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Chair of Construction Management

Developing BIM-Enabled Built Asset Facility Information Management System: A Case of Public Universities in Addis Ababa

By

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ABSTRACT

Facilities management (FM) is a discipline comprising various processes, activities and maintenance services to support the main functions of built asset facilities. It demands sets of comprehensive information. Lack of information is one of the major challenges in the O & M phase of the built asset. The emergence of Building Information Modelling (BIM) systems, helped to solve the issue and improve the efficiency of built asset facilities management. Currently, the public universities have no data/information and related documents on the built asset facilities. The built asset facilities information management system is conventional and has a major difficulty. Therefore, it is necessary to study BIM-Enabled Built Asset Facility Information Management System. This study aims to explore the current practice of built asset facility information management systems in public universities and identify the required information for BIM-enabled built asset management. The importance of identifying the required information is to facilitate the FM decision-making process. Finally, this study aims to develop the conceptual framework of a BIM-enabled built asset facilities information management system. The study adopted both descriptive and exploratory types of research. A multiple-case study was conducted on the three public universities in Addis Ababa. Data collection and analysis were based on an extensive literature review of similar studies followed by a semi-structured interview, document analysis, and observation. The study adopted both quantitative and qualitative methods. All interview, document analysis, and observation data were analyzed using the thematic and statistical analysis method. The study findings indicated that the FM office in public universities didn't have the data or information of the old built asset facilities but to some extent, they have as-built drawings for recently completed projects. So, the lack of information has an impact on the time and the cost of the O & M process of the built asset. The FM office practiced the conventional method to capture, visualize, transfer and manage the built asset information. Currently, all the basic, technical, managerial, commercial, financial, and legal information are extremely relevant for built asset management in the selected public universities. Accordingly, to manage the built asset information, the FM office in public universities needs a single platform. As a result, a BIM-enabled FM conceptual framework was proposed. Finally, the future study should further develop the proposed framework and adopt it in public universities.

Keywords: FM, Built asset, BIM, BIM-FM Integration, Information requirement, information management system, Asset Information Modeling (AIM).

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ABBREVIATIONS

AEC	Architecture, Engineering, and Construction
AI	Artificial Intelligence
AIA	American Institute of Architects
AIM	Asset Information Model
AIR	Asset Information Requirement
AR	Augmented Reality
BAS	Building Automation Systems
BCF	BIM Collaboration Format
BIM	Building Information Modelling
BIFM	British Institute of Facilities Management
BMS	Building Management Systems
BSI	British Standard and Specification Institution
CAFM	Computer-Aided Facility Management
CMMS	Computerized Maintenance Management System
COBie	Construction Operations Building Information Exchange
ECA	Economic Commission of Africa
ECPMi	Ethiopian Construction Project Management Institute
EDMS	Electronic Document Management System
EIR	Exchange Information Requirements
EMS	Energy Management Systems
FM	Facility Management
FMAA	Facility Management Association of Australia
GDP	Gross Domestic Product
GEFMA	German Facility Management Association
GTP	Growth and Transformation Plan

HKIFM	Hong Kong Institute of Facility Management
HVAC	Heating, Ventilation, and Air Conditioning
IDM	Information Delivery Manual
IFC	Industry Foundation Classes
IFMA	International Facility Management Association
LOD	Level of Development
LOG	Level of Geometry
LOI	Level of Information
IoT	Internet of things
ISO	International Organization for Standardization
IT	Information Technology
IWFM	Institute of Workplace and Facilities Management
IWMS	Integrated Workplace Management Systems
MVD	Model View Definitions
OIR	Organizational Information Requirement
O&M	Operations and Maintenance
PIM	Project Information Model
PIR	Project Information Requirement
RIBA	Royal Institute of British Architects
RICS	Royal Institution of Chartered Surveyors
SAFMA	South African Facilities Management Association
UAV	Unmanned aerial vehicles
VR	Virtual reality

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CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

The construction industry significantly contributes to the economic growth and social development of the nations. The construction industry also plays a key role in satisfying a wide range of physical, economic, and social needs and contributes significantly to the fulfilment of various major national goals. It includes residential buildings, commercial buildings, factories, office buildings, school buildings, roads, bridges, ports, railroads, sewers, tunnels, etc. Construction is also an activity that creates all types of new buildings, and engineering structures, as well as the operation and maintenance activities of the existing facilities(Wang et al., 2018). The Construction industry is large, volatile, requires great capital outlays and is one of the largest industries in many developing countries, the same is true in the case of Ethiopia.

The construction industry in Ethiopia is a major source of economic growth(Falcioni,2015). However, the percentage share of the construction sector to GDP at the constant basic price has decreased from 11.3% in 2007/08 to 9.9% by 2019/20(NBE, 2021). The expansion of economic infrastructure (buildings, roads, railways, telecom, power, irrigation) is critical to achieving the country's Growth and Transformation Plan (GTP). A significant amount of the country's budget is allocated to economic development through financing infrastructures for the development of education and power projects, and the construction of railways and road projects (Tefera, 2013).

The operations and maintenance (O & M) phase is one of the lifecycle phases of the built asset facility. Hence, it requires serious follow-up for the effective use of the built asset. It also proper management with specific skills. Facility Management(FM) refers to the management of a facility during its O & M phase.

According to ISO (2018), FM is the organizational function that integrates people, place, and processes within a built environment to improve the quality of life of people and the productivity of a core business. Furthermore, IFMA(2021) defines FM as a profession that encompasses multiple disciplines to ensure functionality, comfort, safety, and efficiency of the built environment by integrating people, place, process, and technology. Typically, facilities account for a significant portion of an organization's annual costs. This is because, for an investment made in the new construction of university buildings, highway projects, railway projects, dam construction, and real estate development, the amount of resources utilized in terms of cost and time is relatively small compared to the lifecycle of the built asset. Thus, there should be a fundamental shift from a reactive FM practice to a strategically managed and proactive FM to improve and efficient utilization of the resource (Parsanezhad, 2019). The existing buildings in Ethiopia have a lot of shortages in providing appropriate services due to a lack of proper FM. Also, Currently, the practice of FM is at the infant stage but it is expected to boom due to its benefits during the operational phase of a building. Accordingly, for the successful operation of a building in the city, the development of FM and improvement of existing FM practices, and, the enhancement of technology-aided practices are recommended(Tsegaye, 2022).

In current practice, Building Information Modeling (BIM) is a prominent initiative that scholars and practitioners frequently address as a game-changer of the construction industry in general and FM in particular. According to Succar (2009), BIM is a set of integrated policies, processes, and technologies generating a methodology to manage building design and project data in digital format throughout a building lifecycle. Various studies have shown how BIM is transforming the way buildings are designed and built; fostering multi-disciplinary collaboration; integrating 3D design analysis; construction scheduling; cost forecasting; sustainability energy evaluation; and FM (project lifecycle information).

One of the requirements for a coordinated FM practice is information logistics. In this respect, BIM models have the potential to improve FM practice by extending the model into the post-occupancy period (McArthur,2015). According to Denton and Mcllroy (2018), BIM provides a robust platform for FM information management. BIM-FM data integration comes with issues related to establishing an effective process to extract, store, and distribute data to ensure interoperability (Farghaly et al., 2019). Although FM information management systems are used to manage the various graphical data, non-graphical data and document in BIM from feasibility to construction phase has still not been sufficiently integrated with existing FM systems (Yalcinkaya et al., 2016a).

Accordingly, built asset FM requires an information management system that automatically captures, stores, and integrates the data to support the decision-making process(Farghaly et al., 2019). Currently, poor integration of project information from Project strategy to closing out phase, lack of standardization on information exchange format, and poor performance in the automation of information exchange from one authoring tool to another affect the built asset information management. Also, there is a mismatch between the type and amount of information that is needed by FM staff and what is currently being delivered by design and construction professionals (Alvarez-Romero, 2014). Moreover, the operation and maintenance of built assets are crucial for optimizing their whole life cost and efficiency. However, there has been a general failure in the transfer of information from the design and construction (D&C) and O&M phases of the built asset lifecycle. The recent steady uptake of digital technologies, such as BIM in the D&C phase has been accompanied by an expectation that this would enable the better transfer of information to those responsible for O&M(Rogage and Greenwood, 2020). In practice, facility information management is quite erratic, slow, and costly procedures and uses printed documents for the handover process(Teicholz, 2013) as shown in the figure below.

Figure 1- 1: Picture of document storage for FM information after the document is transferred by the contractor (Teicholz, 2013)

A preliminary assessment was conducted to identify the problem of the built asset facility information management system in selected public universities and NGOs. Also, the pilot data was collected from experts and professionals through an informal discussion regarding the information management system of the built asset facility. As a result, built asset management is frequently erratic, slow, and uses complicated procedures, as well as the quality of some built asset facility information is poor. Moreover, the data/information transferred from the developer to the owner is in printed document format. Decisions are not verified by statistically relevant information and knowledge-driven method from consistently composed data. Furthermore, the believable scenario is information management system has not been sufficiently captured, researched, and documented. Thus, the above issues draw starting point for the research motivation to explore the BIM-Enabled Built asset information Management system of the public universities in Addis Ababa as case studies.

1.2 Statement of the Problem

The designated built asset facilities owner/FM office needs reliable information for the O&M of a built asset and data-driven decision-making process. Typically, data/information is generated during the planning, design, and construction stages of a facility and it is usually delivered at the end of construction in the form of as-built mainly paper-based (Alvarez-Romero, 2014). BIM has been recognized as a system to manage the facility lifecycle information. Currently, the implementation of BIM at the handover and O&M phase of the built asset facilities are limited (Wetzel et al., 2018). From a technical standpoint, there are limitations between the BIM-authoring tool and the FM information management system. Effective FM workflow requires timely and reliable information on various aspects of a system for built asset management(Alvarez-Romero, 2014).

BIM applications for the planning, design and construction phases of a new building have been thoroughly discussed and researched. However, BIM for the existing building and FM applications is still acknowledged as an emerging area for research and practice. O and M stage is also the most expensive phase during the life cycle of a building. Currently, much of the information used there is still paper-based and is not properly delivered to the owner (Patacas et al., 2015). Extensive data/information and documents are needed for effective O & M of the built facilities. Also, finding efficient ways for collecting, accessing, and updating this information is very important (Teicholz,2013).

FM information systems on the market claim to address the needs of FM requirements (Liu and Issa, 2021). Furthermore, FM demanded comprehensive sets of information about the built asset facility(Yalcinkaya et al., 2016a) and (Nicał and Wodyński, 2016).

In Ethiopia, the current use of BIM and FM is being talked about, but it is still at its infant stage and there is no contractual background for the implementation of BIM for the project delivery and operation phase. Also, there is a gap to understand FM and BIM very well, and what data/information is required by the FM team/owner in the O & M phase of facilities in the building construction industry. However, data/information is everything and critical for built asset management. Based on the overall preliminary assessment the problem was identified as follows:

- The ministry of education as well as the Ethiopian government allocated a huge amount of budget for project development. The data collected from the ministry of finance indicated that the Ethiopian government spent around ETB 61 billion to develop 4th generation universities, ETB 12 billion for 3rd generation universities, and ETB 4.1 billion for 2nd generation and has been continuously invested especially since 2005. The government has invested around ETB 91.5 billion for the construction of the project in public universities for the last four years (MoF, 2021). However, the O & M phase is overlooked and faced multifaceted challenges(Nibret,2015) and (Tsegaye, 2022).
- The public universities incorporate different types of facilities such as laboratories, libraries, lecture halls, offices, student and staff residence buildings and other infrastructures and thus proper built asset facilities information management system is very important.
- Public universities are suitable places for innovation and adoption of technologies like BIM as one of the major functions of universities is to serve as research, innovation and technology centres.

Currently, the public universities are practising conventional methods for data capturing, delivering, and managing the built asset in built asset information management systems. This brings inefficiencies of data/information management, information loss, wasted time in searching for the built asset data, inconsistencies of the available data, poor building maintenance management, loss of workforce productivity and reworks, and inconvenience to end-user. Currently, the growth of the construction industry is rapid and the ministry of education, as well as the country, spent substantially economy to develop the public universities. But, the Built asset Facility in public universities does not meet the intended purpose. Due to this, substantial economic losses occurred.

Thus, the main problems in public universities include:

- Lack of appropriate FM information /maintaining quality of information and the practice to manage the data/information of constructed facilities are conventional.
- Lack of awareness and understanding of the concept of BIM, FM as well as the required information for FM.
- Quite there seems to be no data/information about the built asset, but some data is usually delivered at the end of the construction in the form of as-built documents (the data transfer format is paper-based), which has an impact on the data/information quality, and the data/information is stored in an unorganized way after handover.
- FM and BIM implementation are still at the infant stage in the construction industry. However, neither public universities nor private institutions have implemented FM or BIM.

In summary, unstructured and late delivery of data/information in the O & M phase of buildings is a recognized issue among researchers and practitioners. Although BIM processes, technologies, workflows, and standards are providing a new possibility to address this challenge. Hence, BIM implementation for new and existing buildings is being talked about in Ethiopia so it is still at an infant stage. Therefore, this study contributes to filling the gap in the literature and the current practice of built asset information management systems in Public Universities. Besides, the essence of this study is to solve the problem and contribute to the existing knowledge by developing a conceptual framework for BIM-enabled built asset Facility information Management system.

1.3 Research Questions

This research addresses the following research questions:

- What is the current practice of built asset facility information management systems in the public Universities in Addis Ababa?
- What type of data and/or information is required for BIM-enabled built asset facility Management?
- What kind of conceptual framework can be developed to address the challenges of a built asset facility information management system?

1.4 Research Objectives

1.4.1 General Objective

The general objective of this study is to investigate the information management practice and develop a BIM-enabled built asset information management system in the Public Universities in Addis Ababa.

1.4.2 Specific Objectives

The specific objectives of this study are:

- To assess the current practice of built asset facility information management systems in the public Universities in Addis Ababa.
- To identify the required data/information for BIM-enabled built asset Facility management.
- To develop a conceptual framework for BIM-enabled built asset Facility information Management system.

1.5 Significance of the Study

The direct beneficiary of this study is the FM and project offices in the public universities. From this study FM and project office will understand the impact of lack of information in the O&M phase of a built asset, will know the data or information transfer format from the developer to the owner /FM office and will identify relevant information during the construction phase to use for built asset management. FM and project offices will also know the benefits of a BIM-enabled built asset information management system. In addition, this study will contribute to pre-existing BIM-enabled FM knowledge Via developing a conceptual framework for BIM-enabled built asset Facility information Management systems for public universities as well as the construction industry.

1.6 Scope and Limitation of the Study

This study focused on the selected public universities in Addis Ababa. The selected public universities are the most advanced institution and have been spending huge amounts of cash to develop new building facilities over the last two decades. Those public universities incorporate a wide range of built asset facility types, such as laboratories, classrooms, conference halls, auditoriums, parking lots and garages, dormitories, restaurants, sports centres, libraries, infrastructures, etc. As a result, it is unrealistic to cover such a vast scope of built asset facilities in a single study. However, this study focused specifically only on the existing building information management system. Due to the current security issues in the country and economical constraints, the study was limited to public universities in Addis Ababa. In order to perform a detailed investigation and because of sample similarity, out of the five public universities in the city, this study was limited to only three public universities in Addis Ababa. The expression “built asset facility” in this study refers to the existing buildings in those public universities.

Furthermore, BIM is a vast subject, and its implementation has numerous aspects, applications, and purposes. So, this study was focused on BIM applications for facility management, specifically on built asset information management systems. Although BIM is encouraged to improve construction projects throughout the life cycle, this study was focused on the O & M phase of built asset information management through BIM-enabled FM.

1.7 Description of the study area

This study was conducted in Addis Ababa. Addis Ababa is a city is located in Ethiopia with GPS coordinates of 8° 58' 50.1708" N and 38° 45' 27.9396" E. The latitude of Addis Ababa is 8.980603, the longitude is 38.757761 and its elevation is 2293.981m. It is the capital and largest city of Ethiopia. It is located on a well-watered plateau surrounded by hills and mountains in the geographic center of the country. Addis Ababa is the educational and administrative center of Ethiopia. It is the site of Addis Ababa University (1950) and the other four public universities. Also located in the city are the Museum of the Institute of Ethiopian Studies and the Yared School of Music, both of which are operated by the university; the National Library and Archives; palaces of former emperors; and government ministries. The selected multiple public university cases are located in Addis Ababa. The current situation of the country and cost constraints are the reasons for choosing and restricting the study area in Addis Ababa.

