as-built scan model of a single building, it applied 3D scanning apps available for iOS devices that utilize the device's built-in sensors, such as the camera and depth sensor, to capture 3D data. These apps use techniques like photogrammetry or light scanning to create a point cloud or mesh representation of the building.

The data collection method for:-

Objective 1:- *To identify the effects of as-built 3D scan models compare to traditional methods for improved building facility management..*

In collecting data for an as-built scan model of a single G+0 building, it coverd three different steps. These are:-

RECORDING DATA: - Unlock the iPhone and launch the 3D Scanner App to begin recording data with the LiDAR scanner. Verify that nothing is blocking the iPhone's LiDAR scanner on the rear. The application launches the "camera interface" by default, which is used to scan 3D models. The app uses the iPhone's primary camera to take pictures during scanning. The purpose of those images is to give the 3D models texture. Pressing the red button on the app's basic UI start a scan. To achieve the necessary scanning criteria, such as good focus and good overlap, move the iPhone around and follow the on-screen directions to expand the scan.

PROCESSING DATA: - The steps involved after the initial data recording phase include loading photos into the software, matching photos for similarities and angular offset, reconstructing camera positions in space, reconstructing positions of points matched from various camera angles (point cloud), reconstructing a dense point cloud, creating a 3D mesh from the dense point cloud, adding a colored texture to the mesh, and exporting the finished 3D model.

A manual measurement also is taken for the same building. It involved

- ✓ Preparing the necessary tools
- ✓ Taking overall measurements by taking overall dimensions by creating sketches
- ✓ Measure individual rooms, openings and features
- ✓ Record measurements

Objective 2:- *To identify the challenges and limitations of implementing as-built 3D scan models for building facility management in Ethiopia.*

One method for out coming existing challenges of implementing 3D scanning tools mechanism is carrying out a focused group discussion with expertise in specific area. This is done by choosing participants who have experience and expertise in building facility management, including professionals from the construction industry, facility managers, and other relevant stakeholders which helps to obtain a variety of viewpoints, try to assemble a diverse group.

During the discussion, the discussion proceed with open-ended questions that guided the conversation. The questions should focus on the challenges and limitations of using as-built 3D scan models for building facility management. The group discussion considers including questions about accuracy, data integration, software compatibility, training requirements, cost, and any other relevant aspects. So it involves selection of Experts who have relevant knowledge and experience in the field of facility management, building technology, 3D scanning, or related areas and preparing discussion guide and an initial questionnaire that focuses on the challenges and limitations associated with implementing 3D scan tools for facility management in Ethiopia.

An open ended questions is applied which encourages the respondent to share their thoughts and experiences. Moreover, probing questions would be followed to reach inside deeper into the challenges mentioned. These questions seek specific details, examples, and any potential solutions or mitigations they have tried. The group discussion would be a face to face interview.

In a questionnaire session, Likert scale questions would be applied to gather quantitative data on the challenges faced. These questions along with the group discussion provide structured options for respondents to select from and help in analysing patterns and trends easily.

3.7 DATA ANALYSIS METHOD

During data analysis period some methods is adopted for as built models processing to models. Data Pre-processing is one method after scanning existing building. pre-processing the collected as-built scan data to ensure its quality and usability. This may involve cleaning the data, removing outliers, aligning or registering multiple scans or data sources, and

normalizing or scaling the data if necessary. And also, it can be visualized and analysed point cloud data directly on your iPhone using available iOS apps. These apps typically provide tools for measuring distances, angles, and areas within the point cloud.

This study also analyses different literatures, documents, and provide interviews so as to identify the current situations which are challenges and limitations in applicability of these 3D scanning tools in different institutions of Addis Ababa. Transcribing of data is done with focus of great accuracy of original data source, then it develops structured and meaning to the interview data which is an input for developing a framework for utilization of 3D scanning tools for existing building in Ethiopia.

Objective 1:- *To identify the effects of as-built 3D scan models compare to conventional method for improved building facility management.*

After collecting data in both methods of 3d scanning tools and manual measurement, different parameters is adopted in comparing both processes and the perceived outcomes of both mechanisms. These are the process mechanism, accuracy, time, detail level, and their integrity with other tools.

The data analysis involves some technical methods in creating models

1. **GEOMETRIC ANALYSIS: -** Analyse the geometric properties of the scanned models. Measure key dimensions, angles, or volumes to verify if they align with the original objects or reference measurements. Look for any deformations or discrepancies that may affect the accuracy or usability of the models.
2. **SURFACE ANALYSIS: -** Assess the smoothness and continuity of the surfaces in the scanned models. Identify any surface irregularities, holes, or other imperfections that may need to be addressed. Evaluate the level of detail captured and determine if it is sufficient for the intended application of the models.
3. **TIME AND EFFORT ANALYSIS: -** recording the time and efforts expenditures that consumes through this process. And also, critically distinguish the different methods adopted and their effects of the scanning tools through recording, and processing the existing building.

Objective 2:- To identify the challenges and limitations of implementing as-built 3D scan models for building facility management in Ethiopia

For objective two

Towards the end of the focus group discussion, summarize the main challenges and limitations identified by the participants. In analysing the collected group discussion data, different methods is adopted.

- ✓ A thematic analysis which involves categorizing the challenges into wider thematic areas, such as technological, financial, organizational, or regulatory challenges
- ✓ A frequency analysis in quantifying the number that each challenge was emphasized by the group attendants.
- ✓ A Contextual analysis help in adopting tailored solutions and strategies to address the context-specific challenges.
- ✓ A cause effect analysis to assess the interrelationships and interdependencies among the various challenges to understand the root causes and their potential effects.

Objective three

After critically understand the data collected and analysed, stakeholder needs, and the facility management context, and then it developed a suitable approach that integrates the as-built 3D scan data into the existing workflows and decision-making processes effectively.

3.8 SAMPLING APPROACH AND SELECTION CRITERIA

When choosing case samples for 3D scanning of existing building different considerations has taken. The sampling techniques focused on residential building in Ethiopia. In this research the existing residential building would be chosen in two directions which are based on purposive sampling and convenience sampling criteria. These sampling techniques selects a case in considering the unique features, condition, and importance of the structures to the local community, and make sure the case samples chosen represent a variety of building types, and accessibility levels in order to give a thorough grasp of the implementation concerns. And also the ease of access, availability of resources, and cooperation from local authorities and communities.

3.9 DATA VALIDATION

For objective one, it is important to validate and verify the accuracy and reliability of as-built scan model. This involves comparing the model with on-site measurements. The 3D model developed using the 2D drawings uses as the ground truth for the accuracy assessment analysis. Manual survey measurements carries out to collect the manual data directly, because it is possible that the original 2D drawings and the existing as-built are not accurate. Assessing the quality and precision of the model strengthens the credibility of this study results.

For objective two, expert evaluations, or other independent data sources are the data validation methods.

For objective three, Expert review would be the validation method for developed framework. It consults with building facility management subject matter experts and specialists who have used as-built 3D scans before to get their opinions and suggestions. And engage these experts on the framework and its elements to get their feedback on its sustainability, effectiveness, and conformity to industry best practises.

3.10 SUMMARY OF RESEARCH METHODOLOGY

Table 4:- Summary of Research Methodology

RESEARCH OBJECTIVE		**METHODOLOGY**
To identify the effects of as-built 3D scan models compare to conventional method for improved building facility management	Data source	Primary data:- Models using 3d scanning tools and traditional method
	Data collection method	Creating existing measurement
	Data collection tool	3D scanning using iPhone 12 ProMax, and Manual measurement
To identify the challenges and limitations of implementing as-built 3D scan models for	Data source	primary and secondary data's: -FM institutions in Addis Ababa
	Data collection	A focused group discussion

building facility management in Ethiopia	method	
	Data collection tool	A review of literatures which are published books, academic journals, articles and research papers
Developing a suitable approach for utilizing as-built 3D scan to create models in enhancing building facility management in Ethiopia	Data source	primary and secondary data's:- construction firms and FM institutions in Addis Ababa
	Data collection method	opened interview and A focused group discussion
	Data collection tool	Questionnaire survey & Literature review

CHAPTER FOUR

4. RESULT AND DISCUSSIONS

4.1 INTRODUCTION

In this chapter, the collected data for the specific objectives be analysed and the perceived outputs would be evaluated. The conclusion is set for each objective stated above at chapter 1. For objective one the iPhone 12promax devise and laser meter is used to collect the data. And then each output would be compared and contrast. For the second objective the respondents answer for 9 different questions from different construction stakeholders is evaluated and the suitable approach would be developed for applicability of 3d scanning tools for objective 3.

4.2 OBJECTIVE 1 DATA ANALYSIS

The existing G+0 residential building in Addis Ababa, Ethiopia is used for applying 3D scanner. An iPhone 12 ProMax phone is also used for scanning the existing building. Beside an application called magic plan is used as an aid for scanning the building. The process is done below.