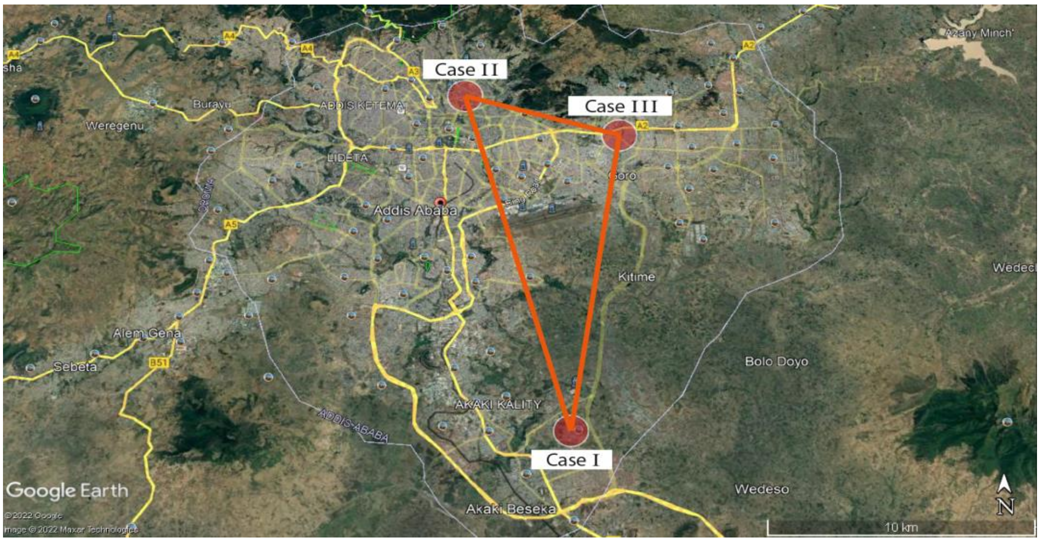


Figure 1- 2: The study area description

1.8 Structure of the Research Report

The structure of this study is presented and discussed in five chapters. These chapters have sub-sections that focus on different aspects of the research and describe how it was carried out. The first chapter discusses the introduction; the second and third chapters discuss the research focus area and methodology respectively; the fourth chapter discusses the analysis and discussion, and the final chapter discusses the conclusion and recommendations. Thus, the outline of this thesis report is as follows:

Introduction

The core issues to be addressed in the research are introduced in this chapter. Thus, this chapter provides a general background to the subject area and presents the problem statement and the research question. It also articulates the research objectives and defines the scope and limitations of the study. Finally, it defines the significance of this study.

Literature Review

This chapter discussed the theoretical background of the subject under investigation. Hence, it also assessed the context of the study and identified the research gap.

Methodology

This chapter reviews the existing literature and formulates scientifically the research approach, strategy, data sources, data collection method, data validation and reliability checking techniques, and data analysis methods employed in this study.

Results and Discussion

In this chapter, the data is analyzed and interpreted, and the results are compared to theoretical justifications. The research questions' findings are first discussed and summarized. For each of the questions, the findings are then examined and validated.

Conclusions and Recommendations

The conclusions and recommendations of the study are covered in this section. It reviews the research questions and objectives once more and relates them to the research findings. The implications of the study for the body of knowledge on BIM-enabled Built asset Facility information Management system is also briefly discussed. Finally, it also presents the recommendations for future investigation.

CHAPTER TWO: LITERATURE REVIEW

2.1 Construction Industry

The construction industry significantly contributes to the economic growth and social development of the nations. The construction industry also plays a key role in satisfying a wide range of physical, economic, and social needs and contributes significantly to the fulfilment of various major national goals. It includes residential buildings, commercial buildings, factories, office buildings, school buildings, roads, bridges, ports, railroads, sewers, tunnels, etc. Construction is also an activity that creates all types of new buildings, and engineering structures, as well as the operation and maintenance activities of the existing facilities (Wang et al., 2018). The Construction industry is large, volatile, requires great capital outlays and is one of the largest industries in many developing countries, the same is true in the case of Ethiopia. Construction is also one of the most important industries, accounting for more than 13.5% of the global economy by 2025 (Betts et al., 2013). As a result, construction is a major contributor and backbone of many countries' economic growth, especially in developing countries (Ofori, 2015 and Rameezdeen, 2017).

Ethiopia spends a significant amount of money every year on new infrastructure projects such as public university projects, dams, highways, railways, hydroelectric power, and other infrastructure projects. It is a major source of economic growth(Falcioni,2015). The construction industry has grown significantly in recent years. The construction's GDP expanded 30 times from 15,130 million ETB in 2010 to 495,283 million ETB in 2019, according to national accounts statistics in the African Statistical Yearbook (ECA, 2019). However, the percentage share of the construction sector to GDP at the constant basic price has decreased from 11.3% in 2007/08 to 9.9% by 2019/20(NBE, 2021). The expansion of infrastructure (buildings, roads, railways, telecom, power, irrigation) is critical to achieving the country's GTP. A significant amount of the country's budget is allocated to economic development through financing infrastructures for the development of education and power projects, the construction of railways and road projects (Tefera, 2013). However, Ethiopia's construction industry has been facing numerous challenges such as policy implementation; corruption; weak capacity of contractors and consultants; lack of collaboration and professionalism; and lack of benchmarking construction industry development (CID) practice from the role of government, resource-related variables, and the nature of the construction industry itself (Ofori, 2018; Mengistu and Mahesh, 2019). In addition, the level of construction project management practices in terms of adopting advanced general project management procedures (such as risk, time, safety, etc.), functions, tools, methods, and techniques are unsatisfactory and very low (Ayalew et al., 2016). Despite these challenges, the country's infrastructure development and FM of big infrastructures such as university buildings, highway projects, rail projects, dam construction, real estate development are still in the infant stage also there is no well-organized CID policy.

2.2 Facility Management

2.2.1 Definition of Facility Management

Different scholars and FM Associations define FM in different ways as shown in the table below;

Table 2- 1: Definitions of FM

Associations Definition of FM	
Association	**Definition of FM**
IFMA(2021)	FM is a profession that encompasses multiple disciplines to ensure functionality, comfort, safety, and efficiency of the built environment by integrating people, place, process, and technology.
ISO 41001:2018	FM is the integration of multiple disciplines to influence the efficiency and productivity of economies of societies, communities, and organizations, as well as how individuals interact with the built environment.
BIFM (2018)	FM is the integration of processes within an organization to maintain and develop the agreed services which support and improve the effectiveness of the client's primary activities.
FMAA (2015)	FM is the practice of integrating an organization's people and business processes with its physical infrastructure in order to improve company performance.

HKIFM (2021)	FM is the process by which an organization integrates its people, work process, and physical assets to serve its strategic objectives. As a discipline, FM is the science and art of managing this integrative process from operational to strategic levels for promoting the competitiveness of organizations.
GEFMA(2013)	FM is defined as the analysis and optimization of all cost-related processes relating to building, construction of another facility, or organization performance that are not related to the principal activity of the organization.
SAFMA (2017)	FM is an enabler of sustainable enterprise performance through the whole-life management of productive workplaces and effective business support services.
Scholars Definition of FM	
Scholar	**Definition of FM**
Abdullah et al.(2013)	FM is multi-disciplinary services and activities that have integration between people, place, process, and technology.
Fadahunsi et al.(2019)	FM is an interdisciplinary feature of a company that coordinates room, infrastructure, individuals, and organization.
Potkany et al.(2015)	FM is a term that is intimately correlated to building management. More broadly, FM should be seen as more than just conventional building management related to day-to-day building operations; it should also include long-term planning and a focus on its users.
Mohanta & Das (2017)	FM is a multifaceted, complex process that also supports the management and maintenance of a building and its services, but it is often challenged by a lack of updated information.

Due to the cultural differences across countries and the numerous temporal dimensions that have led scholars to focus their attention on slightly different meanings of FM over the years, it still has a common vision and mission.

Based on a critical analysis, the researcher proposes the following FM definition: FM is the Science and Art of managing the integrated process from operational to strategic levels to ensure the functionality, comfort, safety, and efficiency of a built environment by integrating People, Place, Process, and Technology.

2.2.2 Scope of Facility Management

The definition and scope of FM are still debatable, and they are influenced by local culture, organizational goals, and individual interests(Ahmad Zawawi *et al.*, 2014). The IFMA model of a triangle of "Ps" summarizes FM concerns: people, process, and place. These three variables are interconnected and have a direct relationship. The three key components of organizations are people, process, and place, and FM involves the entire organization. The location of FM in the center implies that relevant aspects of any organization will work together more effectively. However, FM is most active when it comes to aspects related to location.

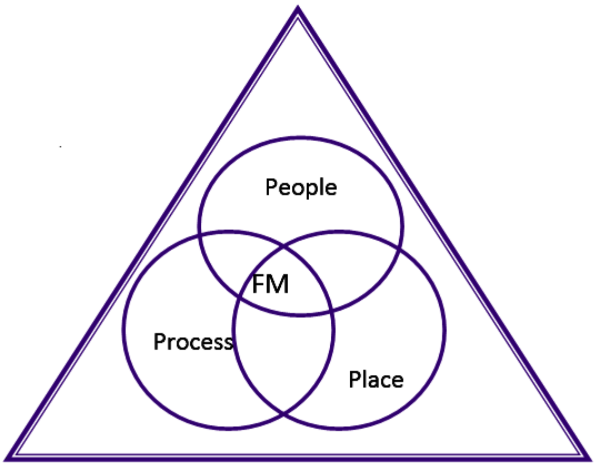


Figure 2- 1: Triangle of 'Ps' and FM (Source: IFMA,2010)

Hard and soft FM services are the two most common forms of FM services (RICS, 2018). Hard FM refers to services intended for the actual fabric and building systems, but it may also include more traditional FM services(IFMA, 2020). The IFMA and BIFM define the scope of each service as follows: Building maintenance, engineering, air-conditioning system, electrical system, plumbing system, fire-fighting, and fire prevention system, security system, building control system, building management system, and building fabric works are all under hard FM services. But Soft FM focuses on catering, cleaning, health and safety, landscaping and internal plants, security, pest control, handyman, waste disposal, and a diverse range of other support services.

Printing, reception services, information systems, space planning, and management services such as business risk assessment, business continuity planning, benchmarking, performance management, and contract procurement are also included in the (IFMA,

2020) as an additional Services category. Moreover, the scope of FM service is not only limited to the daily operation elements but also strategic aspects. The key aspect of the FM service revolves around the total management of the services to ascertain a quality service delivered to the clients and customers. In general, the scopes of FM services focus on the functional, technical, and image aspects that are from both management and operations components (Myeda, 2013).

The function of FM in the organization is to reconcile demand and supply. FM works in the area of the place in the IFMA model, but with obligations to support the needs of the people and processes associated with those places. Kincaid considers FM to be a support role or service that is part of the organization's non-core business (supply-side) and serves the needs of primary activities or core business (demand side).

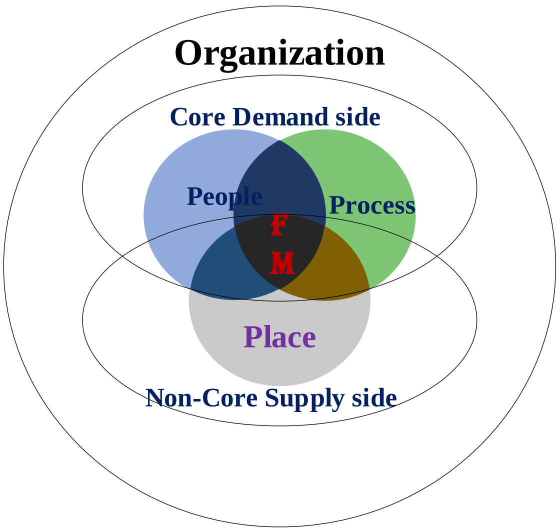


Figure 2- 2: Relationships & Organization in FM (Source: adapted from the Triangle of 'Ps'(source: IFMA)

In short, the scope of FM includes hard, soft service and disciplines. Moreover, the scope of FM service is not limited to the daily operation but also strategic aspects. FM can be broadly defined as support services integrated into a process to facilitate core business function effectively and efficiently by integrating Process, people, place and technology. it is critical to focus on the end-user, and the client, and ensure communication of agreed service levels and expectations.

2.2.3 FM process

The FM process has its basis in the administrative function of facilities, which includes issues such as maintenance, cleaning, and tenant security. The need to introduce tactical and strategic short and long-term FM functions. Other support functions, such as human resource management and information technology, are becoming increasingly crucial(Alvarez-Romero, 2014). Yet, Wood (2017) stated that FM processes are identifying business needs; developing FM Policy and Strategy; creating and implementing business support activities. In addition to that Shin et al.(2018) stated as the FM process is to define the facility, and the occupant's characteristics, establish an FM plan, gather necessary information, implement operation and maintenance, and review the performance of complementary actions. Those FMs processes work with the FM function to establish the object requirements and share FM information.

2.2.4 FM Level of Decision-Making

FM acts as an intermediate and integrating agent that attempts to reconcile the demand and supply sides. FM provides and manages a variety of support services in order to organize all of the organization's functions. It focuses on the integration of primary activities at both the strategic and operational levels(B. Atkin & A. Brooks, 2015). Based on function analysis FM is classified into operational and management functions. Routine support functions involving the staff are referred to as operational activities. At this level, tasks are focused on a limited time frame and require simple direct operations. However, management functions can be categorized as tactical and strategic. Tactics are plans of action that involve routine, specific, and short-term preventive and managerial operations. Hence, these activities are centered on safety procedures for prevention, as well as the proper use and care of maintenance resources(Patanapiradej, 2015).

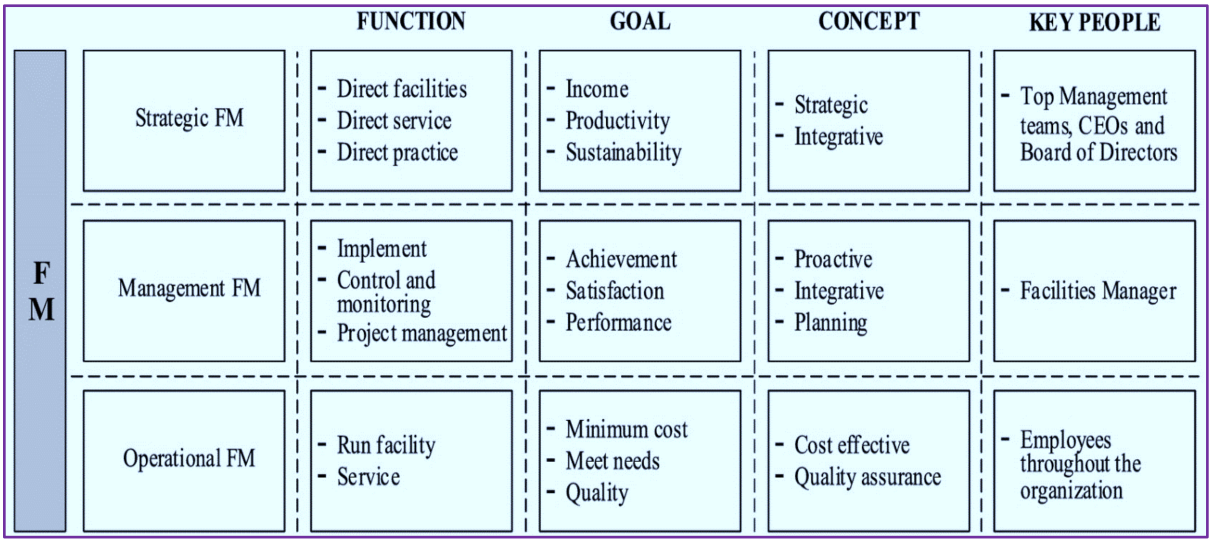


Figure 2- 3: Characteristics of FM Works in different levels (Source: Chotipanich, 2002).

The scope of FM should include all three levels of the decision pyramid of the FM organization (Svensson, 1998). In addition, management functions are commonly believed to operate on the three levels of an organization(Atkin & Brooks, 2015).