Figure 4:- Existing G+0 residential building

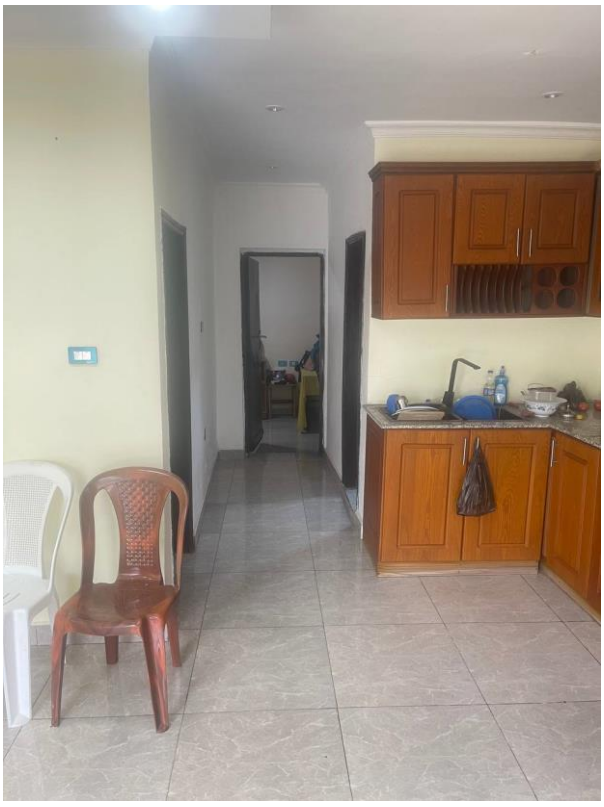


Figure 5 :- Internal view of scanned residential building

4.2.1 STEPS OF DATA COLLECTION METHOD

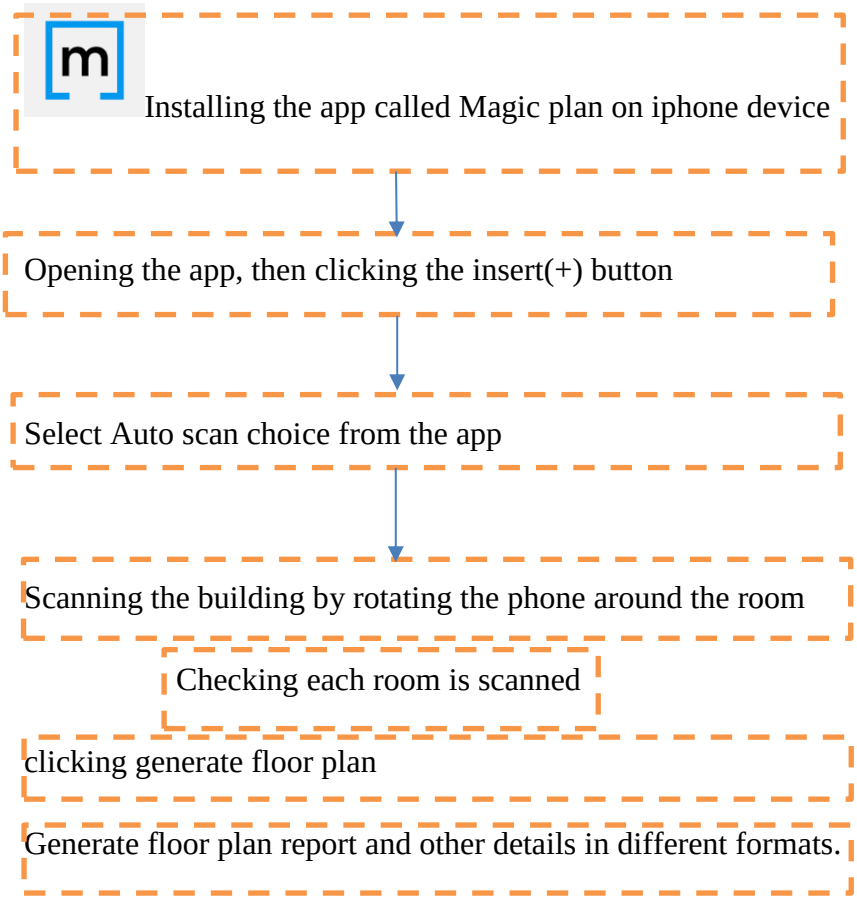


Figure 6:-steps in generating scanned model

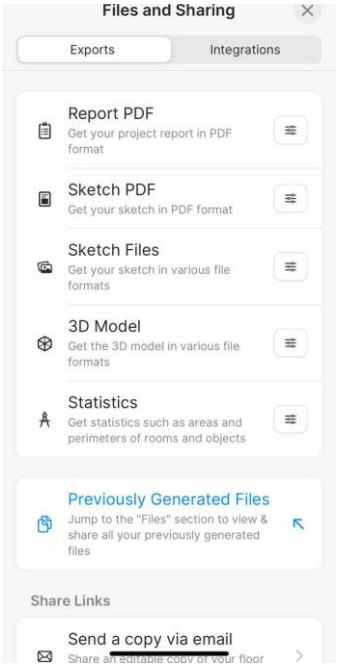


Figure 7:- Generating reports from iPhone pro scanned file

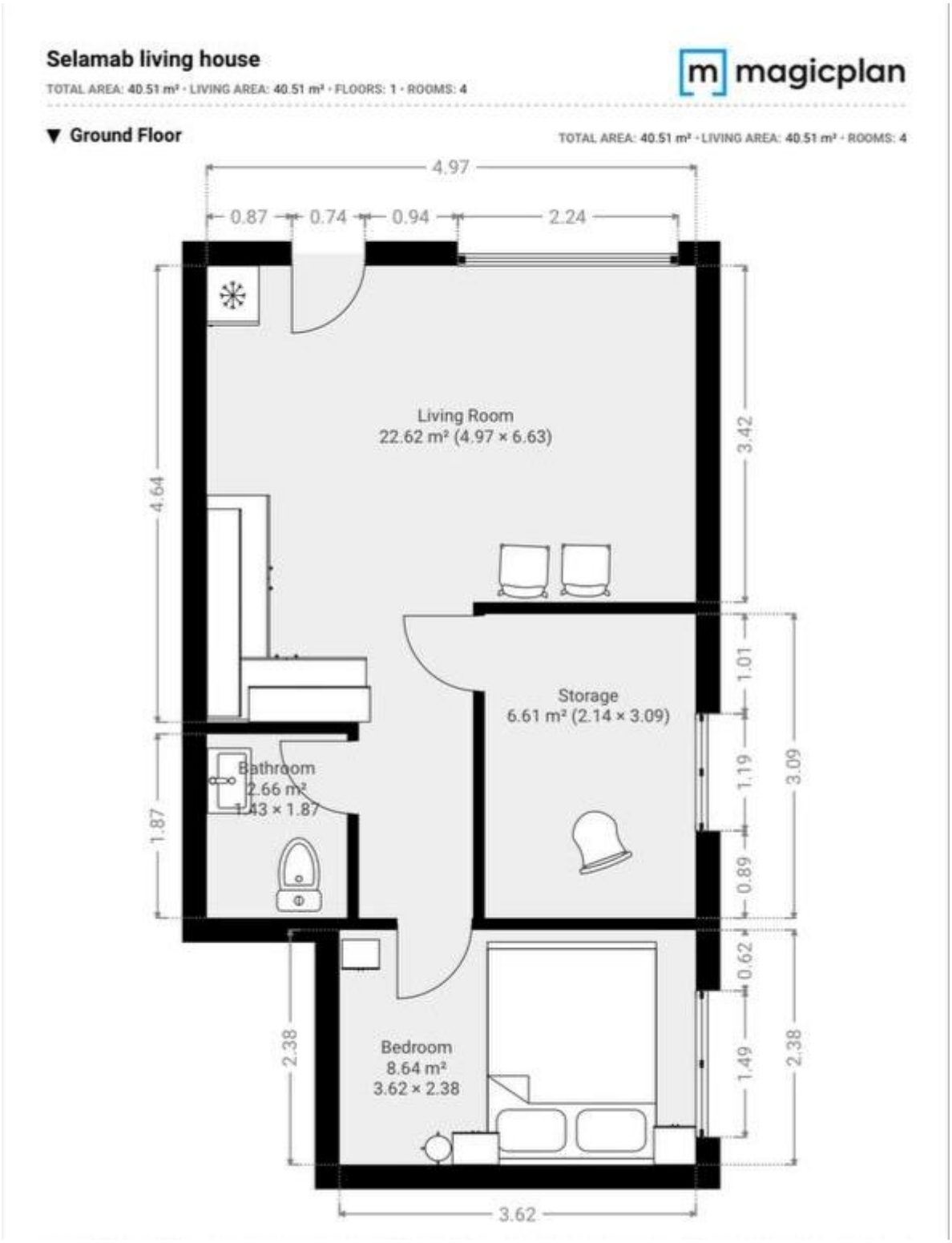


Figure 8:- Outputs of 3D scanned file

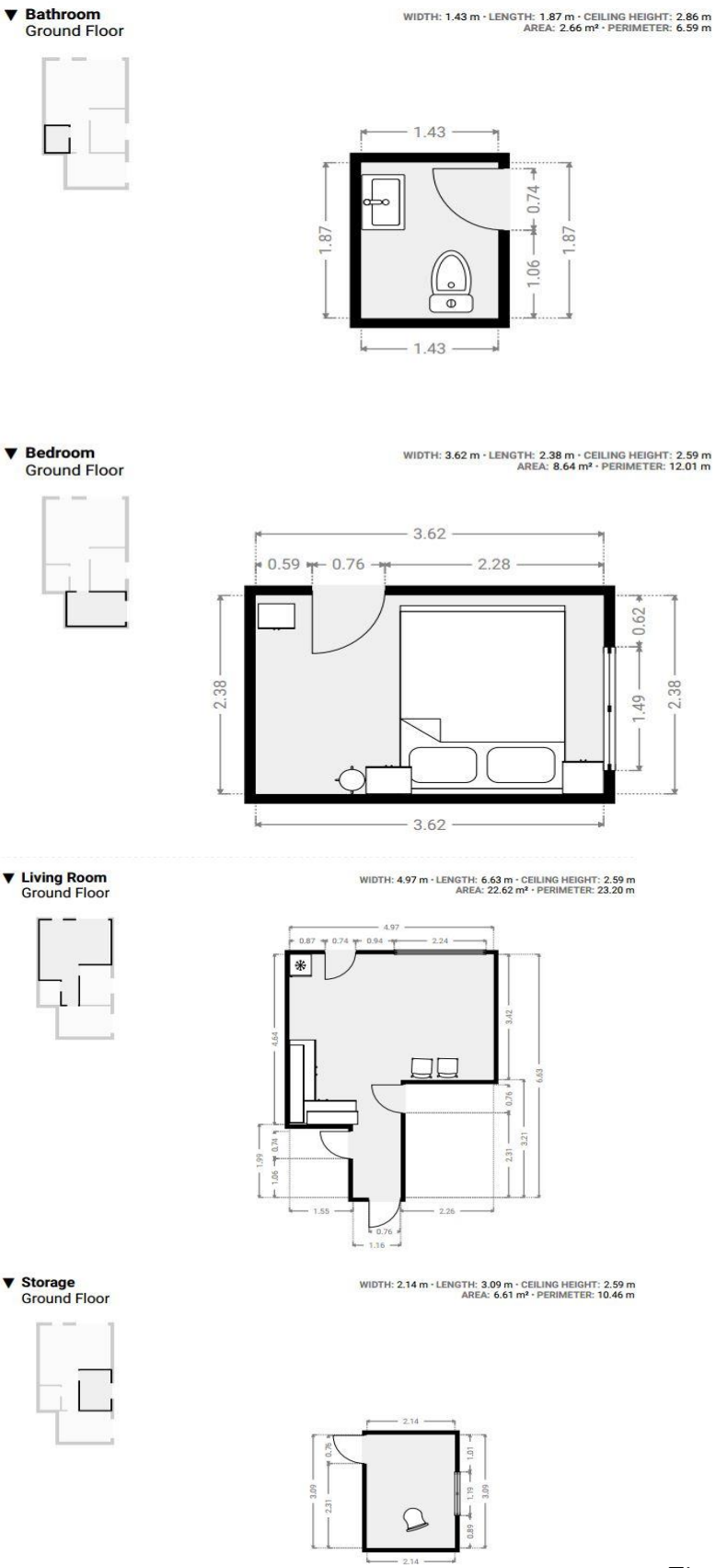


Figure 9:- Outputs of detailed report

4.2.2 DATA ANALYSIS FOR OBJECTIVE ONE

The whole process of generating floor plan by using the iPhone ProMax device took 4minutes and 25 seconds. Now let's do the comparison of this scanning device with the manual laser meter measurement.