- **Strategic FM:** The strategic level is concerned with the long-term aim and direction of the FM functions. Strategic management is concerned with determining the organization's direction and ensuring that the means to achieve its long-term goals are in place (B. Atkin & A. Brooks, 2015). Planning, modelling, and simulation are some of the methods used to complete the work and carry out long-term planning while keeping external requirements in mind(Svensson, 1998). The strategic level manager has the responsibility for the outcomes and profitability of the Facility.
- **Tactical FM:** The gap between the strategic and operational levels is too great to bridge unless the strategy is translated into plans that can be implemented, monitored, and controlled (B. Atkin & A. Brooks, 2015). Moreover, the tactical (managerial) level is where one is concerned with making the entire FM organization function. This entails identifying needs and developing goals to meet needs(Svensson, 1998).In general defining routine methods, establishing standards, creating schedules, and securing resources are the responsibility of the Managerial FM level.
- **Operational FM:** At the operational level, the most important priority is to follow established procedures and lead progress toward the organization's strategic

goals(Atkin and Brooks, 2015), and the operational level is concerned with the day-to-day operations of the facilities(Svensson, 1998).

In most FM organizations, the management levels are the same(B. Atkin & A. Brooks, 2015). But, information requirements at each level are different (Svensson, 1998).

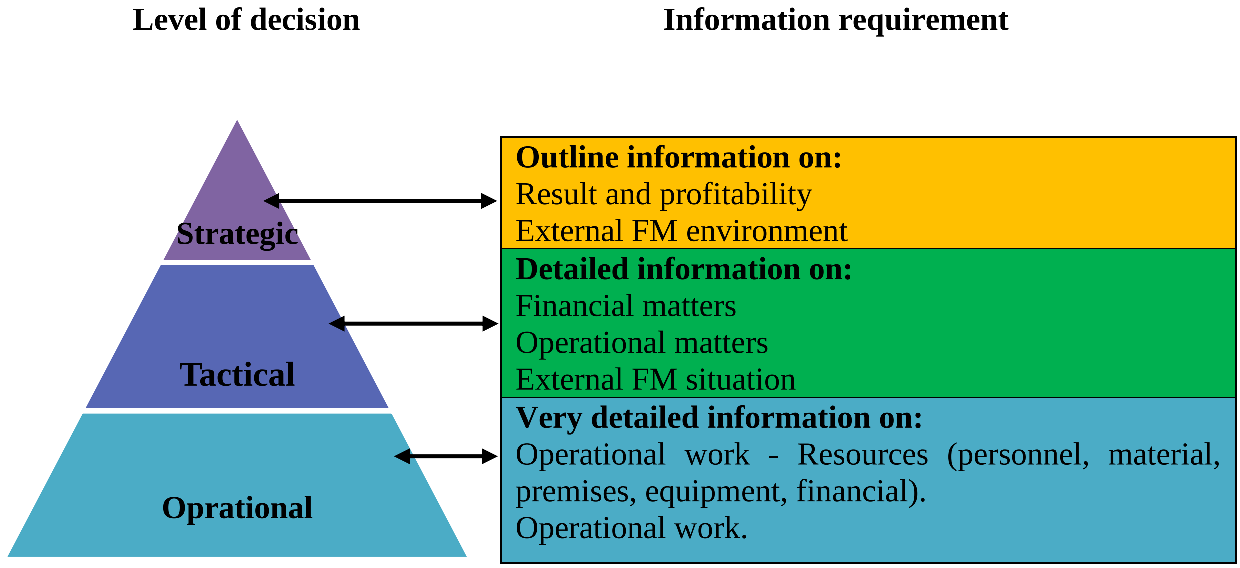


Figure 2- 4:The Decision pyramid of an FM organization(Svensson, 1998)

2.2.5 Facility Management Practice

The practice of FM is the process by which the organizations guarantee their buildings, systems, services, support the core activities and even contribute to the attainment of their strategic goals under stable business conditions. The practice of FM looks to enhance communication, streamline coordination, make choices based on objective facts, and ensure operations are related to the overall strategy initiative and developed by the organization. Depending on the aforementioned information, FM practices are different in different countries around the world.

2.2.5.1 International FM Practice

FM services were first provided in the 1950s and 1960s in the USA and they were fully developed in the 1970s, while in Europe FM practices had started to develop in the 1980s (Nielsen, 2012). The United Kingdom was the first country in Europe where FM practices began to grow. Back then, the United Kingdom was recognized as Europe's most important FM market, followed by Germany and France(Sari, 2018). Currently, the United Kingdom, the United States, the Nordic European countries, and the Netherlands are thought to be leading international developments in FM (Nielsen, 2012). Italy is one of the European countries experiencing a delay in FM practices when compared to other countries. Such a delay could be caused by an abnormality in the Italian economic structure, which is heavily skewed toward small and medium-sized businesses(Sari, 2018). However, FM practices in Asia and Africa are still considered a stranger in the industry if compared to those in Europe and the USA. Hong Kong as the door to Asia and the meeting point of western and Asian culture has become one of the leading countries of FM in Asia. The FM in Hong Kong has begun in 1994 under the local IFMA (Isa *et al.*, 2016) and (Maliene et al., 2008).

In conclusion, FM has a long history in the United States and Western European countries. The type of activities that originated in the United States in the middle of the 20th century, and in Europe around 1980, have weathered various stages of evolution. However, FM in Asia and Africa is still in its infancy. With the development of new technologies, complex construction, the expansion of telecommunications and electronic commerce, FM has widened beyond traditional services such as real estate and property management, financial management, market analysis, and building maintenance. Currently, facilities are viewed as strategic business resources.

2.2.5.2 National FM Practice

According to the researcher's assessment, FM practice in Ethiopia is currently inadequate and considered to be at its infant level. However, property management and maintenance management especially corrective maintenance are practiced. Furthermore, there is a knowledge gap in the definition and scope of FM between the facility executive committee at all levels of management, from strategic to operational. The majority of Ethiopian FM practitioners who work in FM directorates define the scope of FM as the maintenance of electrical lines, sanitary lines, water supply lines, painting, and general services. Furthermore, facilities managers are not recognized as a unique profession. On the contrary, FM practice has been successfully developed in non-governmental organizations (NGOs) and international organizations having headquarters in Ethiopia.

According to Nibret (2015), Ethiopian FM practice lacks a policy or standards, also the industry has faced a variety of issues, including a lack of skilled manpower in the Public University buildings, Integrated FM, and efficient FM planning. Additionally, Sahelu (2015) stated that poor maintenance management, deficiency of skilled manpower was also evident in the public hospital building maintenance management. In addition, FM practice on the Federal Housing Corporation includes a variety of issues relating to proper operation, maintenance, risk, sustainability concepts, emergency management, and integrated facility information management. Housing Corporation, on the other hand, demonstrated remarkable planning, stakeholder management, performance evaluation, and improvement practices (Nuru, 2020).

In general, Ethiopia is still considered a greenhorn in the FM industry when compared to other countries, particularly developed ones. Currently, FM has expanded far beyond the realms of real estate management and the tradition of building maintenance to the level where facilities are considered strategic business resources and have developed into integrated facilities management services (Nibret,2015) and (Tsegaye, 2022).

In Ethiopia, so far, there are not enough studies undergone to identify problems in built asset facility management practice, information Management, and FM information requirements and there are also no perceptible suggestions and recommendations for how to improve the current practice of FM. However, to some extent, the growth of FM practices and research in Ethiopia indicates that there is an interest in this area, which indicates well for the future development of the FM industry in the Country.

2.2.5.3 FM practice in Public Universities of Addis Ababa

The Ethiopian government has launched a massive expansion and reform initiative in higher education, to dramatically expand the number of students enrolled in HEIs and the number of universities in the country. According to national statistics, the country had only two universities in 2005, but an expansion of 40 new universities and the upgrading of existing colleges to university status will raise the total number of public universities to 50 in 2020. Construction of the university includes new construction, maintenance, renovation, and expansion of student dormitory, library, lecture halls, classroom, office, student cafeteria, laboratories assembly halls, and staff residence. Facility briefing, design, construction, and post-occupancy processes are all involved in the above university projects (RIBA, 2020). The University Construction project has experienced several challenges, but those challenges that extend beyond the development phase (Project Planning and Implementation) to the FM stage for developed buildings after completion.

These Public university facilities serve a variety of purposes, including educational, research, and administrative services. Because a facility is complicated and used by a variety of users, it needs a variety of maintenance requirements. Since FM is a new profession, there are a few literatures on the practice of FM in higher education institutions. In practice, the organizational structure, operation methods, and functions of the FM Unit in any university are different but determined by a variety of factors such as the age of infrastructure; the size of the university; multi-campuses; the number of student enrolment and new technologies. According to Kim(2020), university facilities are classified into four types: basic education facilities, support facilities, research facilities, and associated facilities.

However, according to the researcher's assessment, the university facilities in Addis Ababa are crudely basic education facilities, support facilities, research facilities, and associated facilities. The universities in Addis Ababa have a common FM practice, such as implementing both soft and hard FM services, conducting maintenance in-house, and outsourcing by service providers as well FM is aligned at the directorate level. Furthermore, none of the universities conducted a building condition assessment and does not have an FM information management system. Except for one University, none of the universities has a clear FM mission statement. To achieve the core teaching and learning objectives, public universities in Addis Ababa require substantial facilities, which frequently include buildings that are integrated with the process, technology, and people who have intricately linked relationships to one another in the university, so higher learning institutions require an efficient and effective facility. Public Universities in Addis Ababa frequently overlook the importance of built asset management to their overall performance and success. There is no regular survey of building conditions. Corrective maintenance and new building development are the main focusing area of the public university in Addis Ababa.

There are no sufficient studies in Ethiopia to identify issues in the built asset facility management practices, and no sufficient suggestions to enhance current practices. Besides, there are no sufficient professional, effective FM planning, training for building maintenance staff, regular building condition surveys, and a computerized maintenance system. Furthermore, the researcher noted that there is also a knowledge gap in FM. Built asset facility data and information loss is a major issue in FM practices of public universities in Addis Ababa as well as in Ethiopia. Additionally, the Lack of As-built drawings, contract documents, warranty documents, Standards, and specifications of the built asset is a critical challenge in public university FM practice. The built asset facility data and information loss impact on the built asset facility O & M cost and time. As a result, the researcher is interested to study the BIM-enabled Built asset facility information management system in the case of Public Universities in Addis Ababa.

One of the most essential aspects of this research is the review of information technology for FM. Technology advancement not only increases employee and consumer convenience but also enables deeper dives into collected data and information of the built asset. To support FM activities, a wide range of FM information technologies are available. Information technology has advanced in line with the scope and complexity of FM. Accordingly, FM requires an information technology that automatically captures, stores, and integrates the required data and information to support better decision-making across a diverse range of requirements. An ideal information system that can store and provide the FM data during all phases of the built facility. The changes are also recorded in the time of maintenance and operation of built assets (Farghaly et al., 2019). In addition to that, the application of emerging technologies within the area of building automation, such as the Internet of Things (IoT), Artificial Intelligence (AI), and Machine Learning (ML) are allowed to control the complexity of FM processes and services in an effective way(Redlein and Grasl, 2018). Hence, the FM industry is entering a new era of user and occupant experience needs, as well as organizational productivity, service integration, and the use of smart, cognitive technologies (Paper, 2020).

2.3 Technologies for Facilities information management

Globalization has demanded technological advancements, which have revolutionized the practice of FM. According to (Sooriyarachchi and Karunasena, 2018), Information Technology is both the hardware and software that are used to store, retrieve, and manipulate information. As a result, cutting-edge technologies such as drone technology, robotics, sensors, cloud-based technology, and the internet of things have become typical tools. Using those technologies by FM managers is important for adding value to the organizations. The adoption of these innovations improves both the core business and employees within an organization (Araszkiewicz, 2017a). Accordingly, Sooriyarachchi & Karunasena (2018) identified Information Technology (IT) as a rapidly evolving field in the world that radically changed the way most professions operate in the recent past. Emerging digital technologies could enable FMs to carry out tasks and processes more efficiently and effectively, freeing up time to spend on value-adding or strategic activities (J.Pinder and I. Ellison, 2020). Moreover, Current facility management practice relies on different systems which require new technologies to integrate and manage information more easily(Marmo et al., 2019).

The efficiency of communication and flow of information is one of the essential prerequisites for the fulfilment of strategic objectives of FM, broadly understood as interdisciplinary practice related to the management of buildings and facilities designed for building users(Araszkiewicz, 2017). Also, identifying, tracking, controlling, and managing Built asset facilities and problems are critical tasks in FM (Lee and Lin, 2011). CAFM, CMMS, BAS, EMS, EDMS, and BIM are Systems that have been proven and used in FM practice. However, the interoperability issues largely limit their functionality(Araszkiewicz, 2017). Accordingly, BMS and CAFM systems are well established, whereas BIM and IWMS are more recent additions with further potential. In general, technology can provide powerful strategic and tactical tools for FM information management (Nawawi, and Ariff, 2016).

The construction industry is undergoing a digital transformation within the innovation of virtual reality (VR) and augmented reality (AR), advanced HVAC technology, building information modelling (BIM) systems, machine learning and artificial intelligence (AI), smart building technology, Internet of Things (IoT), sensors technology and wearable technology. Outsourcing FM, Integrated Value and Related Services, Workplace Strategy, the Advent of the Robot, Augmented Reality and substantially simplifies building maintenance are the emerging FM concepts.

Table 2- 2: Information Technology

Digital technologies	Benefits and its Characteristics	Technologies Example for FM
Gateway	A gateway is a device that connects IoT devices, sensors, systems, and the cloud. It can perform local processing and storage, as well as control devices depending on sensor input. The data flow through the gateway can also be focused on meeting particular security requirements(IWFM, 2018). However, gateway technologies are already used to varying degrees within FM(J.Pinder and I. Ellison, 2020).	Augmented reality, BIM, BMS, CAFM, and Virtual reality(J.Pinder and I. Ellison, 2020).
Automation	Automation technology automates workflows, enabling FM to monitor repair and maintenance management in a rapid, easy, and efficient way. Automation is about doing things without human assistance, usually intending to do them better in some way(J.Pinder and I. Ellison, 2020). So, Automated FM focuses on putting facility services on autopilot.	IWMS, Cloud computing, IoT, Robotics (inc. drones), Additive manufacturing, and Autonomous vehicles(J.Pinder and I. Ellison, 2020).
Artificial intelligence	AI is all math that's used to analyze information and make decisions based on defined variables and preferred outcomes. AI in facilities management increases the ability of Facilities Managers to oversee and memory day-to-day operations in detail. Using self-optimizing systems, powered by the IoT(J.Pinder and I. Ellison, 2020).	Machine learning, Virtual Assistants, Chatbots, Image/visual recognition, and Virtual reality(J.Pinder and I. Ellison, 2020).
Analytics	Analytics operates as funnels to improve data specificity; as data becomes more detailed, it may become more relevant to various functions within the facility management system. Moreover, The use of analytics in FM is an excellent way to transform raw data into advanced, applicable insights(Neupane and Kim, 2020).	Data mining, Big data, Blockchain, and People analytics(Neupane and Kim, 2020).

Technological advancement now has a significant impact on FM practice (Jonathan and Michell, 2018). However, there is a continuing need to analyze and align its influence with the profession's current level of development, although keeping in mind the essential concepts of integrating people, place, process, and technology. Furthermore, by integrating each in the FM practice, digital technologies are used to acquire, record, integrate, model, store, translate and transform information. In short, drone technologies and BIM are crucial for built asset facility management to capture data and manage the data and information of the built asset respectively.

Drones can be one part of a multi-faceted FM aerial imaging strategy. Piloted drones can be utilized to provide aerial imagery and 3D maps(Paper, 2020). They are also known as unmanned aerial vehicles (UAV). Drone technology can be utilized in FM to access problematic spots that technicians cannot safely access or/and where the cost of accessing would be too high(Jonathan and Michell, 2018).

BIM is a process of organizing and accessing information about a structure in 3D format(Paper, 2020). According to Schley et al.(2016), BIM is used to create, maintain, and utilize built asset information to manage operations and maintenance of buildings throughout their operational lifecycles. Moreover, the emergence of technologies is used to record the information throughout the facilities lifecycle to improve the efficiency of FM (Dawood et al., 2013). Likewise, Hossain and Yeoh (2018) stated that BIM has a significant role in effective built asset FM by integrating information management tools.

In short, graphical and non-graphical data is collected in BIM during the project lifecycle. The data/information used for commissioning, quality control, energy management, O&M and closeout of the FM processes. While there are various computer- FM systems that can process data related to space management, built assets, and change management. However, the sources of information in these systems vary throughout the project life-cycle and information handover processes are challenged in those systems. In short, BIM has the potential to be a catalyst for the increased efficiency of FM. However, the majority of existing buildings in worldwide lack BIM-based modelling. Currently, research on BIM for existing buildings has great attention. Most of the research findings indicated that developing BIM for existing buildings is complex, time-consuming, and expensive.

2.4 Building Information Modeling (BIM)

The concept of BIM was first proposed by Professor Chuck Eastman at the Georgia Institute of Technology in late 1970 (Aryani, Brahim and Fathi, 2014) and (Talamo and Bonanomi, 2015). Subsequently, Talamo and Bonanomi(2015) stated that 3D modelling has been slowly developing as an integrated analysis and object-oriented tool until the 2000s. So, BIM started to be adopted in pilot projects to support designers' activities.

In short, BIM defines differently by different scholars and professionals. Some define BIM as a software application, others say it is a process for designing and documenting the information of the built asset facilities. Also, some define BIM as a holistic approach to the design, construction, and maintenance of the built asset.

An early definition of BIM was put forward by Charles Eastman in his theory combines the terms building product model. BIM is a system that integrates all of the geometric and non-geometric information, functional requirements and capabilities in a single system of the building project over its lifecycle. It also includes process information generated with construction schedules and production processes(Suprabhas, 2016). Also, Boukara and Naamane(2015) define BIM as an intelligent model-based process that provides insight to help you plan, design, construct, and manage buildings and infrastructure. So, BIM systems drive further than traditional CAD drawings by providing intelligence to individual building components.

BIM is a new methodology that involves the use of technologies to improve the collaboration and communication of construction players as well as the management of documentation(Aryani et al., 2014). As well, BIM is the idea of the continuous use of digital building models throughout the entire lifecycle of a built facility, starting from the early conceptual design and detailed design phases, to the construction phase, and the long phase of operation (Borrmann et al., 2018a; Sabol, 2018). Succar (2009) defines as BIM a set of integrated policies, processes, and technologies. Also, BIM is a methodology to manage the essential building design and project data in digital format throughout the building's life cycle. Furthermore, BIM is a process of information sharing that enhances communication and which helps in visualizing complex problems in the building industry (Frida Krantz, 2012). BIM is a digital technology for holistically managing the construction project information from planning, design, construction, and operations (ECPMI, 2019). In short, BIM is a digital system that integrates people, technology, and processes to create and manage information throughout the project lifecycle.

2.4.1 BIM Dimensions

BIM dimension has characterized the process of linking additional information to project models. When it comes to the usage of BIM for FM, there is no agreement on which of the BIM nD dimensions should be included. This is due to the current lack of standards and parameters for defining the nD BIM model with embedded information needed at various stages of a facility's lifecycle. The extent to which the term "dimensions" is used in BIM without appropriate agreement on what they represent and what constitutes them has sparked debate on the subject(Ângelo et al., 2020). In short, almost all scholars and countries share a similar ground in 2D,3D,4D, and 5D BIM dimensions and their definitions and Properties. However, there is a debate among scholars and country implementation priority on additional project model information above 5D BIM dimensions. This study focused on the 7D BIM dimensions, which are based on prominent researchers who agree on the definitions and the properties of BIM dimensions as well as the (ECPMi, 2019) roadmap BIM dimension definition.

2.4.2 BIM Maturity Level

The BIM maturity model represents levels of maturity regarding the ability of the construction supply chain to collaborate and exchange information. The UK Government Task Group proposed the concept of BIM maturity levels. The concept of BIM maturity is used to identify a set of process improvements that allow for the development of certain benefits. Also provides a wider awareness of BIM implementation development and diversity (Barros et al., 2021). Likewise, BIM Maturity refers to the quality, repeatability, and degree of excellence within its capability(Martin et al., 2019). Moreover, Maturity models are derived from the software industry and attempt to improve productivity and reduce defects by continuously improving organizational practices. The Capability Maturity Model was developed to respond to poor project performance and it is the basis for other maturity models(Munir *et al.*, 2019). According to Succar and Kassem (2016), BIM Maturity has three BIM stages a fixed starting point, and a variable ending point, allowing for technological developments in the future. At Levels 0 and 1 there is either a lack of BIM or an over-reliance on different systems of data.

In summary professionals in the construction industry practically never collaborate in the information generating process, and information is created and distributed using non-interoperable, paper-based documents. Although CAD drawings are used, no model information is exchanged. Aside from that, this professional was competent in 3D CAD and 2D drafting. While 3D CAD is utilized for conceptual work, 2D CAD is used to generate statutory approval documentation and product information. Currently, the majority of professionals are using BIM-oriented software, yet they are unable to communicate with one another. In Ethiopia, BIM Level 1 is practiced by building designers (Desbalo and Bargstadt, 2020) and (Belay et al., 2021). In short, the author of this study concludes that BIM Level 0 is practiced in the construction industry.

In conclusion, BIM maturity is used to define progressive stages of BIM implementation. The standard BIM maturity classification as specified in PAS1192:2 in 2013 has been assigned a number between 0 and 3, while the exact meaning of each level is debatable.

2.4.3 BIM Level of Development (LOD)

LOD describes the minimum dimensional, spatial, quantitative, qualitative, and other information included in the Model Component(Natspec, 2013). Besides, LOD is a method for managing BIM basic information. LOD is used to determine the specific content requirements of BIM model elements at a given instant. It is used to address the issue of insufficient project information(Latiffi *et al.*, 2015). In general, LOD defines both the required Level of Geometry (LOG) and the required textual Level of Information (LOI)(Borrmann *et al.*, 2018a).

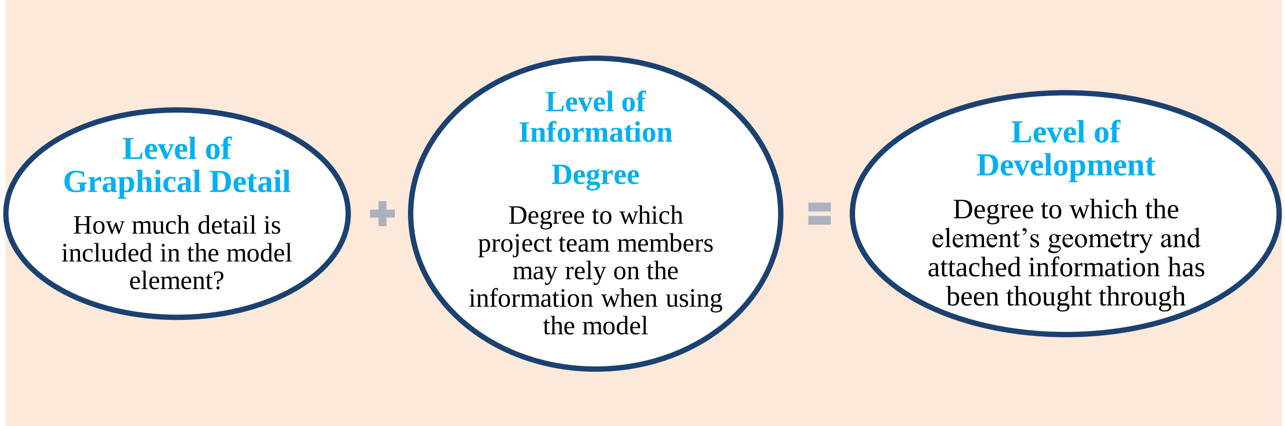


Figure 2- 5:Level of Development(Borrmann *et al.*, 2018a)

There are several systems to classify LOD in models, and different standards to adhere to depending on the geographical location or the reference institution. Two main LOD Standards or frameworks are widely used since they correspond to the main two blocks of influence:

- In the US American Institute of Architects (AIA) - BIM Forum LOD Standard.
- In the UK BSI - British Standard Institution Specification (BS EN ISO 19650).

LOD was first introduced by the AIA E202 in 2008 when it defined five different levels of development to define the detailing levels in a BIM model. But the concept of LOD was stated before on that(United BIM, 2021). However, AEC (UK) introduced Level of Definition as a new classification system with seven levels in 2013. It includes Level of Detail/Grade and Level of Information (LOI) to include both aspects of model detail.

BS EN ISO 19650 Specification for information management for the capital/delivery phase of construction projects replaced by LOI(ReBIM, 2021) and (Gobalcad, 2021). In a basic sense, at each stage of the project assign a LOD code to each building component or system. As a result, the basic codes differ between the US and UK standards, significantly complicating the situation. In general, LOD, LOI, and LOMD came to life through PAS1192, the provisional standard that defined BIM in the UK. Level of Detail(LOD); Level of Information(LOI); Level of Model Definition (LOMD) (also referred to as Level of Development within American texts) and Level of Information Need (LOIN) (GlobalCad, 2021).

In conclusion, this study is focused on LOD 500. As a result, the researcher noted, LOD 500 is the post-construction as-built model. Additionally, the integration of the 400-level fabrication model data into the 300-level model is a typical phase of the process of developing a 500-level model. So, the model includes all building elements and is geometrically correct while avoiding unnecessary fabrication level complexity at LOD 500. Furthermore, the model is delivered to the Facility Manager once the 500 level is completed.

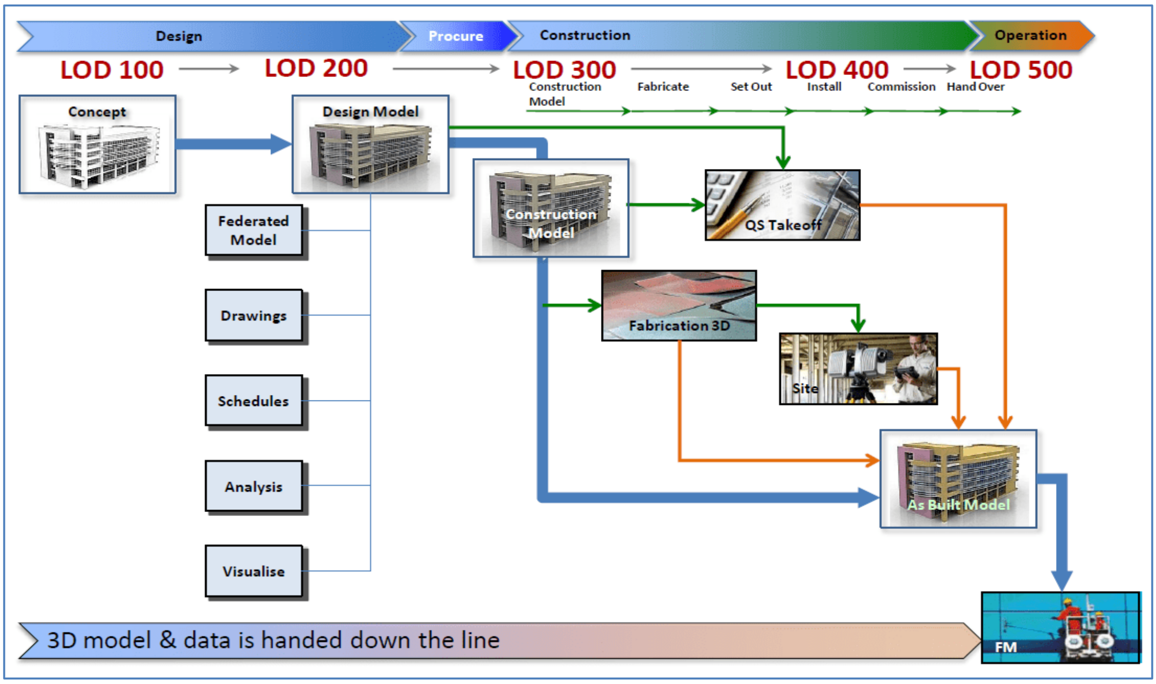


Figure 2- 6:Types of LOD to use in the BIM workflow process(Sources : https://www.interscale.com.au/bim-101-bim-level-of-development-lod-explained/)

2.4.4 BIM Standards, Specifications, and Classification system

Before defining and discussing BIM Standards and Specifications for Built asset management using AIM, first know the data type. As a result, data generated by software may be classified as either proprietary or open data. Open data is information that is freely available to the public and may be used, re-used, republished, and redistributed by anyone. To put it another way, everyone can access open data, but proprietary data can only be read by specific software solutions(UK BIM Framework, 2019). From the Conceptual to the operation phase of a project, the development of codependency of industry standards is the cornerstone of interoperability. The non-profit international organization building-

SMART developed and maintained the most commonly used standards in this field. This section briefly introduces international, US, Swedish, and a variety of building-SMART standards, including IFC, IDM, bSDD, and BCF.

2.4.4.1 Industry Foundation Classes (IFC)

IFC is a neutral open platform that enables building information to be exchanged between different CAD applications. The format may contain information such as the building hierarchy, element type, geometry, material, systems, zones, etc. The open standard was created by the buildingSMART alliance to meet the CAD software compatibility requirement of (Aðalsteinsson, 2014) and (UK BIM Framework, 2019). Also, IFC is a vendor-neutral data model for the exchange of building information among software and companies(Parsanezhad, 2019). Furthermore, the IFC schema was defined as an express schema within the step to address interoperability challenges within the AEC industry. The latest version of the IFC schema is currently registered with ISO as ISO16739, in EXPRESS and XSD(Batini et al., 2019). In short, IFC is a natural data transfer format to describe exchanges and share information specifically used in the modelling and FM.

2.4.4.2 Information Delivery Manual (IDM)

The methodology can be used to document existing/ new processes and describe the associated information that has to be exchanged between parties. The output from the standard can be used to specify the detailed specification of the software development process(UK BIM Framework, 2019).ISO 29481-1:2010 - Part 1 defines IDM as a methodology for documenting processes for the exchange of built asset and construction information. IDMs also specify the types of information that each actor should provide software-based information in the exchange process. Also, the exchange process could be executed successfully and minimize the loss of data during the transferring and interpretation processes (Parsanezhad, 2019). In short, IDM is integrating the business process and providing detailed project specifications.

2.4.4.3 Model View Definition (MVD)

MVD is a subset of the IFC data model that needs particularly to support the specific data exchange requirement during the project life cycle. MVD is used as an implementation guide for all IFC classes, attributes, relationships, and quantity definitions (UK BIM Framework, 2019) and (Parsanezhad, 2019).

An MVD consists of three main components:

- A set of concept templates. These concept templates define additional agreements on how to use the IFC Schema.
- A set of Exchange Requirements. This is a selection of entities and properties from the IFC Schema that are found suitable for a selection of use-cases.
- A description of how Software should deal with the data that are exchanged. It defines software to use the data as a reference, or should the data be mapped to internal objects during import.

2.4.4.4 Construction Operations Building information exchange (COBie)

The development of COBie began in late 2006 under the NIBS Facility Maintenance and Operations Committee and it is currently specified as a part of the United States National Building Information Model Standard. COBie is a widely-used MVD for facility management information handover. COBie is used to identify and exchange information about facility assets, throughout the lifecycle of facilities (Batini *et al.*, 2019) and (Parsanezhad, 2019). In June 2011 the UK Government published its BIM Working Party Strategy. This report announced the Government's intention to require collaborative 3D BIM with all project and asset information, documentation, and data being electronic on its projects by 2016. The software and data requirements for this detailed in the report are Construction Operations Building Information Exchange (COBie). In January 2019, the UK National Annex within BS EN ISO 19650-2 states that non-geometric information exchanges in open data formats should be structured to COBie format. As a result, COBie is a non-proprietary data format for the publication of a subset of BIM focused on delivering asset data as distinct from geometric information. Besides this, the COBie approach was developed as an organizational solution to address the lack of standardization and organization of the several documents that are handed over to the owner at the end of the construction stage. The COBie approach is to enter the data in a pre-specified format as it is created during design, construction, and commissioning (Alvarez-Romero, 2014).

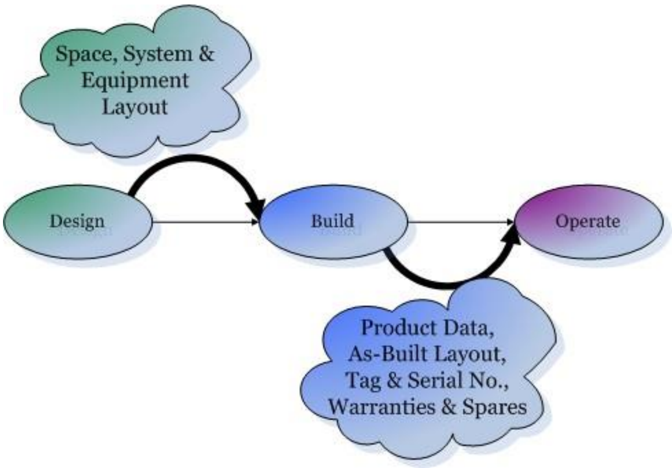


Figure 2- 7: Illustration of what information is captured and when using COBie(Alvarez-Romero, 2014).