Table 5:- Comparison between 3D scanner and Laser distance measurement

PARAMETER	**IPHONE 3D SCANNER**	**LASER DISTANCE METER**
process	Used Iphone12 ProMax with magic plan app.	Laser distance meter, sketching, hand meter, paper, and pencil.
Time	Takes 4minute and 25 seconds for the specified building.	23minutes till finishing sketch and 15minutes more for generating pdf.
Accuracy	More Accurate since hand tools task are not applied. It would get the same result for different trials.	Less accurate since dimensional differences can be seen for different measurement.
Detail level	Furnitures, doors and windows are added automatically. It has a choice of different types of doors and windows. It can also generate a report for each room separately with in specified time described above.	Furnitures, doors and windows are added manually.

Integration	It produces floor plans with measurement,3D models solely.	It needs further integration with other software's and tools to develop models. It can result for further error.

4.3 OBJECTIVE TWO

4.3.1 OBJECTIVE TWO DATA COLLECTION

To identify the challenges and limitations of implementing as-built 3D scan models for building facility management, it took discussion's with stakeholders specially who had an experience around the specified area. This data is a collection of different construction firms' aspects in Addis Ababa. Professionals from 7consultant office, 3 contractor office and 2 government construction representative firms (ERA and AACRA) had a face-to-face, phone interview, and questionnaires. Thirteen professionals are participated for the described nine questions listed for a discussion.

Table 6:- participants of discussion

Level of participant	**Frequency**
Design manager	2
Senior architect	4
Project manager	3
Professional engineers	4
TOTAL	**13**

4.3.2 FACILITY MANAGEMENT PROCESS

From those participated 2 firms have their program on Tracking and managing physical assets, including maintenance schedules and lifecycle management. Most of the construction

firms doesn't have facility management process program. This is due to less focus for maintenance period of construction and some companies view as unnecessary expenses. And some thoughts they can manage without formal processes.

Table 7 facility management process

What is the current method of facility management process?		
responses	frequency	Extra explanation
Applies Tracking and managing physical assets, some uses corrective and preventive methods	2	
Done without formal program	8	less focus for maintenance period
Not applicable	3	No response

4.3.3 MAIN CHALLENGES THAT HAVE BEEN FACED DURING CURRENT FACILITY MANAGEMENT PROCESS

Developing Countries like Ethiopia grapes many challenges for the encouragement of facility management process. Some barriers are mainly existed on infrastructures of Ethiopia. Some are mentioned by the group discussion.

Table 8 main challenges that have been faced during current facility management process

What are the main challenges that have been faced during current facility management process?		
responses	frequency	Extra explanation
Budget Constraints	2	The limited budgets condition of Ethiopia restricts maintenance and upgrades, impacting overall facility performance.
Data formation	5	There is no programmed data system. It couldn't be get much available data for a facility.

Skilled labour shortage	3	Unavailability of skilled facility manager professionals
Resistance for change	1	There is resistance to change for updated facility management techniques.

4.3.4 THE ADOPTION AND IMPLEMENTATION OF 3D SCANNING TOOL FOR BUILDING FACILITY MANAGEMENT IN ETHIOPIA

Most of Ethiopian construction firms have less awareness on application of 3D scanning tools for facility management process. In conceding this group discussion finding professionals with awareness of this tool was difficult. So, in finding why it is difficult adopting 3D scanning tools, they answered some repetitive answers.

Table 9 the adoption and implementation of 3D scanning tool for building facility management in Ethiopia

What are the main challenges associated with the adoption and implementation of 3D scanning tools for building facility management in Ethiopia?		
Response	Frequency	Extra Explanation
Awareness	13	Lack of awareness for existence of this tools.
expertise	2	Shortage of well skilled professional.
cost	4	High cost of advanced 3D scanning tools.

4.3.5 SOCIO-ECONOMIC FACTORS THAT MAY IMPACT THE APPLICATION OF 3D SCANNING TOOLS FOR BUILDING FACILITY MANAGEMENT IN ETHIOPIA

The development of new infrastructures and the economic condition of a country had raised as a major issue that affects for applying new systems on former conditions adopted.

Table 10 socio-economic factors that may impact the application of 3D scanning tools for building facility management in Ethiopia

What are the specific socio-economic factors that may impact the application of 3D scanning tools for building facility management in Ethiopia?		
Response	Frequency	Extra Explanation
Development of infrastructure	1	Limited access with developed infrastructure
Variation of economy	5	Variation of economy results for poor funding on technologies
knowledge	2	Less training programs for new systems

4.3.6 CULTURAL AND REGULATORY DIFFERENCES IN ETHIOPIA

Table 11 Cultural and regulatory differences in Ethiopia

How do cultural and regulatory differences in Ethiopia influence the use of 3D scanning tools for building facility management?		
Response	Frequency	Extra Explanation
Prioritizing former system	10	Many conditions in Ethiopia give emphasis for early system. Many don't appreciate for new changes smoothly.
Managerial directions	1	Many managerial leads are tending to classical methods.
Regulatory supports	1	Government mainly not appreciating innovation on this specific facility management

4.3.7 BARRIERS TO THE ADOPTION OF 3D SCANNING TOOLS, SUCH AS INITIAL INVESTMENT COSTS, OPERATIONAL EXPENSES, OR TRAINING REQUIREMENTS, IN ETHIOPIA

Table 12 Barriers to the adoption of 3D scanning tools, such as initial investment costs, operational expenses, or training requirements, in Ethiopia

What are the potential barriers to the adoption of 3D scanning tools, such as initial investment costs, operational expenses, or training requirements, in Ethiopia?		
Response	Frequency	Extra Explanation
Initial cost	13	High initial cost for buying advanced 3D scanning tool
Operational expense	13	Expecting high expenses
Training requirement	13	Expecting not finding trained professionals, if it doesn't need higher expense

4.3.8 TECHNICAL CHALLENGES AND LIMITATIONS IN USING 3D SCANNING TOOLS FOR BUILDING FACILITY MANAGEMENT IN ETHIOPIA

Table 13 Technical challenges and limitations in using 3D scanning tools for building facility management in Ethiopia

What are the key technical challenges and limitations in using 3D scanning tools for building facility management in Ethiopia, such as data processing, software compatibility, or hardware accessibility?		
Response	Frequency	Extra Explanation
Data processing	9	There is little data acquiring system in Ethiopia.so finding data's need much energy and takes time.
	1	Finding data is impossible
Software issues	13	Less awareness on software

		compatibility with existing facility.
Hardware accessibility	13	Limited availability of 3D scanning tools

4.3.9 SKILL GAPS OR TRAINING NEEDS

Table 14 skill gaps or training needs

What are the specific skill gaps or training needs that could hinder the effective use of 3D scanning tools for building facility management in Ethiopia?		
Response	Frequency	Extra Explanation
Software professionals	13	Limited skill on software management
Training	1	Unavailability of training for the scanning tools
Decision	1	Less awareness on interpretation of features of the tool.

4.3.10 POLITICAL AND GOVERNANCE FACTORS

Table 15 Political and governance factors

How do political and governance factors, such as government support, policies, and regulations, influence the use of 3D scanning tools for facility management in Ethiopia?		
Response	Frequency	Extra Explanation
Innovation and technology adoption	8	Initiating and promoting innovation and technology acceptance.
Collaboration	2	Encouraging collaboration between government and construction firm.

4.4 FINDINGS ON OBJECTIVE TWO DISCUSSION

The above session gives some emphasis on which the barriers making applicability of 3D scanning tools on construction firms of Ethiopia. In defining the major critical points there comes some pillar points.

TABLE 16:-Findings on Objective Two discussion

Budget Constraints	The limited budgets condition of Ethiopia restricts maintenance and upgrades, impacting overall facility performance.
Data formation	There is no programmed data system. It couldn't be get much available data for a facility.
Skilled labour shortage	Unavailability of skilled facility manager professionals
Resistance for change	There is resistance to change for updated facility management techniques.
Awareness, expertise, and cost	Lack of awareness for existence of this tools. Shortage of well skilled professional High cost of advanced 3D scanning tools.
Development of infrastructure, Variation of economy, and knowledge	Limited access with developed infrastructure, Variation of economy results for poor funding on technologies, and Less training programs for new systems
Prioritizing former system, Managerial directions, and Regulatory supports	Many conditions in Ethiopia give emphasis for early system. Moreover, many don't appreciate for new changes smoothly, and Government mainly not appreciating innovation on this specific facility management
Initial cost, Operational expense, and Training requirement	High initial cost for buying advanced 3D scanning tool, and Expecting high expenses.
Data processing, Software issues, and Hardware accessibility	There is little data acquiring system in Ethiopia.so finding data's need much energy and takes time. Less awareness on software compatibility with existing

	facility, and Limited availability of 3D scanning tools
Software professionals, decision on user	Limited skill on software management, and Less awareness on interpretation of features of the tool.
Innovation and technology adoption with Collaboration	Initiating and promoting innovation and technology acceptance by encouraging collaboration between government and construction firm.

4.4.1 AWARENESS OF CONSTRUCTION SECTOR

As it be seen in discussion, Limited exposure to these technologies in academic institutions can reduce awareness among professionals. Consequently, it results for less exposure of professionals for these technologies. So, promoting the use of 3D scanning techniques in facility management requires raising awareness through focused educational initiatives and industry involvement.

4.4.2 BUDGET CONSTRAINTS

The high cost of advanced 3D scanning tools that are workable for institutions has been a barrier for applicability of 3d scanning tools. Which means a developing country like Ethiopia could have a struggle since budget shortages. Also, the budgets for lifetime and training cost can also affect in implementing the technology.

4.4.3 SKILLED MAN POWER

It is seen that; inadequate training initiatives may leave workers unable to handle and make efficient use of 3D scanning equipment. And the availability of less number of skilled professional makes a great obstacle for adoption of the 3D tool.

4.4.4 REGULATORY BODIES

It is courage for collaboration of regulatory bodies and the construction to work so as to the government may appreciate innovation on this specific facility management.

4.5 OBJECTIVE THREE

4.5.1 DEVELOPING APPROACH FOR A SUITABLE UTILIZING AS-BUILT 3D SCAN TO CREATE MODELS IN ENHANCING BUILDING FACILITY MANAGEMENT IN ETHIOPIA

Since it is described how to develop a 3Dscanned model, and ac challenges in current Ethiopia situation, it is possible to adopt a suitable approach for utilizing 3D scanning tools. A suitable approach for utilizing 3D scanning tools in building involves defining the scope, identifying stakeholders, outlining processes, and establishing key performance indicators (KPIs). It also considers factors like cost, training, efficiency, time, and integration with existing systems which mentioned on objective two session.

Scope Definition clearly define the facilities objectives describes the object area to be scanned, and after defining the stakeholder’s roles which can be architect, engineers or any other user, then it works on each step work methodology with processing the data and generating the desired output. And also Establish quantifiable indicators, such as accuracy, efficiency, cost reduction, and time saving, to control the implementation's process. It is possible to create a suitable approach with applying these important factors which maximizes the advantages and minimizes any potential drawbacks of using 3D scanning tools in construction may be created. Finally, I developed the suitable approach for applicability of 3D scanning tools in Ethiopia based on the findings above.

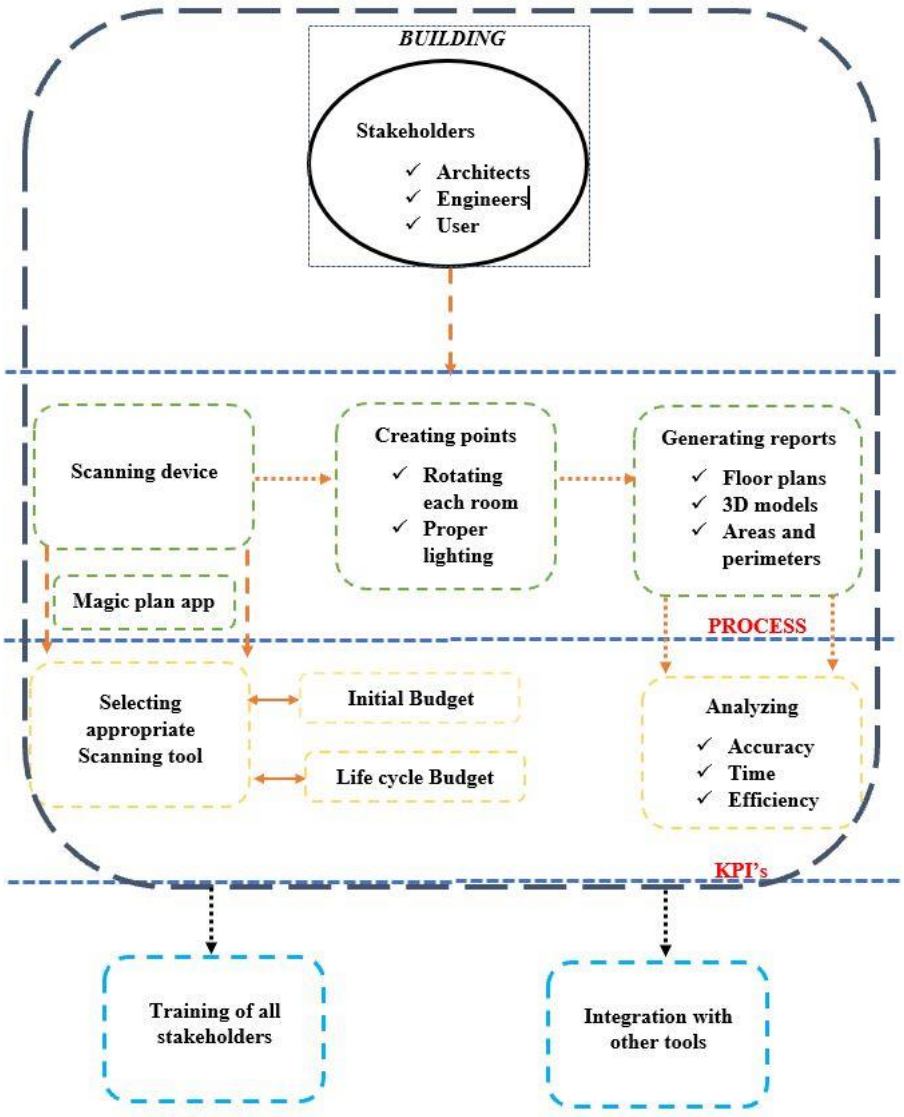


Figure 10:- A suitable approach for utilizing as-built 3D scan to create models in enhancing building facility management in Ethiopia

4.5.2 RESEARCH VALIDITY

The validation of the framework is done by sending back an evaluation paper for those who are participated on objective two experts. The evaluation paper has a point on making the suitable approach to be applicable. These are specificity, simplicity, attainability, comprehensiveness, and applicability. Their result has demonstrated below: in chart. (Xiao, 2017).

A. SPECIFITY

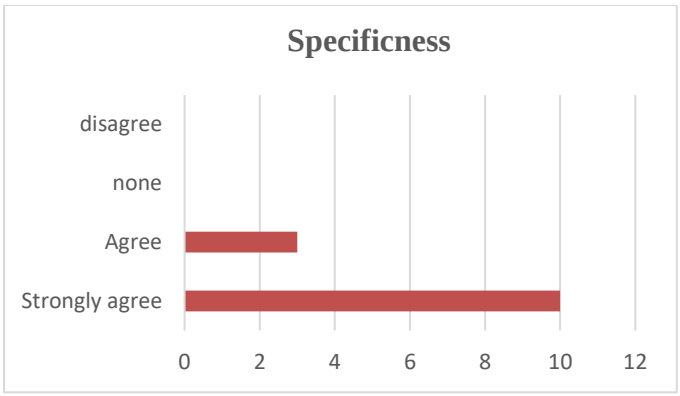


Figure 11:- Validity for specifity

B. SIMPLICITY

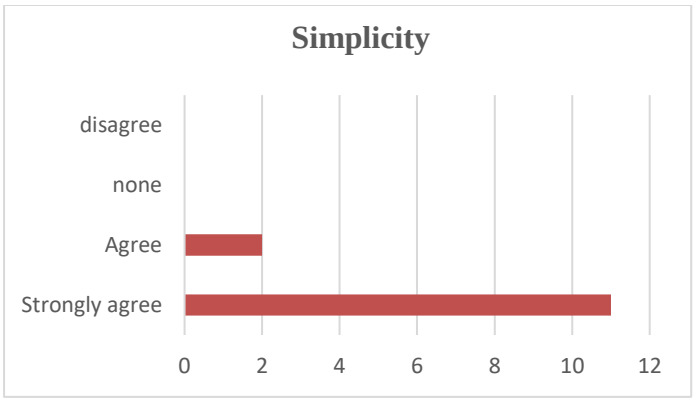


Figure 12 Validity for simplicity

C. ATTAINABILITY

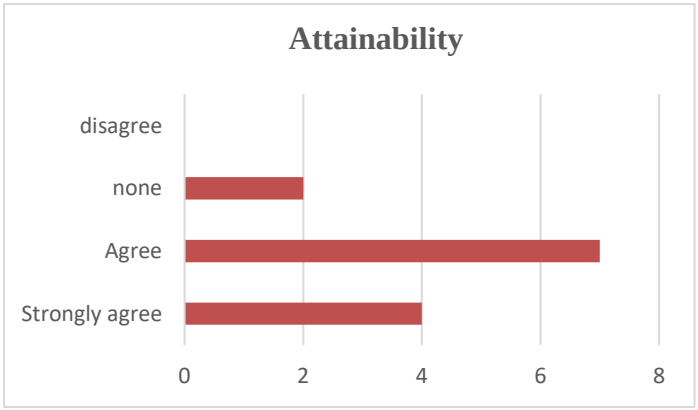


Figure 13 Validity for attainability

D. COMPREHENSIVENESS

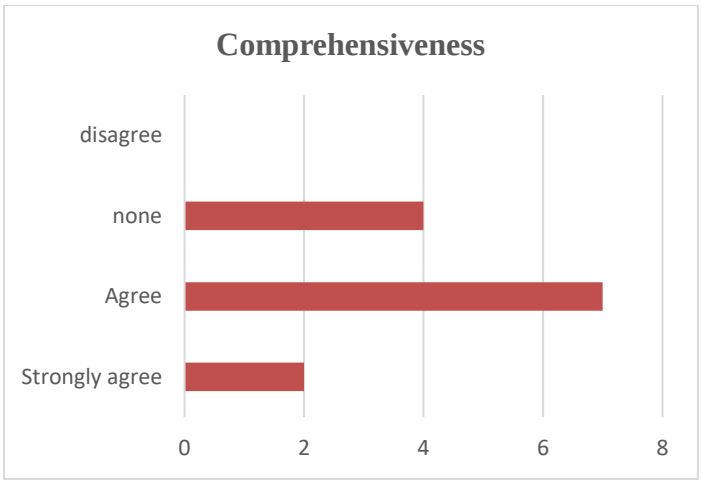


Figure 14 Validity for comprehensiveness

E. APPLICABILITY

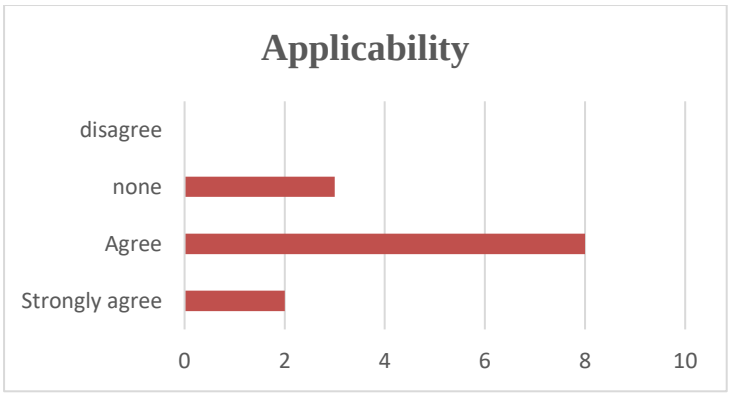


Figure 15 Validity for Applicability

CHAPTER FIVE

5.CONCLUSION AND RECOMMNEDATION

5.1 CONCLUSION

Objective one

In the first objective, A comparisons taken between 3D scanning tool and the traditional manual measurement gave a result that adopting a 3D scanner tool has more better features in different scenarios. Those features are using 3D scanning tools would decrease a time and an effort with more accurate results. As it seen above it took one-tenth time to finish the whole process of generating floor plans than the laser distance measurement. Moreover, it gave more detailed information about each room with in the same consumed time than traditional measurement system.