The format does not provide answers on what the information deliverables should be is still the work of each owner/FM manager to define but rather how information is collected and presented during the building's whole LCC(Aðalsteinsson, 2014). Furthermore, COBie is a specification that evolved from the idea of Computer Aided Facility Management (CAFM). The specification describes processes and information requirements that streamline the handover of specific data from the design and construction phases to the facility's operation and maintenance (FM)(Schwabe et al., 2018). But, COBie is not a software application. COBie provides a template based on the composition of existing information specifications and exchange standards that have been in use for years. The information structure and the delivery format of COBie specifications are based on existing processes to reduce inefficiencies in facility information handover. Currently, COBie handover could be delivered in IFC, IFC XML, and spreadsheet formats. By considering the end-users inexperience and limited familiarity with the first two file formats, the spreadsheet has become the common way to represent COBie(Yalcinkaya and Singh, 2015) and (Parsanezhad, 2019). A COBie spreadsheet is composed of several predefined tabs namely Space, Zone, Type, Spare, Resource, Document, and Attribute. COBie is based on the U.S. classification system OmniClass(Parsanezhad, 2019). As a result, COBie incorporates several OmniClass tables as default classification resources for the object types it describes. Among the OmniClass tables used by COBie are Table 13 (Spaces by Function), Table 21(Elements), and Table 23(Products) (CSI, 2012).

The conceptual schema of COBie is specified in two major stages of the project life cycle. The schema corresponds to the Design stage, which includes the planning and programming. However, In the construction stage, the contractor provides submittals for the designer's specified required documents(Alvarez-Romero, 2014) and (Schwabe *et al.*, 2018).

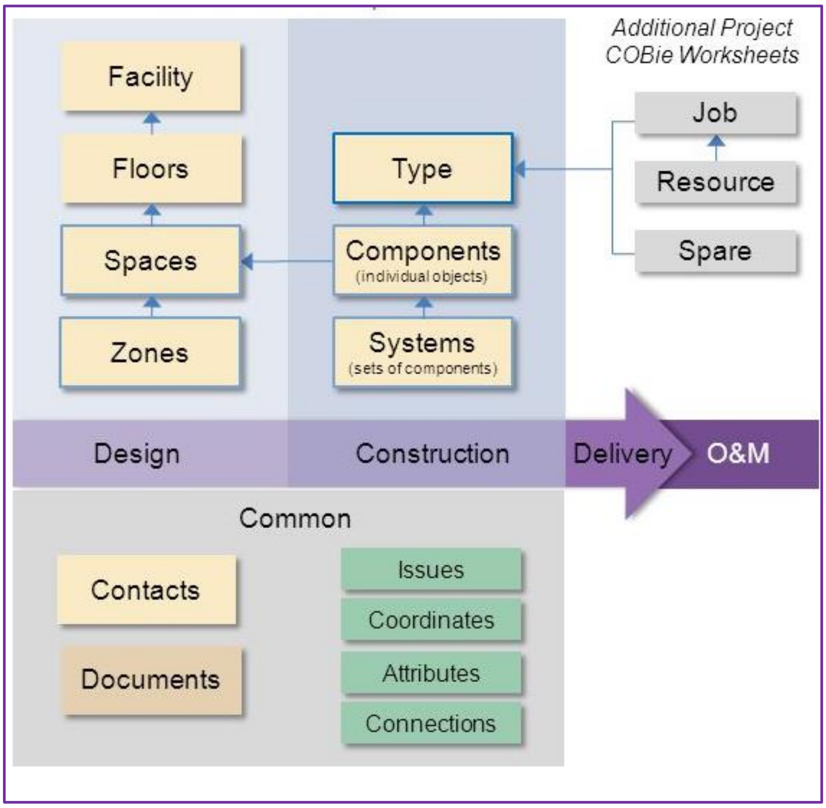


Figure 2- 8: COBie Conceptual Schema adopted(Alvarez-Romero, 2014).

In conclusion, COBie is a subset of the IFC definition, and it can be produced from an IFC model that contains the information needed to create the COBie model, alternatively, the COBie model can be populated by manual methods using the spreadsheet representation of the model. However, the scope is the owner's definition of what information should be inserted into the COBie dataset it serves as an instruction manual on how information shall be inserted into the BIM model and by which project participant. Also, the scopes can be as different as there are different facilities.

2.4.4.5 Building-SMART Data Dictionary (bSDD)

BuildingSMART Data Dictionary initially called the International Framework for Dictionaries (IFD) is a standardized terminology for data and products used in virtual design, construction, and operation. bSDD identifies the multilingual names and defines the types and properties of many construction products. bSDD, IFC and IDM are the core of buildingSMART deliverables which facilitate the process of generating, exchanging, and linking open-standard BIModels to various projects and specific product data. Also, bSDD is intended for interlinking the broad variety of ontologies and vocabularies used for describing components of the built environment and their properties across different countries, sectors, lifecycle phases, and corporations(Parsanezhad, 2019).

2.4.4.6 BIM Collaboration Format (BCF)

BCF is an alternate information transfer format that is commonly used during the design process for minor information transfers between actors. BCF improves cross-disciplinary model collaboration by eliminating the requirement for time-consuming BIM model importing and exporting. The BCF file format is an open XML file format. During the design phase, the BCF file format allows for visual tracking of issues and change requests using object-oriented building models, as well as verification and validation processes. BCF import and export capabilities are currently available in the majority of popular BIM software systems(UK BIM Framework, 2019). In short, BCF is a simplified open standard XML schema that encodes a message to enable work communication between different software tools.

2.4.4.7 Building Classification Systems

Building classification systems have developed standard terminology and semantics in the construction industry. When dealing with requirements, document structuring, and cost estimation, it is critical to use classification systems. A key part of managing building product libraries is standardizing the classification of building models. The product models can be structured for various purposes, such as cost estimation, by providing them with the proper classification code(Afsari and Eastman, 2016). However, there is no globally accepted classification system for building components and processes. In the U.S., OmniClass Construction Specifications (OCCS) is the most widely-used classification schema. OmniClass is developed by the OCCS Development Committee and consists of 15 interrelated tables.UniFormat (for building components), MasterFormat (for work results), and Uniclass are used in the U.K. The Swedish CoClass is the latest construction classification system. According to, the (Autodesk, 2017) report, classification management refers to a strategy for classifying the built environment. Different Classification Management systems are in use all over the world. The following are the most prevalent ones:

- **Master Format:** A master list for organizing the results, requirements, products, and activities of construction projects. Master Format originated in North America and is published by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC).
- **UniFormat:** A method of organizing construction data around the physical components of a facility, known as functional elements, and mostly used for cost estimates. UniFormat originated in North America and is produced by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC).
- **OmniClass:** Used to organize, sort, and retrieve product information for all objects in the built environment throughout the project lifecycle. OmniClass originated in North America and is produced by the Construction Specifications Institute (CSI) and Construction Specifications Canada (CSC).
- **Uniclass :** For all parts of the design and construction processes. Specifically, for organizing library materials, as well as structuring product documentation and project information. Uniclass was developed in the United Kingdom by the Construction Industry Project Information Committee (CPIC) and the National Building Specification Committee (NBS).
- **CoClass:** it is the latest Swedish construction classification system which is developed by Svensk Byggtjänst a company owned by 32 Swedish construction and FM organizations. CoClass is intended as a modern replacement for such earlier systems as BSAB for design and construction and Aff codes for FM. The expected advantage of CoClass over earlier systems is its focus on digital communication of information, embracing all disciplinary actors, the entire built environment, and all lifecycle phases, relying on international standards and focusing on functionality(Parsanezhad, 2019).

2.4.4.8 Content Management Interoperability Services (CMIS)

The CMIS standard has been identified to support the AIM document data requirements. CMIS is an OASIS standard that allows content and information to be exchanged between different content management systems. Unstructured data sources like documents, images, videos, and so on are managed by content repositories. CMIS was established to manage unstructured data sources through the use of metadata, as well as supporting data access and exchange between multiple content repositories. This is achieved by standardizing repository access, data storage, retrieval, and search processes. CMIS also has a SQL-based query language for querying content(Batini *et al.*, 2019). Also, the use of CMIS should be a requirement for the development of a CDE for AIM, both for the structuring of data requirements as metadata, and as a standardized communication protocol between EDMS, FM, and other tools in the CDE. The CMIS data model defines a repository that contains the other CMIS data types, including object types, versioning, documents and folders, and query functionality.

2.4.4.9 Semantic web standards

The use of semantic web technologies has been recommended as a means of solving interoperability issues in the AEC/FM industry. Semantic web technologies can be utilized to support special data domains that are not supported by the existing open BIM standards of IFC and COBie(Batini *et al.*, 2019). Additionally, the Semantic Web refers to W3C's vision of the Web of linked data. Semantic Web technologies are used to create AIM data on the Web, build vocabulary and write rules for handling data.

In conclusion, inadequate data, poor integration and interoperability is a recurring challenges when developing information models due to discrepancies in syntax, schema, and semantics. The graphic and semantic information is used for Built asset management. Therefore, COBie and IFC data models are used to transfer BIM data with FM systems.

2.5 BIM for Built Asset Facilities

The application of BIM into existing buildings/built asset facilities is relatively a new trend. There is still uncertainty about the real benefits of information modelling of already constructed buildings. The idea of BIM still sounds to many as unnecessary technical innovation which can have a limited impact on the business while there are other reliable information management systems in place. Besides this implementing BIM to create a model of an existing facility challengeable than designing a new facility from scratch(Alvarez-Romero, 2014). A new design offers greater flexibility in specifying components and their locations, whereas an existing facility model must accurately represent existing systems. There is an additional factor that is not present in new project designs when BIM is implemented for an existing facility. Because the components have been in service for a long time, they may demonstrate physical durability, deformation, and corrosion(Volk et al., 2014).

BIM has enormous potential for building O&M and FM. However, the benefits of BIM in O&M and FM have not been fully realized yet. In fact, most existing buildings do not have a BIM, and creating a BIM for an existing building is challenging(Hossain and Yeoh, 2018)and (Braila, Panchenko and Kankhva, 2021). On the other hand, the use of BIM for new buildings is easy to start with a fresh, clean file, and layout everything as we need precisely where it is supposed to be(Morrical and Silman, 2013). While BIM processes are established for new buildings, the majority of existing buildings are not maintained, refurbished, or deconstructed with BIM yet(Volk et al., 2014).

In summary, the figure below illustrates the BIM creation processes for new and existing buildings. BIM is created for new buildings in a process that spans several Building life cycle stages, beginning with inception, brief, design, and progressing to construction and project delivery. Existing buildings can be updated or a new model created depending on the availability of previously existing BIM. Public university buildings as well as almost all construction buildings in Ethiopia lack BIM building documentation.

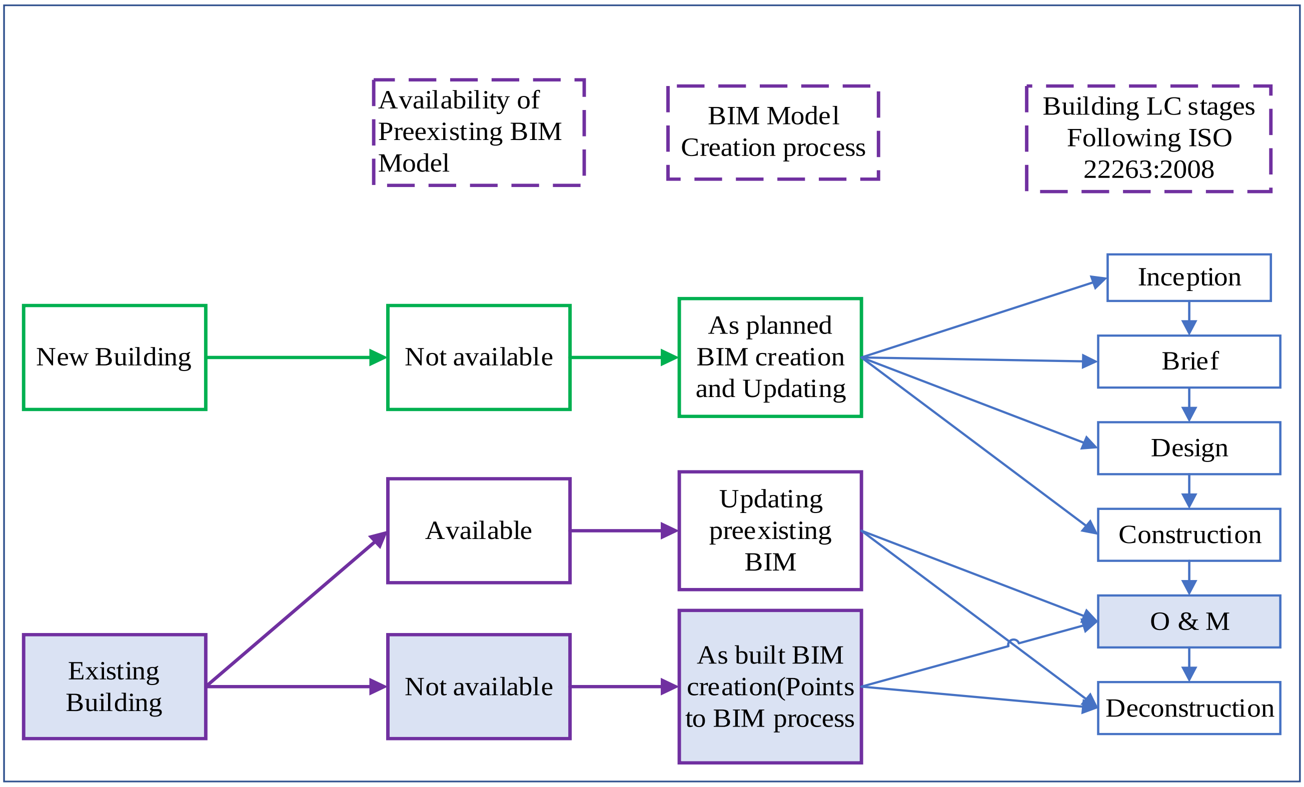
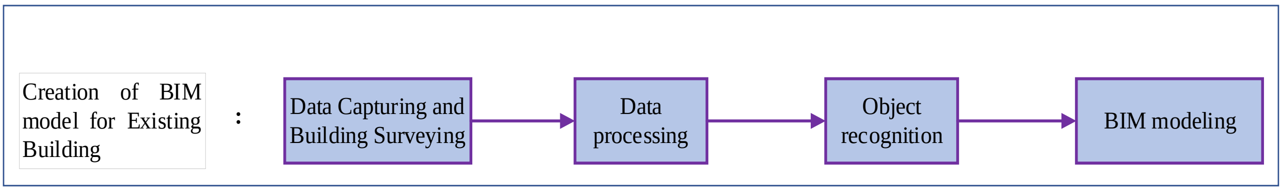


Figure 2- 9: BIM model creation processes in new and existing buildings(Sources: adapting from Volk et al., 2014 and Braila et al., 2021).

Accordingly, this study mainly focuses on BIM for existing buildings that do not have a preexisting model. According to Braila et al.(2021), the built asset does not have a preexisting BIM model the creation process begins with a technical audit of the building, analysis of the construction documentation, and determination of the current properties of the building.



For existing buildings, the building information is insufficient. to collect data about a building, data capturing techniques are required. According to various researchers, there are two types of data capturing techniques: non-contact and contact capturing techniques. Image-based techniques, range-based techniques, and combined or other methods are the three types of non-contact data capture techniques. However, contact methods include manual or other methods. The information extracted by image-based and range-based techniques is primarily about space, colour, and reflectivity.