Objective two

In second objective, it gives some emphasis on which the barriers making applicability of 3D scanning tools on construction firms of Ethiopia. Some are awareness of construction sector which is a limited exposure to these technologies in academic institutions can reduce awareness among professionals. Consequently, it results for less exposure of professionals for these technologies. The great issues is raised when we deal on budget issues that is the high cost of advanced 3D scanning tools that are workable for institutions has been a barrier for applicability of 3d scanning tools. Which means a developing country like Ethiopia could have a struggle since budget shortages. Also, the budgets for lifetime and training cost can also affect in implementing the technology. skilled man power and regulatory bodies are the other main issues for less implementation of 3D scanning tools in Ethiopian facility management.

5.2 RECOMMENDATION

There are some insight points for the next tasks from the finding of these task.

- ✓ Construction firms should promote the use of 3D scanning techniques in facility management requires raising awareness through focused educational initiatives and industry involvement. This in result has an outcome for improved time and efficient maintenance system.

- ✓ It is courage for collaboration of regulatory bodies and the construction to work so as to the government may appreciate innovation on this specific facility management.
- ✓ Further studies are appreciable 3D scanning tools on different compounds like cultural heritages for sustainable heritages.
- ✓ Further studies are appreciable with advanced 3D scanning tools for more indication of the benefits of these 3D scanning tools.
- ✓ Further studies are appreciable on integrating these 3D scanning tools with other platforms.

BIBLIOGRAPHY

Cotts, D. G., Kathy , O. . R. & Richard, P. . P., 2010. *The Facility mangement Hand book.* New York: AMACOM.

19111:, I., 2007. *ISO.* s.l.:s.n.

Abdi, K., Andrew, T. & Ertu, n., 2009. Computer Applications in Engineering Education. september.

Abdil, K., 2009. *Implementation of 3D Optical Scanning Technology for Automotive Applications.* Bursa, Nilufer, Turkey: s.n.

Alexander, S., 2015. *Architectural Design with SketchUp: 3D Modeling, Extensions, BIM, Rendering, Making, and Scripting.* UK: s.n.

Ali, R., 2017. s.l.:s.n.

Anon., 2014. *Fundamentals (ISO 19115-1:2014).* s.l.:Scheizerische Normen-vereinigue.

Anon., n.d. *Agisoft LLC. (n.d.). Agisoft Metashape User Manual..* s.l.:s.n.

Arayci, 2004. *An approach for real world data modeling with the 3D terrestrial laser scanner for built environment.* Northumbr: s.n.

Artur, P., Aleksandra, M., Jacek, S. & andIwona, S., 2023. A Case study of 3D scanning techniques in civil engineering using the terrestrial Laser scanning technique.

Atkin, Brian; Brooks, Adrian, 2009. *FM services source.* UK: willey.

Atkin, B. & Brooks, A., 2016. *Total Facility Management.* west sussex, UK: John Wiley & Sons, Ltd.

Baldry, B. :., 2003. *Facilities Management Towards Best Practices.* oxford: Blackwell Science.

Barrie, C. & Peter, S., 2007. *Building maintenance management.* s.l.:black well.

Booty, F., 2009. *Facilities Management Handbook.* s.l.:Elsevier Ltd.

Brian, J. B. & Wood, 2009. *Building maintenance.* London: Blackwell Publishing Limited.

Brodt, W. & East, W., 2007. *BIM based facility mangement.* New York: building SMART alliance (National Institute of Building Sciences).

Capturing Reality, n.d. *RealityCapture User Manual.* s.l.:s.n.

Clive, B., Paul, B., Lee, M. & Thomas, R., 2018. *3D Laser Scanning for Heritage. Advice and Guidance on the Use of Laser Scanning in Archaeology and Architecture.* UK: Historic England.

Creaform., 2014. *Reverse engineering of physical objects.* s.l.:Creaform Inc..

Createmaster, 2014. *Construction handover and digital O&M.* UK: Createmaster.

David, C. & Edward, R., 2008. *Facilities Management: Theory and Practice.* s.l.:Americana management association.

David, M., 2016. *3D Scanning and Photogrammetry: A Practical Guide to Computer Vision and 3D Imaging.* s.l.:willey.

Diaz-vilarino, Frias, Balado & Gonzales-Jorge, 2018. *Scan planning and route optimization for control of execution of as-designed BIM.* s.l.:Creative Commons Attribution.

Douglas, J. & Noy, E., 2011. *Building Surveys and reports.* west sussex, UK: A John Wiley & Sons, Ltd.

Edl, M., 2018. 3D laser scanners: History and applications.

Facilities Management association in UK, 2021. UK: IFMA.

George, V., 2010. *Airborne and Terrestrial Laser Scanning..* Twente: whittles publishing.

Gerald, F. & Ramash, J., 2017. *3D Imaging on Mobile Devices.* s.l.:Springer.

Gregor, L., 2010. *iPhone LiDAR tutorial V.2.* Copenhagen: s.n.

Häusler, G. & Zhang, S., 2016. *Handbook of Optical 3D Metrology.* s.l.:s.n.

Hu, C. & Linghui, K., 2020. Application of 3D laser scanning technology in engineering field.

Jaud, K., M. Delacourt & Bertin, 2019. *Potential of smartphone SfM photogrammetry to measure coastal morphodynamics.* s.l.:s.n.

Joncic, N. & Zachar, J., 2017. *3D DIGITAL RECORDING OF ARCHAEOLOGICAL, ARCHITECTURAL AND ARTISTIC HERITAGE.* s.l.:CONPRA.

Joseph, G. F., 2003. *The Facility Manager's Handbook.* New York: The Fairmont Press, Inc.

Karl, K. & Sabry, E.-H., 2016. *Photogrammetry: Geometry from Images and Laser Scans.* s.l.:Walter de Gruyter.

Kothari, 2004. *Research Methodology. Methods and Techniques.* New Delhi: New Age International (P) Ltd..

Kumar, R., 2011. *Research methodology. a step by step guide.* third ed. London: SAGE Publications Ltd.

Laguela, Diaz-vilarino, Armesto & Arias, 2014. *Non-destructive approach for the generation and thermal characterization of an as-built BIM.* Paris: s.n.

Levit, J., 2003. *Complete Guide to Preventive and Predictive Maintenance.* Philadelphia: Industrial Press.

Levitt, J., 2013. *Facilities Management: Managing Maintenance for Buildings and Facilities.* s.l.:Momentum Press.

Marczyk, D, D. & D, F., 2005. *Essentials of research design and methodology.* New Jersey: John Wiley & Sons, Inc.

Mobley, K., 2003. *An Introduction to Predictive Maintenance.* Tennesie: Elsevier Science.

Mohid, j., Abid, H. & Rajiv, S., 2021. A case study on use of 3D scanning for reverse engineering and quality control..

Murphy, M. & Conor, D., 2017. *CURRENT STATE OF THE ART HISTORIC BUILDING INFORMATION MODELLING.* Ottawa: s.n.

Nam, H., Nguyen, Q. & Van Yen, N., 2024. Scan-to-BIM for facility management: A case study of an existing office building in vietnam.

Palmer, D., 2019. *Maintenance Planning and Scheduling Handbook.* s.l.:McGraw-Hill Education.

Peter, B. & David, B., 2003. *Facilities Management: Towards Best Practice.* 2nd ed. s.l.:Blackwell.

R. & H., 2021. Industrial perspectives of 3D scanning: Features, roles and it's analytical applications.

Richard, P. P. & Roper, K. O., 2014. *The Facility Management Handbook.* New York: AMACOM.

Sacks, R., Eastman, C., Lee, G. & Teicholz, P., 2018. *BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors.* s.l.:willey.

Shalabi, F. & Yelda, T., 2016. IFC BIM-Based Facility Management Approach to Optimize Data Collection for Corrective Maintenance.

Stefano, C. & Roberto, S., 2018. *3D Technologies for Cultural Heritage: An Introduction to 3D Technologies for Museums, Archaeology, and Art.* Italy: s.n.

Teicholz, E., 2004. *Facility Design and Management Handbook.* s.l.:McGraw-Hill Professional.

Toru, Y., Jorge, C. & Jose, P., 2015. *Handbook of optical metrology: principles and application.* s.l.:CRC Press.

Toth, C. & Renslow, M., 2017. *Introduction to LiDAR.* s.l.:CRC Press.

Wang, Q. & Kim, M., 2014. *Applications of 3D point cloud data in the construction industry: A fifteen-year review from 2004 to 2018.* UK: s.n.

wang, zhang, Qi, C. & Zhaoyu, Z., 2019. *A Survey of Mobile Laser Scanning Applications.* Guangzhou: s.n.

Wan, J., 2022. Application of 3D Laser scanning technology using Laser Radar system to error Analysis in the curtain wall construction.

Xiao, Y., 2017. *Exploring the impacts of facility management.* s.l.:s.n.

Zhana, Liangb & Xiaoa, 2009. *From point cloud to BIM: a survey of existing.* s.l.:s.n.

Zhang, S., 2018. *3D Laser Scanning Technology: Principles and Applications.* s.l.:s.n.

APPENDIX I: GROUP DISCUSSION QUESTIONS

This questions are designed to provide the suitable approach in enhancing the facility management of existing buildings in Ethiopia.

1. What is the current method of the facility management process?

_____

_____

_____

2. What are the main challenges that have been faced during current facility management process?

_____

_____

_____

3. What are the main challenges associated with the adoption and implementation of 3D scanning tools for building facility management in Ethiopia?

_____

_____

_____

4. What are the specific socio-economic factors that may impact the application of 3D scanning tools for building facility management in Ethiopia?

_____

_____

_____

5. How do cultural and regulatory differences in Ethiopia influence the use of 3D scanning tools for building facility management?

6. What are the potential barriers to the adoption of 3D scanning tools, such as initial investment costs, operational expenses, or training requirements, in Ethiopia?

7. What are the key technical challenges and limitations in using 3D scanning tools for building facility management in Ethiopia, such as data processing, software compatibility, or hardware accessibility?

8. What are the specific skill gaps or training needs that could hinder the effective use of 3D scanning tools for building facility management in Ethiopia?

9. How do political and governance factors, such as government support, policies, and regulations, influence the use of 3D scanning tools for facility management in Ethiopia innovation?

APPENDIX 2 - PUBLISHABLE MANUSCRIPT

Exploring Suitability of 3D Scanning Tools To Enhance Facility Management Practice In Ethiopia: The Case of As-Built Modelling Using iOS 3D Scanning Tools.

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ABSTRACT

Facility management specifically focuses on the management of individual infrastructure or properties which involves ensuring its functionality, safety, efficiency, and overall performance by overseeing the operation, maintenance, and enhancement. In maintenance period, conventional manual method of measurement, which works without the use of automated or computerized systems, of existing buildings is a common method used currently, these manual method approaches are subjected to human errors, since it is done through human manual collaboration which can lead to measurement inaccuracies. These inaccuracies could cause distinctness with existing condition when performing facility maintenance, repairs, or upgrades. Moreover, this method takes a lot of time and effort. When working in large and complicated facilities in particular, it can be a laborious and tiresome process to manually measure, sketch, and annotate the drawings. In this study the way of using technology aid instruments like 3D scanning usage is investigated. Moreover, it studied the perceived difference of the measurement methodologies between these conventional and 3D scanning tools. the data collection and data analysis are done by taking scanned data from existing buildings taken from Addis Ababa residential buildings. The focus group discussion is also taken to reach the challenges of implementing the 3D scanning devices in Ethiopia. It is seen using 3D scanning tools would decrease a time and an effort with more accurate results and give more detailed information with in the same consumed time than traditional measurement system. Then, after comparing two methods, this study figured out what has been the challenges for the vast applicability of this 3D scanning tools in construction sector.

It gives some emphasis on which the barriers making applicability of 3D scanning tools on construction firms of Ethiopia. Some are awareness of construction sector which is a limited exposure to these technologies in academic institutions reduced awareness among professionals. And also, the budget issues that is the high cost of advanced 3D scanning tools that are workable for institutions has been a barrier for applicability of 3D scanning tools. Which means a developing country like Ethiopia could have a struggle since budget shortages. After analysing these challenges, this study develops the suitable approach for applicability of this 3D scanning tools in Ethiopia. And finally, the study sets some conclusions and future directions to improve the applicability of these tools in vast.

Key words: - Facility management, Maintenance, Existing building, As built modelling, 3D scanning, iOS device

INTRODUCTION

Facility management is a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process, and technology. Facility management embraces the concepts of efficiency, cost-effectiveness, productivity, improvement, and employee quality of life (Richard & Roper, 2014). Nowadays the significance of facility management is far more widely recognized. Facility management recently encompasses physical and non-physical services. It generally covers the hard and soft facility services. Some of them are the maintenance of the structure, fabric, building engineering services, installations, fittings, and furnishings that form the facility. Maintenance in facility management works to prevent and deal with failure or breakdown of parts, components, systems and other elements. This maintenance process should take crucial concern, and needs plans for handling any operational impact by being prepared and updated (Atkin & Brooks, 2016).

Facility managers are the professionals most responsible for integrating people with their physical environment. As such, facility management is both a people and an environmental issue. Their role, which includes operations and compliance, involves managing people, productivity, and the associated costs. They are responsible for coordinating policies and procedures with current standards and best practices as well as legal requirements (Joseph, 2003). Facility managers should have access to complete data on the facility, including

system operation and maintenance, during commissioning and before handover. Information should be supplied in digital form, wherever possible, with paper copies (Atkin & Brooks, 2016).

Facility management in existing buildings involves understanding the particular difficulties and factors involved in managing existing built and-operated. In this regard, facility managers are in charge of maintaining, maximizing, and improving the performance existing buildings to satisfy the occupant needs, assure legal compliance, and maximize the efficiency of operations. And also, Facility management in existing buildings requires a proactive, strategic approach to address the unique challenges and complexities associated with maintaining and optimizing the performance of an operational facility. Facility managers play a crucial role in the long-term success and sustainability of a building by effectively managing maintenance, energy usage, compliance, and occupant needs.

PROBLEM STATEMENT

According to Creatmaster (2014) which is a company specialist in construction information hand over management, and operation and maintenance in UK, addressed that "the construction costs of building take approximately 24% of the total building costs during its lifetime and the design costs are around 3% while the rest of the costs are taken by 73%. During the operations and maintenance phase, facility management (FM) teams, whom works for attaining useful data of a building for managing efficiently, often spend a considerable amount of time and effort" (Brodt & East, 2007).

Although conventional Manual method of measurement, which works without the use of automated or computerized systems, of existing buildings is a common method used currently, these manual method approaches are subjected to human error, since it is done through human manual collaboration which can lead to measurement inaccuracies. These inaccuracies could cause distinctness with existing condition when performing facility maintenance, repairs, or upgrades. Moreover, this method takes a lot of time and effort. When working in large and complicated facilities in particular, it can be a laborious and tiresome process to manually measure, sketch, and annotate the drawings.

Manual drawings documents have a difficulty for several team members to share or change at once which in turn makes difficult in revising documents through times. This makes a less

collaboration between facility management participants. And also archival of documents in manual drawings is the big difficulty especially when there is much documents which might cause time delays while performing maintenance. Along with this, the owners should have all the details and specifications of the equipment such as doors, windows, curtain walls, lights, and other fixtures that would be placed during the project. It is sometimes challenging to obtain the actual information for the installed equipment that reflects the as-built conditions, which aids the owners in understanding the specific condition of the existing building. This information is derived from various subcontractors and is subject to significant change during construction.

Currently in Ethiopia it can be seen a problem of a limitation of required pre-information of existing buildings, which can be an input for facility management. To mitigate these problems, facility management professionals now rely on digital tools and technologies. This study rely on practical applicability of supportive scanning tools for facility management by integrating existing buildings and facility management of buildings using iOS 3D scanning tools.

This study can contribute for current facility management process by exploring new methodologies, techniques, and technologies. This can help to improve the overall efficiency and effectiveness of building facility management processes in Ethiopia.

RESEARCH QUESTION

The study is expected to answer the following issues:

1. What are the role/contribution of as-built 3D scan models in improving building facility management and maintenance planning in facility management?
2. What are the challenges and limitations of implementing as-built 3D scan models for building facility management in Ethiopia?
3. What is the suitable approach for utilizing as-built 3D scans to create models for enhancing building facility management in Ethiopia?

RESEARCH OBJECTIVE

The general objective of this study is exploring the potentials and suitability of 3D scanning technologies in enhancing building facility management practice in Ethiopia

SPECIFIC OBJECTIVE

1. To identify the effects of as-built 3D scan models compare to conventional methods for improved building facility management.
2. To identify the challenges and limitations of implementing as-built 3D scan models for building facility management in Ethiopia.
3. To develop a suitable approach for utilizing as-built 3D scan to create models for building facility management in Ethiopia.

SIGNIFICANCE OF THE STUDY

The facility management system in Ethiopia often lack proper documentation and facility management systems for existing buildings. The current widely used method of manual measurement in Ethiopia needs high effort and time. 3D scanning tools are valuable for retrofitting and renovating existing structures by capturing accurate measurements and data, these tools aid in the planning and implementation of modifications, additions, or upgrades. Based on this study, it elaborates how the existing buildings have a better operational management, and this gives better management for owners on their assets and to implement proactive maintenance for improved facility management than conventional method. The study demonstrated the effects of using 3D scanning technologies in creating precise and thorough digital models of buildings in efficiently and effectively. More over this study demonstrate how as built models, using recent 3D scanning tools, can be developed for the challenging existing building scenarios and effectively used to improve building management and performance.

SCOPE OF THE STUDY

This scope of this study is focused on how scanning tool technology is used in facility management by developing as-built models so as to optimize the efficiency of facility management practice in Ethiopia existing buildings. It focusses on comparing 3D scanning tools specified to iOS devices with the manual method of data collection for building facility management. This involves conducting comparison to assess the differences in data accuracy, completeness, and the time required to capture and process data using each method.

RESEARCH METHODOLOGY

Research methodology is a way to systematically solve the research problem to acquire new knowledge or insights in a particular field of study. It may be understood as a science of studying how research is done scientifically. Inside it studies the various steps that are generally adopted by a researcher in studying his research problem along with the logic behind them since the methodology may differ from problem to problem (Kothari, 2004). It involves the overall framework and techniques used to design, implement, and analyse research studies.

SOURCE OF DATA

The source of data to identify the effects of as-built 3D scan models compare to traditional methods, the as built 3D scan model of specific existing G+0 building is the primary data in identifying the effects of as-built 3D scan models for improved facility management and performance of existing buildings. This data is collected using iPhone 12 pro max mobile phone. And the manual measurement of the same building is taken. In identifying the challenges and limitations of implementing as-built 3D scan models for building facility management in Ethiopia, a review of literatures which are published books, academic journals, articles and research papers published in the field of the study area often contain relevant studies, methodologies, and findings related to as-built 3D scan model. the qualitative interview taken from construction firms like consultants, contractors, and facility management institutes. A questionnaire, which involves experts' interview and questionnaire in building facility management is the secondary data sources for this study. These sources can provide theoretical frameworks, case studies, best practices, and insights that can inform and support the study. In developing a suitable approach for utilizing as-built 3D scan to create models for enhancing building facility management in Ethiopia, a review of literatures, questionnaire and qualitative interviews done for objective two above would be the inputs for attaining this objective.

DATA SOURCE SELECTION

The selection of data source should capture and answer the necessary information for described research questions and scope of the paper. So, the data source for the primary data of as built 3D scan model for achieving objective one corresponds to the specific G+0

building in Addis Ababa. And the interviews for objective two and three has covered the institutions in Addis Ababa which has facility management team.

DATA COLLECTION METHODS

In collecting data for an as-built scan model of a single building, it applied 3D scanning apps available for iOS devices that utilize the device's built-in sensors, such as the camera and depth sensor, to capture 3D data. In collecting data for an as-built scan model of a single G+0 building, it involves

One method for out coming existing challenges of implementing 3D scanning tools mechanism is carrying out a focused group discussion with expertise in specific area. This is done by choosing participants who have experience and expertise in building facility management, including professionals from the construction industry, facility managers, and other relevant stakeholders which helps to obtain a variety of viewpoints, try to assemble a diverse group.

During the discussion, the discussion proceeds with open-ended questions that guided the conversation. The questions should focus on the challenges and limitations of using as-built 3D scan models for building facility management. The group discussion considers including questions about accuracy, data integration, software compatibility, training requirements, cost, and any other relevant aspects. So it involves selection of Experts who have relevant knowledge and experience in the field of facility management, building technology, 3D scanning, or related areas and preparing discussion guide and an initial questionnaire that focuses on the challenges and limitations associated with implementing 3D scan tools for facility management in Ethiopia.