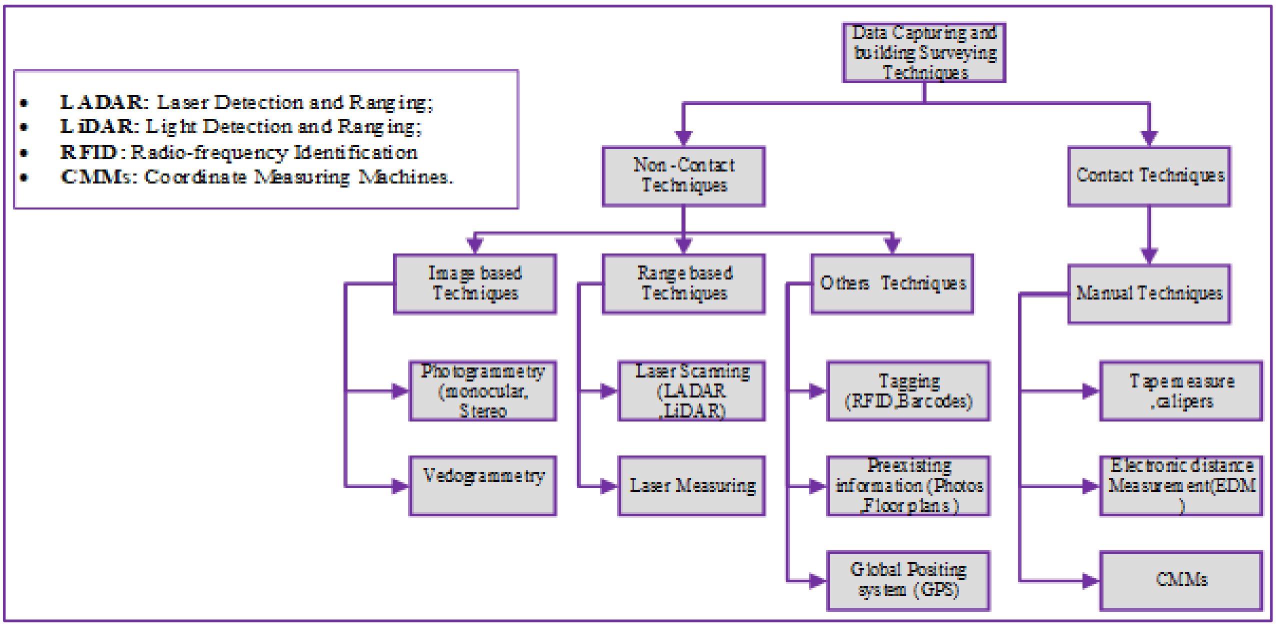


Figure 2- 10: Data capturing and building surveying techniques (sources: Volk et al., 2014 and Braila et al., 2021)

In general, the O&M process requires high LoD components, the installed equipment, services, and appliances. Consequently, tagging is rather inadequate for application in maintenance in terms of spatial accuracy, LoD, and degree of automation. Time and cost restrictions are major decisive features in deconstruction processes, but a related LoD and appropriate capturing technique are yet to be defined(Volk et al., 2014) and(Braila, Panchenko and Kankhva, 2021). Furthermore, decisive characteristics of the main Data Capturing Techniques in the Construction Industry are discussed below[(Klein, Li and Becerik-Gerber, 2012);(Valero, Adan and Cerrada, 2012);(Volk et al., 2014); (Costin, Teizer and Schoner, 2015); (Wang et al., 2015);(Kalyan et al., 2016) and (Braila, Panchenko and Kankhva, 2021)].

Table 2- 3:Data capturing techniques

Decisive features	Data capturing techniques			
	Laser scanning	**Photogrammetry**	**RFID tagging**	**Barcode tagging**
Applicability in existing buildings	Yes	Yes	Limited	Limited
Cost	High	Midium	Midium	Low
Time	Midium	Fast	Fast	Fast
Spatial accuracy, Level of Detail (LoD).	High	High	Midium	Midium
Influence of size and complexity of the scene.	High	High	Low	Low
Influence of environmental conditions	High	High	Low	Low
Import ability into BIM Data	Yes	Yes	No	No
Data volumes	High	Medium	Low	Low
Degree of automation	Medium	Medium	Low	Low
Operability	Low	Medium	Medium	Medium
Equipment portability	Low	High	High	High
Equipment durability and robustness	Medium	High	High	Medium

Besides this, Data processing is performed to enable the recognition of functionality-relevant BIM objects in previously captured building data. During processing steps, image-based and range-based point cloud data is registered, aligned, and merged into the same coordinate system(Volk et al., 2014) and (Braila, Panchenko and Kankhva, 2021).

The collected and processed data about the building is used to recognize the components of the buildings and their characteristics. Object recognition involves identifying an object, extracting information, and handling and removing clutter. But Methods and tools vary depending on: the geometric complexity, the LoD required, the data collection technique used, and the data format (Klein, Li and Becerik-Gerber, 2012) and (Braila, Panchenko and Kankhva, 2021). Generally, there are two main types of Object recognition methods;

Data-driven approaches extract building information from collected and processed data and can be divided into methods based on characteristics, shape, materials, and statistical comparison(Braila, Panchenko and Kankhva, 2021). Model-driven approaches are rather based on a predefined structure such as e.g., topologic relations or constraints and perform matching of captured data through knowledge or contextual information. Other approaches include manual identification or tags(Volk et al., 2014).

The use of BIM for existing buildings can help improve the lifecycle of the facility but the BIM implementation process and interoperability for new and existing buildings have inadequacies. However, the synergistic benefits of technology in construction may not be realized until it is used in collaborative settings.

2.6 BIM Practice in Ethiopia

In Ethiopia, the current use of BIM is being talked about but it still is at an infant stage. Although few private companies and institutes are testing BIM, they are implementing it in the design phase. On other hand, few companies and organizations in Ethiopia also have initiated to inquiry about BIM application for information technology and management in the construction industry. Despite this, it is possible to say that BIM is still at the infant stage in Ethiopia(ECPMi, 2019). The level of BIM implementation in the Ethiopian construction industry is at its infant stage(Getachew, 2016) and (Desbalo & Bargstadt, 2020). Besides this (Muluneh, 2020) noted that Ethiopia is lagging to apply BIM at the projects level. However, ECPMI has so far undertaken the following major activities;

- Purchase server-based BIM software and training manuals, BIM-compatible desktop computers,
- Training and certification of 115 trainees,
- Piloting on two projects (Converting the Conventional design packages of 40/60 2B+G+13 and B+G+7 ECWC (ICT Park) Buildings to Integrated Design using BIM technology,
- Developing a BIM Road map for BIM adoption, and
- Delivery of BIM Training for the universities, professional associations, public clients, and regulatory bodies.

BIM will be an industry standard for the implementation of building projects worth more than 250 million ETB by 2025, with a "Typical Practice Level" on the BIM/VDC Score rating system(ECPMi, 2019). Currently, the Construction industry and investment in large infrastructures are rapid growth in Ethiopia so there is a need for a proactive method to identify the data /information that transfers from the design & construction phases to the post-construction phase for better management of a built asset infrastructure.

2.7 BIM-FM Integration

Built Asset management entails balancing costs, opportunities, and risks against the desired performance of assets to meet an owner's goals. It also enables asset owners to assess the need for and performance of their assets and systems at various levels. Consequently, having appropriate and reliable information about an asset is critical for asset management to support the decision-making, planning, and execution of asset activities and tasks, particularly during operations and maintenance(Love, 2015). Streamlining the process for preventative and scheduled maintenance of facilities has always been challenging due to a lack of communication between designers and future facility maintenance crews. As the evolution of BIM has been proven to increase efficiency and improve buildings' construction, it is also improving processes and decreasing costs of built asset management (AUTODESK, 2021). There are several ways in which BIM can be used to improve FM processes: ease of access to real-time data; maintenance verification; built asset management; space management; and energy monitoring and control(BIMCommunity, 2021).

In the operations and maintenance of the built asset, FM teams often spend a considerable amount of time and effort collecting information in the form of electronic data and hardcopy documents. Also, Employees engage in constant redundant activities for searching, sorting, validating, and recreating information(Matarneh, Danso-amoako, et al., 2018). So, BIM is one of the most prominent initiatives frequently addressed by scholars and practitioners as a game-changer in the construction industry in general and FM in particular(Parsanezhad, 2019). In addition to that BIM models can also be used to support FM by extending the model beyond the post-occupancy phase(Arayici et al.; 2012). Furthermore, according to (Parsanezhad, 2019), BIM incorporates a methodology focused on stakeholder collaboration using ICT to exchange vital information throughout the lifecycle. Such collaboration is considered a solution to the building industry's fragmentation, which has resulted in various inefficiencies. Although, BIM provides a robust platform for information management in FM systems BIM- FM data integration has come with issues related to establishing an effective process to extract, store, and distribute data to ensure interoperability (Denton, P. and Mcllroy, 2018) and (Farghaly et al., 2019). Besides this to manage such information, FM information management systems are currently being implemented; however, the diverse graphical and non-graphical information recorded in BIM from the pre-use phase has not been effectively linked with existing FM systems(Yalcinkaya et al., 2016a).

However, BIM into FM has generated fervent debate within the extant literature given an increasing realization amongst practitioners that the majority of BIM benefits reside within the whole lifecycle management(Hosseini et al., 2018). In general, Automated data processing and information transfer from the early stages of a project to the operation and maintenance phases, as well as increasing the efficiency of work orders and decision-making processes by access to real-time and previously-stored graphical and non-graphical data, are all benefits of BIM in FM practices(Yalcinkaya et al., 2016). Likewise (Alvarez-Romero, 2014) stated that the opportunity to include real-time data into the geometry of the building included in the model is one of the new technologies developed for BIM. According to Mirarchi (2018), the integration of FM and BIM is an innovative and critical undertaking process to support facility maintenance and management. Moreover, it is important to note that the information necessary for the management of these processes must be inserted into the BIM model. It must be clear what information is requested, whose responsibility it is to insert the information, and what is the appropriate timing for the insertion of this information(BIMCommunity, 2021).

2.8 Information Requirement

Information is a reinterpretable representation of data that is suitable for transferring, storing, processing, translating, communication, interpretation, and it may be processed by people or automatically (Singh, Fosselie and Wiggen, 2010),(Parsanezhad, 2015) and (Pavan *et al.*, 2020). Also, Barnes(2020) information is data that has been aggregated, structured, and placed in context to give it meaning and purpose. Furthermore, Information is one of the key aspects of management. Almost all workplace activities now involve the production, consolidation, and conversion of information into recognized organizational formats. Using information, organizations can create business rules, make robust decisions and learn from the consequences of their actions(Kaya, 2011a).

Information requirements are the sets of information that support some of the process activities at a particular phase of the product life cycle (Alvarez-Romero, 2014). Bolpagni and Hooper (2020) define information requirements as to how and when information should be exchanged in the project/asset lifecycle. Besides this,(RIBA, 2020) stated that at the critical phases of a project the information requirements are released for the client's assessment and approval. In addition to the various informal exchanges that occur during the iterative design process. In general, UK BIM standard PAS 1192-3 and BS EN ISO 19650-D provide information requirements are inputs for the whole information management system, which includes organizational information requirements (OIR), asset information requirements (AIR), project information requirements (PIR), and employer/exchange information requirements (EIR). Hence, the owner of the facility in defining and translating strategic information requirements (OIR) into operational information requirements (AIR and PIR) and how it may be included in the tender specification (EIR)(BCA, 2018),(Barnes, 2020) and (Pavan *et al.*, 2020).

The critical value of information requirement management, processes, and strategies is growing rapidly in the construction sector as a whole. This is being guided by new and developing technologies, with the support of industry standards entirely focused on BIM and Asset Management(Heaton, Parlikad and Schooling, 2019). As a result, the information requirements methodology incorporated asset management standards ISO 55000 and BIM-related standards PAS/BS 1192 2-5/BS EN ISO 19650 2-5 information management frameworks (Heaton, Parlikad and Schooling, 2019) and (Hermann, Thomas and Pansera, 2020). In general, Asset owners are seeking to utilize new genetic information to achieve whole-life cycle performance efficiencies from their physical assets as BIM adoption, implementation, and development become more widespread in business. However, one of the primary issues for organizations today is determining how to develop a clear asset information strategy (Heaton, Parlikad and Schooling, 2019).

2.8.1 Organizational Information Requirements (OIR)

Organizations must consider information requirements around in-use (including operation) before they consider information requirements around project delivery. OIRs are the information required by an organization for asset management and operation to inform decision-making about high-level strategic objectives(BCA, 2018) and (Heaton et al.; 2019). Bolpagni and Hooper (2020) stated in the BS EN ISO 19650 Guidance Part D, that OIR is the starting point for all information management initiatives. According to Barnes(2020), OIR is high-level information required by an organization across its whole asset portfolio and different departments (such as human resources, information technology, finance, facilities management, and operations/production).In general, it is necessary to understand "who" needs the information and "why" the information is needed before a building/facility owner requests asset information delivery from their project team to prevent information loss(BCA, 2018) and (Bolpagni and Hooper, 2020).

OIR is clearly stated as a part of the organization's business activities, permitting for a better understanding of the high-level activities pieces of information needed about the assets throughout their lifecycle (Bolpagni and Hooper, 2020). Besides this, It's important to consider more about high-level activities that require information within an organization to determine what they include in OIR and how to begin the process. The following standards cover these high-level activities: ISO 19650-3, BS 1192-4:2014 clause 5.2, and ISO 55001:2014 (BCA, 2018)(Barnes, 2020) and (Bolpagni and Hooper, 2020). OIR is created by appointing parties: the client, the asset owner, and their representative(Aðalsteinsson, 2014),(Dwairi, 2020) and (Bolpagni and Hooper, 2020). After the OIR has been completed AIR and PIR will be generated. The principles and processes established in ISO 19650 Parts 1, 2, and 3 should be used to define the AIR and PIR during the operational and delivery phases of the asset lifecycle (Bolpagni and Hooper, 2020).

2.8.2 Asset Information Requirements (AIR)

AIR is a part of the BIM process that defines the graphical and non-graphical data, information, and document required for a built asset's lifetime O&M (BIM WiKi, 2021). According to, BS EN ISO 19650 - Guidance Part D standard AIR is an information requirement specification for “what”, “when”, “how”, and for “whom” information is to be produced. As well, PAS 1192-3/ BS EN ISO 19650-3 defines AIR as data and information requirements of the organization in relation to the built assets. As a result, AIR is an important organizational business activity to support asset management, as well as design and construction projects(Bolpagni and Hooper, 2020). AIR is a subset of the overall project brief (Barnes, 2020). Accordingly, the typical asset information would include physical asset data (name, description, and technical characteristic of the asset); location and spatial data **(**where the asset is and how it relates to other assets); performance data **(**how this asset contributes to the serviceability target) and condition data (what is the life expectancy of the asset) (BCA, 2018). Besides this, AIR is derived from the purposes for which the appointing party requires the information so these can include the relevant OIR such as corporate policies; asset use and condition monitoring; energy consumption, operational costs monitoring; and asset stakeholders, such as visitors and users, who require information (Bolpagni and Hooper, 2020).

According to (BCA, 2018) report, AIR for operation and maintenance purposes the key assets are usually those associated with the space and building services system to be captured for the deliverable such as Mechanical Ventilation, Building Automation, Monitoring, Space Control, Air-conditioning, and Refrigeration Function, Plumbing and Sanitary Systems, Building Envelope, Gas and Electrical System. AIR should provide the basis for the commercial, managerial, and technical aspects of producing and managing asset information and should include the standards, methods, and procedures to be implemented by the Delivery Team. The AIR should provide the detailed specification for the delivery of the Asset Information Model (AIM)(CIC BIM, 2020).

According to the standard Publicly Available Specifications (PAS) 1192-3:2014/ BS EN ISO 19650-3 asset management standard, these AIRs logically exist within five categories as summarized in Table below (Trust, 2018) and (BIM WiKi, 2021).

Table 2- 4:Information requirement categories and types

Category	Information Requirement Types
Technical	Engineering data Design parameters Interdependencies Commissioning dates and data Performance data Operational data Services requirements
Managerial	Type of asset Photograph Identification numbers (specification number, product number, serial number) Location Floor area Space management information Warranties and guarantee periods Access planning and work schedules Maintenance and inspection schedules and records Operation and Maintenance manual Outstanding tasks Record of planned and unplanned maintenance Standards, processes, and procedures Hazardous contents or waste End of the life cycle of the asset Emergency plans Performance Test Reports
Commercial	Description of the asset The function of the asset Details of supplier Lead time Facilities and Equipment condition Key performance indicators Performance targets or standards Non-conformance criteria and actions to be taken The criticality of assets and spaces to the organization Identities and levels of spares held, inter-changeability, specifications, and storage locations.
	Original purchase/leasing Cost Operating cost Planned maintenance cost Historical maintenance cost Replacement value

Financial	Downtime impact
Legal	Details Ownership maintenance demarcation Contractual information Property boundaries Work instructions Legal obligations (H&S, etc.) Risk assessments and control measures

Furthermore, Munir, et al.(2020) categorize the information requirements of individual assets as building details, energy data, contract details, planning details, and performance optimization as shown in the table below.