An open-ended question is applied which encourages the respondent to share their thoughts and experiences. Moreover, probing questions would be followed to reach inside deeper into the challenges mentioned. These questions seek specific details, examples, and any potential solutions or mitigations they have tried. The group discussion would be a face to face interview.

DATA ANALYSIS METHOD

During data analysis period some methods is adopted for as built models processing to models. Data Pre-processing is one method after scanning existing building. And pre-processing the collected as-built scan data to ensure its quality and usability. This may involve cleaning the data, removing outliers, aligning or registering multiple scans or data sources, and normalizing or scaling the data if necessary. And also, it can be visualized and analysed point cloud data directly on your iPhone using available iOS apps. These apps typically provide tools for measuring distances, angles, and areas within the point cloud.

This study also analyses different literatures, documents, and provide interviews so as to identify the current situations which are challenges and limitations in applicability of these 3D scanning tools in different institutions of Addis Ababa. Transcribing of data is done with focus of great accuracy of original data source, then it develops structured and meaning to the interview data which is an input for developing a framework for utilization of 3D scanning tools for existing building in Ethiopia.

After collecting data in both methods of 3D scanning tools and manual measurement, different parameters is adopted in comparing both processes and the perceived outcomes of both mechanisms. These are the process mechanism, accuracy, time, detail level, and their integrity with other tools.

Towards the end of the focus group discussion, summarize the main challenges and limitations identified by the participants. In analysing the collected group discussion data, different methods is adopted.

- ✓ A thematic analysis which involves categorizing the challenges into wider thematic areas, such as technological, financial, organizational, or regulatory challenges
- ✓ A frequency analysis in quantifying the number that each challenge was emphasized by the group attendants.
- ✓ A Contextual analysis help in adopting tailored solutions and strategies to address the context-specific challenges.

After critically understand the data collected and analysed, stakeholder needs, and the facility management context, and then it developed a suitable approach that integrates the as-built 3D scan data into the existing workflows and decision-making processes effectively.

3.8 SAMPLING APPROACH AND SELECTION CRITERIA

When choosing case samples for 3D scanning of existing building different considerations has taken. The sampling techniques focused on residential building in Ethiopia. In this research the existing residential building would be chosen in two directions which are based on purposive sampling and convenience sampling criteria. These sampling techniques selects a case in considering the unique features, condition, and importance of the structures to the local community, and make sure the case samples chosen represent a variety of building types, and accessibility levels in order to give a thorough grasp of the implementation concerns. And also the ease of access, availability of resources, and cooperation from local authorities and communities.

RESULT AND DISCUSSIONS

In this chapter, the collected data for the specific objectives be analysed and the perceived outputs would be evaluated. The conclusion is set for each objective stated above at chapter 1. For objective one the iPhone 12promax devise and laser meter is used to collect the data. And then each output would be compared and contrast. For the second objective the respondents answer for 9 different questions from different construction stakeholders is evaluated and the suitable approach would be developed for applicability of 3D scanning tools for objective 3.

The whole process of generating floor plan by using the iPhone ProMax device took 4minutes and 25 seconds. Now let’s do the comparison of this scanning device with the manual laser meter measurement.

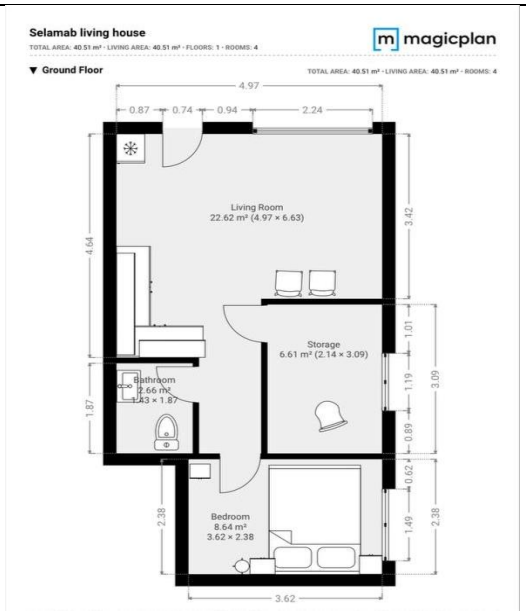

Figure 4,5: - Existing building, and output of iOS 3D scanner

Table 17:- Comparison between 3D scanner and Laser distance measurement

parameter	iPhone 3D scanner	Laser distance meter
process	Used Iphone12 ProMax with magic plan app.	Laser distance meter, sketching, hand meter, paper, and pencil.
Time	Takes 4minute and 25 seconds for the specified building.	23minutes till finishing sketch and 15minutes more for generating pdf.
Accuracy	More Accurate since hand tools task are not applied. It would get the same result for different trials.	Less accurate since dimensional differences can be seen for different measurement.
Detail level	Furnitures, doors and windows are added automatically.	Furnitures, doors and windows are added manually.

	It has a choice of different types of doors and windows. It can also generate a report for each room separately with in specified time described above.	
Integration	It produces floor plans with measurement,3D models solely.	It needs further integration with other software's and tools to develop models. It can result for further error.

To identify the challenges and limitations of implementing as-built 3D scan models for facility management, it took discussion's with stakeholders specially who had an experience around the specified area. This data is a collection of different construction firms' aspects in Addis Ababa. Professionals from 7consultant office, 3 contractor office and 2 government construction representative firms (ERA and AACRA) had a face-to-face, phone interview, and questionnaires. 13 professionals are participated for the described nine questions listed for a discussion.

FINDINGS ON GROUP DISCUSSION

The above session gives some emphasis on which the barriers making applicability of 3D scanning tools on construction firms of Ethiopia. In defining the major critical points there comes some pillar points

Table 18:-FINDINGS ON OBJECTIVE TWO DISCUSSION

Budget Constraints	The limited budgets condition of Ethiopia restricts maintenance and upgrades, impacting overall facility performance.

Data formation	There is no programmed data system. It couldn't be get much available data for a facility.
Skilled labour shortage	Unavailability of skilled facility manager professionals
Resistance for change	There is resistance to change for updated facility management techniques.
Awareness, expertise, and cost	Lack of awareness for existence of this tools. Shortage of well skilled professional High cost of advanced 3D scanning tools.
Development of infrastructure, Variation of economy, and knowledge	Limited access with developed infrastructure, Variation of economy results for poor funding on technologies, and Less training programs for new systems
Prioritizing former system, Managerial directions, and Regulatory supports	Many conditions in Ethiopia give emphasis for early system. Moreover, many don't appreciate for new changes smoothly, and Government mainly not appreciating innovation on this specific facility management
Initial cost, Operational expense, and Training requirement	High initial cost for buying advanced 3D scanning tool, and Expecting high expenses.
Data processing, Software issues, and Hardware accessibility	There is little data acquiring system in Ethiopia.so finding data's need much energy and takes time. Less awareness on software compatibility with existing facility, and Limited availability of 3D scanning tools
Software professionals, decision	Limited skill on software management, and Less

on user	awareness on interpretation of features of the tool.
Innovation and technology adoption with Collaboration	Initiating and promoting innovation and technology acceptance by encouraging collaboration between government and construction firm.

As it be seen in discussion, Limited exposure to these technologies in academic institutions can reduce awareness among professionals. Consequently, it results for less exposure of professionals for these technologies. So, promoting the use of 3D scanning techniques in facility management requires raising awareness through focused educational initiatives and industry involvement.

BUDGET CONSTRAINTS

The high cost of advanced 3D scanning tools that are workable for institutions has been a barrier for applicability of 3d scanning tools. Which means a developing country like Ethiopia could have a struggle since budget shortages. Also, the budgets for lifetime and training cost can also affect in implementing the technology.

SKILLED MAN POWER

It is seen that; inadequate training initiatives may leave workers unable to handle and make efficient use of 3D scanning equipment. And the availability of less number of skilled professional makes a great obstacle for adoption of the 3D tool.

REGULATORY BODIES

It is courage for collaboration of regulatory bodies and the construction to work so as to the government may appreciate innovation on this specific facility management.

DEVELOPING A SUITABLE APPROACH FOR UTILIZING AS-BUILT 3D SCAN TO CREATE MODELS

Since it is described how to develop a 3Dscanned model, and ac challenges in current Ethiopia situation, it is possible to adopt a suitable approach for utilizing 3D scanning tools. A suitable approach for utilizing 3D scanning tools in building involves defining the scope, identifying stakeholders, outlining processes, and establishing key performance indicators

(KPIs). It also considers factors like cost, training, efficiency, time, and integration with existing systems which mentioned on objective two session.

Scope Definition clearly define the facilities objectives describes the object area to be scanned, and after defining the stakeholder's roles which can be architect, engineers or any other user, then it works on each step work methodology with processing the data and generating the desired output. And also Establish quantifiable indicators, such as accuracy, efficiency, cost reduction, and time saving, to control the implementation's process. It is possible to create a suitable approach with applying these important factors which maximizes the advantages and minimizes any potential drawbacks of using 3D scanning tools in construction may be created. Finally, I developed the suitable approach for applicability of 3D scanning tools in Ethiopia based on the findings above.

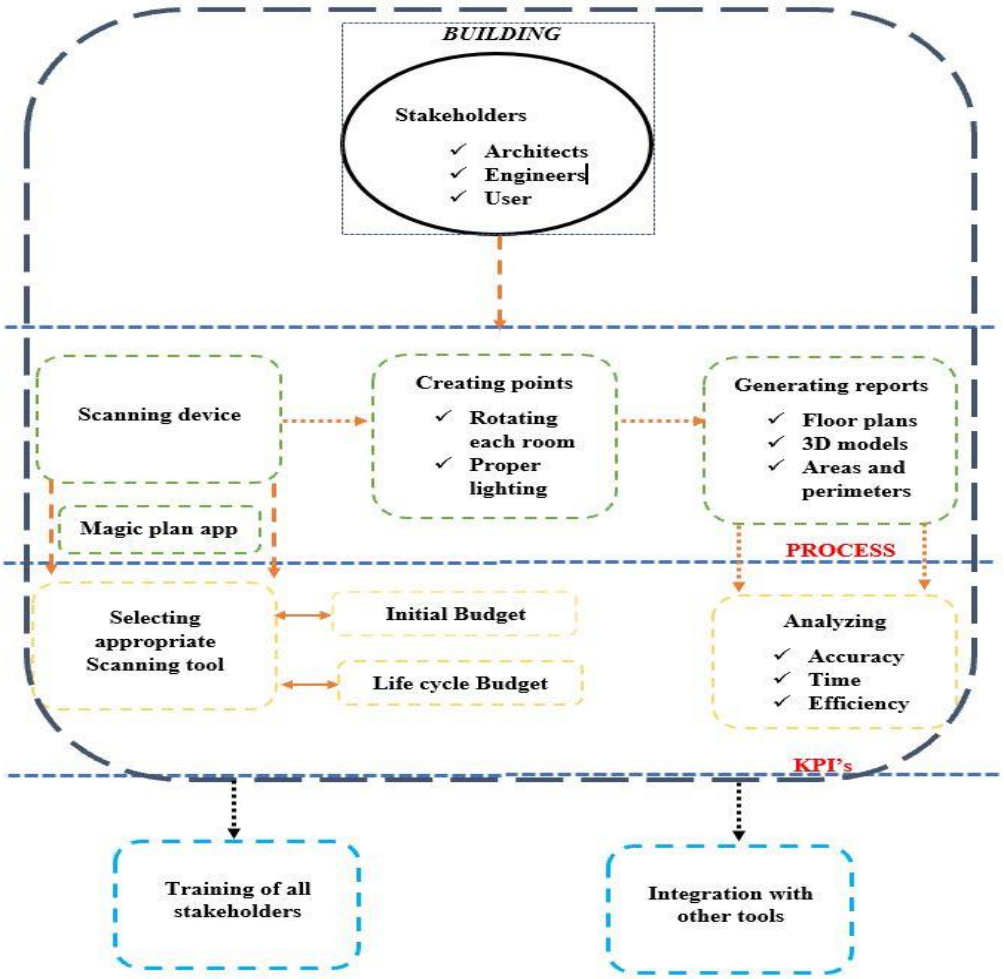

FIGURE 10: - A suitable approach for utilizing as-built 3D scan to create models in enhancing building facility management in Ethiopia

RESEARCH VALIDITY

The validation of the framework is done by sending back an evaluation paper for those who are participated on objective two experts. The evaluation paper has a point on making the suitable approach to be applicable. These are specificity, simplicity, attainability, comprehensiveness, and applicability

CONCLUSION

In the first objective, A comparisons taken between 3D scanning tool and the traditional manual measurement gave a result that adopting a 3D scanner tool has more better features in different scenarios. Those features are using 3D scanning tools would decrease a time and an effort with more accurate results. As it seen above it took one-tenth time to finish the whole process of generating floor plans than the laser distance measurement. Moreover, it gave more detailed information about each room with in the same consumed time than traditional measurement system.

In second objective, it gives some emphasis on which the barriers making applicability of 3D scanning tools on construction firms of Ethiopia. Some are awareness of construction sector which is a limited exposure to these technologies in academic institutions can reduce awareness among professionals. Consequently, it results for less exposure of professionals for these technologies. The great issues is raised when we deal on budget issues that is the high cost of advanced 3D scanning tools that are workable for institutions has been a barrier for applicability of 3d scanning tools. Which means a developing country like Ethiopia could have a struggle since budget shortages. Also, the budgets for lifetime and training cost can also affect in implementing the technology. skilled man power and regulatory bodies are the other main issues for less implementation of 3D scanning tools in Ethiopian facility management.

REFERENCE

Cotts, D. G., Kathy , O. . R. & Richard, P. . P., 2010. The Facility mangement Hand book. New York: AMACOM.

19111:, I., 2007. ISO. s.l.:s.n.

Abdi, K., Andrew, T. & Ertu, n., 2009. Computer Applications in Engineering Education. september.

Abdil, K., 2009. Implementation of 3D Optical Scanning Technology for Automotive Applications. Bursa, Nilufer, Turkey: s.n.

Alexander, S., 2015. Architectural Design with SketchUp: 3D Modeling, Extensions, BIM, Rendering, Making, and Scripting. UK: s.n.

Ali, R., 2017. s.l.:s.n.

Anon., 2014. Fundamentals (ISO 19115-1:2014). s.l.:Scheizerische Normen-vereinigue.

Anon., n.d. Agisoft LLC. (n.d.). Agisoft Metashape User Manual.. s.l.:s.n.

Arayci, 2004. An approach for real world data modeling with the 3D terrestrial laser scanner for built environment. Northumbr: s.n.

Artur, P., Aleksandra, M., Jacek, S. & andIwona, S., 2023. A Case study of 3D scanning techniques in civil engineering using the terrestrial Laser scanning technique.

Atkin, Brian; Brooks, Adrian, 2009. FM services source. UK: willey.

Atkin, B. & Brooks, A., 2016. Total Facility Management. west sussex, UK: John Wiley & Sons, Ltd.

Baldry, B. :., 2003. Facilities Management Towards Best Practices. oxford: Blackwell Science.

Barrie, C. & Peter, S., 2007. Building maintenance management. s.l.:black well.

Booty, F., 2009. Facilities Management Handbook. s.l.:Elsevier Ltd.

Brian, J. B. & Wood, 2009. Building maintenance. London: Blackwell Publishing Limited.

Brodt, W. & East, W., 2007. BIM based facility mangement. New York: building SMART alliance (National Institute of Building Sciences).

Capturing Reality, n.d. RealityCapture User Manual. s.l.:s.n.

Clive, B., Paul, B., Lee, M. & Thomas, R., 2018. 3D Laser Scanning for Heritage. Advice and Guidance on the Use of Laser Scanning in Archaeology and Architecture. UK: Historic England.

Creaform., 2014. Reverse engineering of physical objects. s.l.:Creaform Inc..

Createmaster, 2014. Construction handover and digital O&M. UK: Createmaster.

David, C. & Edward, R., 2008. Facilities Management: Theory and Practice. s.l.:Americana management association.

David, M., 2016. 3D Scanning and Photogrammetry: A Practical Guide to Computer Vision and 3D Imaging. s.l.:willey.

Diaz-vilarino, Frias, Balado & Gonzales-Jorge, 2018. Scan planning and route optimization for control of execution of as-designed BIM. s.l.:Creative Commons Attribution.

Douglas, J. & Noy, E., 2011. Building Surveys and reports. west sussex, UK: A John Wiley & Sons, Ltd.

Edl, M., 2018. 3D laser scanners: History and applications.

Facilities Management association in UK, 2021. UK: IFMA.

George, V., 2010. Airborne and Terrestrial Laser Scanning.. Twente: whittles publishing.

Gerald, F. & Ramash, J., 2017. 3D Imaging on Mobile Devices. s.l.:Springer.

Gregor, L., 2010. iPhone LiDAR tutorial V.2. Copenhagen: s.n.

Häusler, G. & Zhang, S., 2016. Handbook of Optical 3D Metrology. s.l.:s.n.

Hu, C. & Linghui, K., 2020. Application of 3D laser scanning technology in engineering field.

Jaud, K., M. Delacourt & Bertin, 2019. Potential of smartphone SfM photogrammetry to measure coastal morphodynamics. s.l.:s.n.

Joncic, N. & Zachar, J., 2017. 3D DIGITAL RECORDING OF ARCHAEOLOGICAL, ARCHITECTURAL AND ARTISTIC HERITAGE. s.l.:CONPRA.

Joseph, G. F., 2003. The Facility Manager's Handbook. New York: The Fairmont Press, Inc.

Karl, K. & Sabry, E.-H., 2016. Photogrammetry: Geometry from Images and Laser Scans. s.l.:Walter de Gruyter.

Kothari, 2004. Research Methodology. Methods and Techniques. New Delhi: New Age International (P) Ltd..

Kumar, R., 2011. Research methodology. a step by step guide. third ed. London: SAGE Publications Ltd.

Laguela, Diaz-vilarino, Armesto & Arias, 2014. Non-destructive approach for the generation and thermal characterization of an as-built BIM. Paris: s.n.

Levit, J., 2003. Complete Guide to Preventive and Predictive Maintenance. Philadelphia: Industrial Press.

Levitt, J., 2013. Facilities Management: Managing Maintenance for Buildings and Facilities. s.l.:Momentum Press.

Marczyk, D, D. & D, F., 2005. Essentials of research design and methodology. New Jersey: John Wiley & Sons, Inc.

Mobley, K., 2003. An Introduction to Predictive Maintenance. Tennesie: Elsevier Science.

Mohid, j., Abid, H. & Rajiv, S., 2021. A case study on use of 3D scanning for reverse engineering and quality control..

Murphy, M. & Conor, D., 2017. CURRENT STATE OF THE ART HISTORIC BUILDING INFORMATION MODELLING. Ottawa: s.n.

Nam, H., Nguyen, Q. & Van Yen, N., 2024. Scan-to-BIM for facility management: A case study of an existing office building in vietnam.

Palmer, D., 2019. Maintenance Planning and Scheduling Handbook. s.l.:McGraw-Hill Education.

Peter, B. & David, B., 2003. Facilities Management: Towards Best Practice. 2nd ed. s.l.:Blackwell.

R. & H., 2021. Industrial perspectives of 3D scanning: Features, roles and it's analytical applications.

Richard, P. P. & Roper, K. O., 2014. The Facility Management Handbook. New York: AMACOM.

Sacks, R., Eastman, C., Lee, G. & Teicholz, P., 2018. BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors. s.l.:willey.

Shalabi, F. & Yelda, T., 2016. IFC BIM-Based Facility Management Approach to Optimize Data Collection for Corrective Maintenance.

Stefano, C. & Roberto, S., 2018. 3D Technologies for Cultural Heritage: An Introduction to 3D Technologies for Museums, Archaeology, and Art. Italy: s.n.

Teicholz, E., 2004. Facility Design and Management Handbook. s.l.:McGraw-Hill Professional.

Toru, Y., Jorge, C. & Jose, P., 2015. Handbook of optical metrology: principles and application. s.l.:CRC Press.

Toth, C. & Renslow, M., 2017. Introduction to LiDAR. s.l.:CRC Press.

Wang, Q. & Kim, M., 2014. Applications of 3D point cloud data in the construction industry: A fifteen-year review from 2004 to 2018. UK: s.n.

wang, zhang, Qi, C. & Zhaoyu, Z., 2019. A Survey of Mobile Laser Scanning Applications. Guangzhou: s.n.

Wan, J., 2022. Application of 3D Laser scanning technology using Laser Radar system to error Analysis in the curtain wall construction.

Xiao, Y., 2017. Exploring the impacts of facility management. s.l.:s.n.

Zhana, Liangb & Xiaoa, 2009. From point cloud to BIM: a survey of existing. s.l.:s.n.

Zhang, S., 2018. *3D Laser Scanning Technology: Principles and Applications.* s.l.:s.n.