Table 2- 5: Information requirement categories and types (source: Munir, et al., 2020)

Category	Information Requirement Types
Building details	Area/volume Building usage type Year of built/renovation Number of people Address Owner Type of HVAC system Year when airflows were calibrated
Energy data	Energy consumption heating Energy consumption electricity Energy consumption cooling Water consumption
Contract details	Cost per year
Planning details	Planned maintenance costs all types Planned maintenance costs all types and subtasks
Performance optimization	System energy performance Indoor conditions Operability Cost per year

The appointing party, such as the asset owner and their representative create AIR. The internal team in charge of built assets management is leading the development of AIR (Bolpagni and Hooper, 2020). For new building creation of the BIM starts with the client firstly identifying what information they need. BIM generates the best value for all parties when you start with the end in mind and focus on gathering useful, purposeful information which is gathered throughout the project. Furthermore, the AIR is part of the specification for each asset-related contract or work. Where these contracts are managed in accordance with PAS 1192-2 then the AIR shall inform the development of the PAS 1192-2 EIR(Trust, 2018). But, the built asset does not have a preexisting BIM model/asset information the AIR are capturing by using conventional/modern data capturing technology begins with a technical audit of the building, analysis of the construction documentation, and determination of the current properties of the building (Braila et al., 2021).In general, Asset information Requirements are managed mainly in AIM in the form of **Documentation**, **Non-Graphical Data**, and **Geometry/Graphical Models**. As a result, critical decisions can be made by the client and their supply chain, based on timely and accurate information(UK BIM Alliance, 2017).

- **Documentation:** Drawings and PDFs from manufacturers, such as Safety Data Sheets, etc. are usually handed over to clients and their facilities management teams via Operation and Maintenance Manuals.
- **Non-Graphical Data:** For BIM Level 2 that is in line with the British Standard BS1192-4 which utilizes the Data exchange format COBie.
- **Geometry, Graphical Models:** 3D Federated models of the building and the systems and components within it.

2.8.3 Project Information Requirements (PIR)

PIR is a set of high information requirements derived from OIR. PIR focuses on the information required by the Appointing Party at key decision points during the design and construction phase (Bolpagni and Hooper, 2020). In general, PIR defines the information that clients will have to make decisions about the project throughout its life cycle. Excerpts from construction and project management documentation, as well as purpose-written reports such as cost and progress reports, may be required. PIRs are often influenced by organizational regulations, such as financial reporting protocols and formats of PIR. Clients with a lot of experience typically have a generic PIR that they use or customize for each project (Barnes, 2020). Project information requirements are under ISO 19650-1 clause 5.4 and ISO 19650-2 clause 5.1.2(UK BIM Alliance, 2020) and (Bolpagni and Hooper, 2020).

- **Project task information:** Negotiate funding and PIR of the area/occupancy information and visualizations required at key decisions to demonstrate to funders what the facility will look like.
- **Project business plan information:** The facility must earn the turnover in the first year, and PIR of retail department area/occupancy information and benchmark sales figures per m2 to be provided at key decision points.in addition to that, the investment target cost of the project must be defined and PIR of Project cost information to be provided at each key decision point.
- **Statutory information:** The project task is a land registry application and the PIR is information about the site's location and surrounding area.
- **Procurement information:** Project task information is issuing invitations to tender for the design team, and main contractor, and ordering the necessary quantity as well as PIR of the tender package information for key decision points.
- **Design information:** Project task information of the facility's Strategic brief and PIR evidence that performance and capacity requirements are required at each key decision point.

2.8.4 Exchange/Employer information requirements (EIR)

The EIR, which was created by the UK BIM Task Group, sets out the information deliverables as well as the standards and processes to be adopted in the supply chain. Hence, the term ‘exchange information requirements' from ISO 19650-1 has the same meaning as the term ‘employer’s information requirements’ from PAS 1192-2(Barnes, 2020). In addition, PAS 1192-2:2013, Specification for information management for the capital/delivery phase of construction projects using building information modelling specifies the requirements of level 2 BIM and specifies the employer's information requirements.

As a result, the contractual status of the employer's information requirements can be established by referencing it and appending it to a BIM protocol. The BIM protocol (such as the freely available CIC BIM protocol) sets out the contractual definition of BIM responsibilities, liabilities, and limitations. The contract used for appointments can be appended with a BIM protocol by the addition of a model enabling amendment clause(BIM WiKi, 2021).

While the AIR and PIR primarily describe what information is required, the EIR is primarily concerned with the who, how, and when of their delivery (Barnes, 2020) and (Bolpagni and Hooper, 2020). (BIM WiKi, 2021) define EIR is the information that the employer would need from both their internal team and suppliers in order to develop the project and manage the completed constructed asset. The appointing party's process for defining OIR, AIR, and PIR conforms with ISO 19650-2 clause 5.2.1 a) by describing the information required and the level of precision required to complete organizational, asset, and project-related activities. The EIR's role, as described in ISO 19650- 2, is to specifically indicate what information is to be delivered at each information exchange for each appointment. Since the appointing party's and lead appointed party's EIRs to perform the same purpose, this section of guidelines accommodates both the appointing party's and lead appointed party's EIRs, with any distinctions highlighted(Bolpagni and Hooper, 2020) and (UK BIM Alliance, 2020). Since the appointing party's and lead appointed party's EIRs to perform the same purpose, this section of guidelines accommodates both the appointing party's and lead appointed party's EIRs, with any distinctions highlighted(Bolpagni and Hooper, 2020) and (UK BIM Alliance, 2020).

In summary, EIR known as the Employer’s BIM requirements is a document that outlines the project and BIM objectives of the client(BCA, 2018). EIR includes a set of requirements and guidelines in three areas: technical, managerial, and commercial (Hafeez *et al.*, 2016) and(BIM WiKi, 2021). However,(Engenharia, 2020) defines that the EIRs are in four areas: technical, managerial, commercial, and legal. Therefore, Technical information (details of software platforms, CDE, CAFM systems used by the Client, etc.); Managerial information (details of information management processes to be adopted), and Commercial information (details of information deliverables, timing of information exchanges, and definitions of information purposes).

Therefore, information requirements should always be based on purposes and defined in sufficient depth to allow each objective to be completed effectively. Information requirements as a whole tell a story that properly incorporates all of the necessary information. The figure below shows the relationships between four different information requirements.

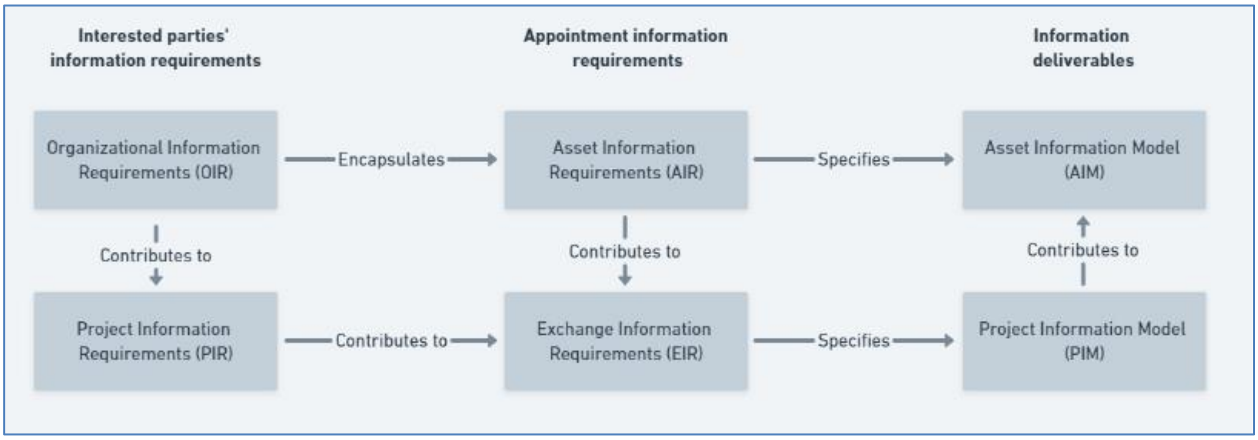


Figure 2- 11:Hierarchy of information requirements adopted from ISO 19650- 1 clause 5.1(Bolpagni and Hooper, 2020).

2.8.5 Information Exchange Form and Formats

The client's information requirements differ from those of the contractor and designer since the client is more interested in facility management and data that can be utilized for operation, maintenance, and refurbishment work. As a result, it is critical for the client to clearly define the information requirements and exchange requirements in the project documents. The information exchange requirements are mainly composed of two parts: facility data and model element of the level of development. This documentation must be developed at the beginning of the project and defines both the facility data and the model level of development that must be properly stored(Brynjolfsson and Karathodoros, 2013). Different information exchange forms and formats are available to undertake effective information handovers of the built asset during the project delivery phase. The efficiency with which information is exchanged is critical to the overall success of construction projects. All contributors must understand what they must provide, what others will provide, and how this information will be delivered and used for information to be properly exchanged(BCA, 2018). Therefore, the owners not only struggle with the amount of data but also with the requirement of numerous data format that needs to be provided when delivering the project(Liu and Gao, 2017). There are different forms and formats available to execute information handovers(Aðalsteinsson, 2014). But the facility information is now more than ever, produced and handled electronically. However, much of the information does not have a formal structure; therefore, the only way to understand or check the quality is actually by reading the document, slowing the process of transferring this information to the computerized systems for managing the information and making it prone to error or omission through the transcription process. Some new approaches can provide facilities information in a structured form that is immediately machine-interpretable, increasing productivity and reducing errors. Even graphics and drawings can be managed in a structured form(Alvarez-Romero, 2014).

In general, there are four major categories of information forms and formats, structured and unstructured and both can be proprietary/standard. Structured information promotes reusability of the information, while standard information promotes longevity of the information(Alvarez-Romero, 2014).

- **Unstructured Forms**

Data that fall into this category are electronic/paper documents that have no formal structure. For these documents, there is no other way of interpreting them or checking their quality to read them. This type of information cannot be interoperable, even though the information is compatible with multiple software products(Aðalsteinsson, 2014). Furthermore, any data that cannot be machine-interpreted are unstructured. not all of the software uses structured data, digital images for example are unstructured data. Documents containing information with unstructured data can be easily filed, retrieved, tracked, and monitored with the support of metadata; however, machine interpretation is really difficult and requires more manually-intensive processes(Alvarez-Romero, 2014).

- **Structured Forms**

The structured data can be accessed and manipulated directly by computer applications, without human intervention, and it has adhered to a well-defined model. Structured data can be quantitative, descriptive, and graphical. This kind of information allows automated search, retrieval and update, therefore is cost-effective. Proprietary software commonly uses structured data and proves its benefits during a limited time (Alvarez-Romero, 2014). Besides, BIM software creates information in a structured form that is immediately machine-interpretable. These permit use of computer tools to assist in managing, using, and checking the data created during the AECO process(Aðalsteinsson, 2014).

- **Proprietary Format**

The data format is defined and owned by a specific software company. Most software outputs data in a proprietary format often referred to as the “native” format. Since the format is in the ownership of a single software vendor, the owner can be at any time modify and change the format in that instance archived data may not be usable in the current version of the application(Alvarez-Romero, 2014) and (Aðalsteinsson, 2014). Evening(2020), define Proprietary format as file formats that are controlled and supported by just one software developer. Proprietary standards may be free to use, but the file specification is often closed rather than being open. Some popular proprietary standards include Microsoft Word (.DOC), Microsoft Excel, Adobe PDF, MP3, MPEG Audio as well as comma-separated values and open document format.

- **Standard Format**

There are two definitions of standard formats:

“Defacto / Ad hoc /Standard” is a format that may have originated from a single vendor, but has been made publicly available and is supported by multiple vendors and products. A good example of this format is the DXF format makes the format usable for anyone that wishes to write an application to access information stored in that format. But as Autodesk decided not to extend the DXF format to include its complete product data structure it is anticipated that there will fewer and fewer commercially available programs that can read and write the format(Alvarez-Romero, 2014) and (Aðalsteinsson, 2014).

“De jure standards/ Formal Standards” are those maintained by a standards development organization, such as the International Organization for Standardization (ISO), The International Alliance for Interoperability (IAI), Industrial Foundation Classes (IFC) maintained by the Building Smart Alliance, Construction Operations Building Information Exchange (COBie) by National BIM Standards of USA. and the Open Geospatial Consortium (OGC). The standards are typically developed through a consensus process that considers the information requirements of many organizations. The standard is therefore often flexible and useful. The consensus process ensures that multiple organizations have an interest in the standard a unilateral decision made by one vendor will not halt support for the extension of the standard(Alvarez-Romero, 2014) and (Aðalsteinsson, 2014).

Accordingly, many of the challenges associated with data/information management can be overcome with data exchange format decisions/ selection criteria some of them are discussed in the table below.

Table 2- 6:Selection criteria for data/information exchange format

Best Practices for the Selection of Electronic File Formats(https://wisconsinhistory.org/Records/Article/CS15427 **)**	**National Archives (Digital Preservation Guidance Note)**	**Library and Archives Canada (LAC) Local Digital Format Registry (LDFR)** **File Format Guidelines for Preservation and Long-term Access**	https://libraries.mit.edu/data-management/store/formats/
Openness Portability Quality and functionality Development support Diffusion Transparency Self-documentation	Ubiquity Support Disclosure Documentation quality Stability Ease of identification and validation Intellectual Property Rights Metadata Support Complexity Interoperability Viability Re-usability	Openness/Transparency Adoption as a preservation standard Stability/Compatibility Dependencies/Interoperability Standardization	Non-proprietary Open, documented standard Common usage by the research community Standard representation (ASCII, Unicode) Unencrypted Uncompressed

- **Accessibility:** The file format must make it easy for the staff and the public to find and view the record data /information (Mauthe and Thomas, 2015) and (Evening, 2020).
- **Longevity:** Developers should support the file format long-term. If the file format will not be supported long-term, you risk having records that are not durable, because the software to read or modify the file may not be available. Records should be migrated or converted if you determine a file format is no longer supported. Open source, open standard, and non-proprietary formats are preferable to completely proprietary ones (Mauthe and Thomas, 2015) and (Evening, 2020).
- **Accuracy:** To convert the records, the file format that converts should result in records that have an acceptable level of data, appearance, and relationship (Mauthe and Thomas, 2015) and (Evening, 2020). Moreover, does the data correctly

represent the asset it relates to? If an asset is replaced, does the information get updated in the Asset Repository (Kaiser *et al.*, 2017).

- **Completeness:** To convert the records, the file format that converts should meet your operational and legal objectives for an acceptable degree of data, appearance, and relationship (Mauthe and Thomas, 2015) and (Evening, 2020). In addition, to cheek are all assets and required attributes populated(Kaiser *et al.*, 2017).
- **Interoperability:** The file format needs to meet the objectives for sharing and using records. For example, to need frequently share copies of the records with another agency, use the records in daily work, or convert and/or migrate the records later. If the file format can only be read by specialized hardware and/or software, the ability to share, use, and manipulate the records is limited(Mauthe and Thomas, 2015) and (Evening, 2020).

Data interoperability is a key to achieving worldwide standardization of BIM methods and usage. An open-source approach based on open standards and workflows, the so-called OpenBIM, is the base for collaborative design, realization and operation of buildings. OpenBIM was developed by leading software vendors using BuildingSMART Data Model and aims to support a transparent workflow, allowing the user to design and maintain quality project data regardless of the software tool they use(Popgavrilova, 2018).OpenBIM data standards such as IFC and specifications such as COBie provide the capability to capture FM data requirements in a structured manner from the early stages of project development(Patacas et al., 2015). OpenBIM® extends the benefits of BIM by improving the accessibility, usability, management and sustainability of digital data in the built asset industry. At its core, openBIM is a collaborative process that is vendor-neutral. openBIM processes can be defined as sharable project information that supports seamless collaboration for all project participants. openBIM facilitates interoperability to benefit projects and assets throughout their lifecycle(BuildingSMART, 2021).

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openBIM processes can be defined as sharable project information that supports seamless collaboration for all project participants. openBIM facilitates interoperability to benefit projects and assets throughout their lifecycle(BuildingSMART, 2021).OpenBIM ensures that:

- **Interoperability** is key to the digital transformation in the built asset industry.
- **Open** and neutral standards should be developed to facilitate interoperability.
- **Reliable** data exchanges depend on independent quality benchmarks.
- **Collaboration** workflows are enhanced by open and agile data formats.
- **The flexibility** of choice of technology creates more value for all stakeholders
- **Sustainability** is safeguarded by long-term interoperable data standards

In conclusion, data Exchange formats and protocols should be developed and agreed to by all parties involved in the information delivery process. At the project level, information is required in the format specified in the BIM Execution Plan (BEP), which may include (but is not limited to) any of the following outputs: Native-3D discipline model files, IFC federated model, and COBie data(BCA, 2018).

O and M costs of built asset facilities represent a large part of the total built asset lifecycle cost. However, project delivery methods in the AEC industry are often focused on capital delivery and associated costs, which occur before the built asset handover to owners and occupiers. With the emergence of data specifications such as COBie, the IFC(data Standard), and IDM (Process Standard) open standard, there has been an increased interest in developing approaches that integrate built asset facility O & M with the capital delivery phases. Those standard data models/schemas are fulfilled by the openBIM specification and standards. As a result, the researcher suggests that public universities use IFC, IDM, and COBie as data transfer models for transferring relevant data from BIM-based PIM to AIM and also form BIM for the existing building to AIM.

2.8.6 Data/Information/ validation and checking Criteria

To ensure that data is trustworthy, it is important to validate, Check and understand the dimensions of data quality.

Similar to the way that data quality expectations for operational or analytical data silos are specified, master data quality expectations are organized within defined data quality dimensions to simplify their specification and measurement/validation. This provides an underlying structure to support the expression of data quality expectations that can be reflected as rules employed within a system for validation, checking, and monitoring the data /information of the built asset. Every organization should have some means of measuring and monitoring data quality. Some of the data/information quality dimensions are discussed in the table below.

Table 2- 7: Data/Information/ validation and checking Criteria

Types of Data dimension	Definition
Accuracy	Data/information accuracy is the level to which data represents the real-world scenario and confirms with a verifiable source. Accuracy of data ensures that the associated real-world entities can participate as planned(Nyaboga and Mwaura, 2011). Also, it is a measurement of the veracity of data to its authoritative source(EDMCOUNCIL, 2017).
Completeness	A measurement of the availability of required data attributes(DAMAUK, 2018) and(EDMCOUNCIL, 2017). Also, the degree to which subject data associated with an entity has values for all expected attributes and related entity instances in a specific context of use(ISO 25000, 2021).
Consistency	Measurement of compliance with required formats, values, or definitions(EDMCOUNCIL, 2017) and (ISO 25000, 2021). Moreover, consistency is a measurement of the alignment of content with the required standards(DAMAUK, 2018).
Timeliness	A measurement of the degree to which data is both representative of current conditions and available for use(DAMAUK, 2018; Nyaboga and Mwaura, 2011 and ISO 25000, 2021).
Validity	Validity is a data quality dimension that refers to information that doesn’t conform to a specific format or doesn’t follow business rules(DAMAUK, 2018). Moreover, this dimension signifies that the value attributes are available for aligning

	with the specific domain/requirement(Nyaboga and Mwaura, 2011).
Uniqueness	This dimension indicates if it is a single recorded instance in the data set used. Uniqueness is the most critical dimension for ensuring no duplication /overlaps(EDMCOUNCIL, 2017) and (ISO 25000, 2021).
Conformity	A measurement of the alignment of content with the required standards(EDMCOUNCIL, 2017) and (Nyaboga and Mwaura, 2011).
Coverage	A measurement of the availability of required data records(EDMCOUNCIL, 2017) and (DAMAUK, 2018).

2.8.7 Information Deliverables

Based on the information requirements specified in the EIR the project team would start planning how to collect, coordinate, and deliver asset information. The typical information deliverables discussed in (BCA, 2018) are summarized in the table below.

Table 2- 8: Information Deliverables

Deliverables	what it is and when to be delivered?
BIM Execution Plan (BEP)	A document to explain in detail how the project team plans to meet the requirements specified by the building/facility owner. To be delivered before the project started.
Project Information Model (PIM)	A progressively developed information model (BIM and non-BIM) across the project lifecycle (Coordinated Design Model → Construction Model → As-built Model). To be delivered at different project stages/milestones.
Asset Information Model (AIM)	An information model (BIM and non-BIM) derived from PIM supports the ongoing management of an asset. To be delivered during project handover.

However, this study is focused on AIM. As a result, the researcher noted, AIM is a model that compiles the data and information necessary to support asset management, that is, it provides all the data and information related to and required for the operation of an asset.

According to (BIM WiKi, 2021), AIM can incorporate graphical and non-graphical data /information as well as documents and metadata. It can relate to a single asset or a portfolio of assets. An AIM can be created from existing asset information systems, from new information and information in a PIM that was created for the construction of a new asset. Likewise, (BCA, 2018) reports AIM is derived from the As-Built BIM model where only information specified in the AIR is to be retained. As-Built BIM Model is a model that should capture the condition and essential information at the end of the construction phase. The as-built model should be kept by the building/facility owner as of the communication protocol and reference for the building was constructed.

PAS 1192:3 is standard for an organization to establish a digital AIM for information management. The standard involves a wide part of the asset life cycle's work stages. This is a set of work phases that may be used across all roles and sectors from asset development and asset operation(Jabri, 2015). AIM comprises models, data, documents, and other records related to or required for the operational phase of an asset. It might include information outlining the original design intent, details of ownership, survey work undertaken, operational performance details as well as 3D models developed on the project(BIM WiKi, 2021).

Furthermore, PAS1192-3 presented the relationship between elements of BIM-based information management such as EIR, OIR, AIR, PIM, and Asset Information Model AIM. These are shown in the Figure below, whilst their connection to the asset's lifecycle. The process starts with the OIR, where the asset owner probes the business needs to identify the data and information required from the BIM-based processes to meet the needs of its AM system and other business functions(Munir, Kiviniemi, Jones, et al., 2020).In general, an effective information management process (IMP), defined in PAS 1192:3, should be instigated to maintain the integrity of the AIM.

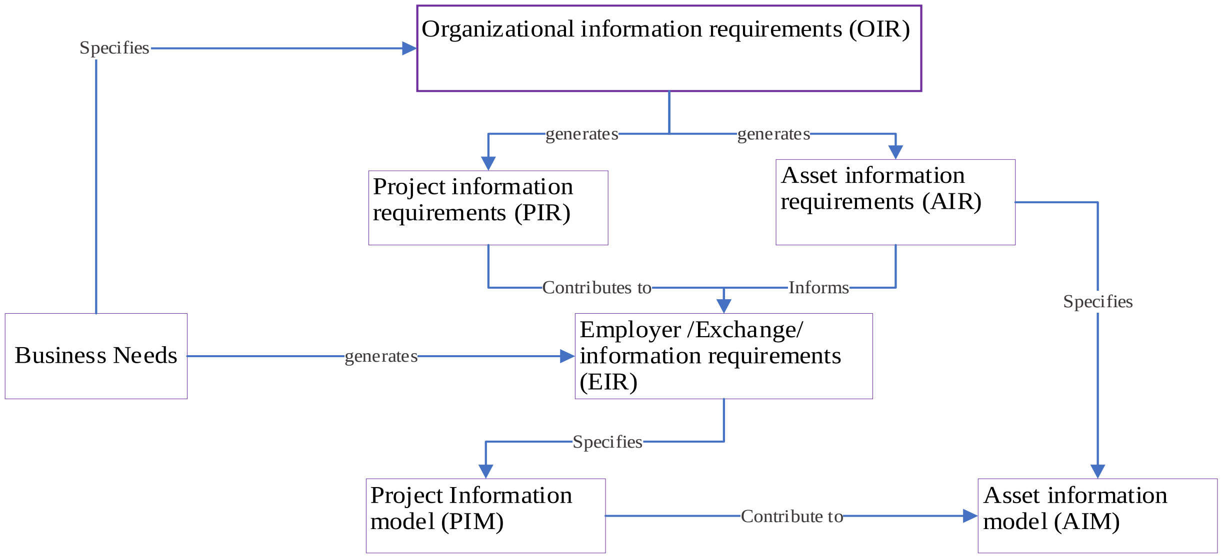


Figure 2- 12: Elements of BIM-based information management adopted from ISO 19650-3(Munir, Kiviniemi, Jones, *et al.*, 2020).

2.8.8 Interoperability

Interoperability is the ability to join up and merge data without losing meaning. In practice, data is considered to be interoperable when it can be easily re-used and processed in different applications, allowing different information systems to communicate with one another(Morales and Orrell, 2017). Likewise, (Measure Evaluation, 2015) report describes interoperability as the extent to which systems and devices can exchange data and interpret that shared data. Additionally, for seamless information exchange between BIM and FM systems, information interoperability and data-mapping are essential (Chen and Cheng, 2018). Besides this interoperability is simply the ability that data generated by any one party can be properly interpreted by all other parties(Parsanezhad, 2019). Interoperability is critical in managing data loss issues in fully integrated systems. A robust BIM adoption and implementation can be possible via solving interoperability problems. Interoperability enables heterogeneous software and hardware systems to collaborate in an integrated manner, allowing for integrated project delivery (Ozturk, 2020).FM information flow is neither automated nor seamless. The value of extending BIM implementation through the operations and maintenance phase is simply to reduce costs associated with inadequate interoperability. Facility managers do not normally use BIM model data, since they claim that BIM does not include their information requirements(Matarneh, et al., 2018).

Interoperability can be achieved without standardization, but it requires the project to establish its standards and deliverables. Efficient interoperability necessitates a set of standards as well as their execution. Different tools and platforms are utilized by different stakeholders throughout the project stages, and interoperability using open standards is crucial to maintaining reliable information transfer. There is a requirement for an optimal information logistics system to standardize and structure BIM data throughout an asset's lifecycle, including exchange file formats and access to shared data(Ângelo, Azenha, and Jure, 2020). Moreover, The National Institute of Standards and Technology (NIST) reported that two-thirds of the projected $15.8bn lost in the USA capital facilities industry was associated with inadequate interoperability during the operations and maintenance (O&M) phase. Interoperability problems in the capital facilities industry stem from the highly fragmented nature of the industry, the industry's continued paper-based business practices, a lack of standardization, and inconsistent technology adoption among stakeholders(Gallaher et al., 2004)

In general, conventionally the information exchange is a paper-based/a combination of paper printed documents along with digital (raster image) versions of printed documents. However, this has proved particularly inappropriate for the use, management, and maintenance of such information, because the only way to do it is manually, and considering the amount of information to be hand. As a result, Common Data Environment (CDE) is a simplified information record, control, exchange, and data generated is accurate and complete and minimizes the cost of delivery.

2.8.9 Common Data Environment (CDE)

The Common Data Environment (CDE) is a central repository where built asset information is housed. The contents of the CDE are not limited to assets created in a 'BIM environment' and it will therefore include documentation, graphical model, and non-graphical assets(Lemsys, 2020). Additionally, CDE is more likely a network of systems that serve more complicated company requirements rather than a single software application. The applications inside the CDE are determined by the project's requirements and the purpose it is intended to serve (BCA, 2018). Moreover, the British Standards Institute (BSI) defines the CDE as a single source of information for any given project or asset, used to collect, manage and disseminate all relevant approved files, documents, and data for multidisciplinary teams in a managed process(Mordue, 2018a).

Basically, CDE is important throughout the project life cycle. However, the benefit of a CDE during the operational stage include: saving time in transferring accurate and comprehensive information from the construction to operational phases; easy access the essential and reliable information; improved real-estate planning, procurement, and maintenance analysis across a portfolio of built assets(Mordue, 2018b). In addition, CDE Strategies is both in terms of the development stage of PIM and the operational stage of AIM for each of the benefits in an Employer's portfolio(Borrmann, 2018). Besides this by implementing data limitation mechanisms, the building/facility owner should consider the security risks of data protection in a CDE. At the start of the project, project team members' roles, permissions, and access control should be specified(BCA, 2018).

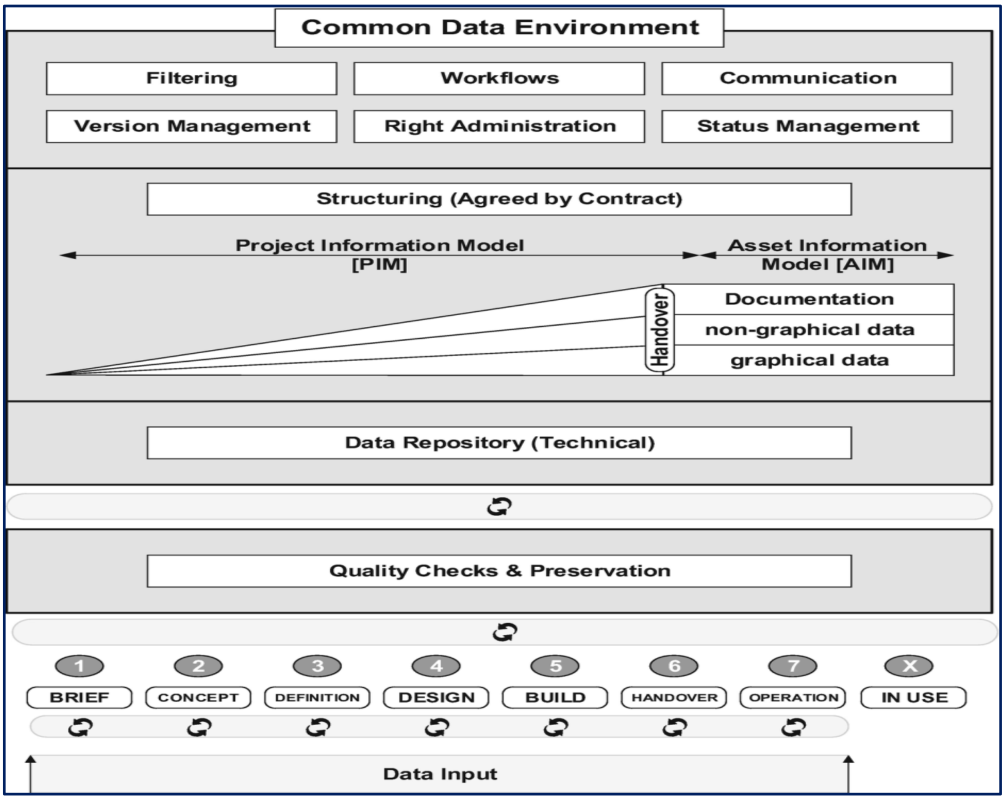


Figure 2- 13: Common Data Environment represented as a layered structure composed of the individual technical elements adopted from ISO 19650-2(Borrmann et al., 2018).

2.9 BIM software for Built Asset Facility Management

Facility managers have to acquire, integrate, edit and update diverse facility information ranging from building elements and fabric data, operational costs, contract types, room allocation, logistics, maintenance, etc. With the advent of standardized BIM such as IFC new opportunities are available for Facility Managers to manage their built asset FM data(Mitchell and Schevers, 2013). BIM software for Built Asset FM is still an infant. However, Software like Archibus, FMSystems, Onuma, Bexcel Manager, and Ecodomus are BIM software for FM. CAFM and CMMS are conventional software for Built asset FM(Alvarez-Romero, 2014). Moreover, BIM software used in the operations and maintenance phase of the projects is mainly the software that uses BIM models and data to operate the FM. Most of this software has features that allow the facility manager to access asset location and information, execute asset maintenance and plan maintenance procedures. One aspect that needs to be researched when selecting FM software is the accepted format as input. It is necessary to identify the software that reads open formats as IFC integrates it with spreadsheets such COBie/ database format(Engenharia, 2020). Currently, several BIM-driven FM systems are available including IFC-compliant ones but only a few are discussed in this study.

2.9.1 Computer-Aided Facilities Management (CAFM)

CAFM software provides the facility manager with the administrative tools and the ability to track, manage, report, and plan facilities operations. This function is associated more with an administrative function and not a technical activity(El-Deeb et al., 2017). Therefore, CAFM is a tool for organizing and managing the facility's assets such as maintenance and operations, facility budgeting and accounting, construction, and project management(Aziz, Nawawi and Ariff, 2016). Data modelling for CAFM systems is the work of integrating all functions related to building management. To build a data model for a CAFM system one is forced to bring all the different understandings of management in the technical, financial sense, and usability together(Schürle and Fritsch, 2000). CAFM is still largely practised based on conventional methods such as tabulated data and 2D (two-dimensional) drawings but it is versatile enough in maintenance management objectives (Gnanarednam and Jayasena, 2013).

2.9.2 ARCHIBUS

ARCHIBUS was designed to integrate workplace management for real estate, infrastructure, and facilities management to define the needs of multiple functions and departments in an organization. It uses a web central-based application to address, check, monitor, and simply access the system using an internet browser(Solla et al., 2020), and ARCHIBUS uses a web-based application that allows quick and simple access to the system using an internet browser(Division, 2021). Moreover, ARCHIBUS is an Integrated Workplace Management System platform developed by ARCHIBUS, Inc. The platform is integrated bi-directionally with building information modelling and CAD design software. ARCHIBUS software solutions are used to manage around 15 million properties around the world(Brandstadter, 2011).

2.9.3 Ecodomus FM

EcoDomus FM is intended to serve as a central facility repository for helping owners by integrating BIM with building automation, computer-aided facility management, computerized maintenance management systems, and GIS. It can do this through custom Revit plug-ins that ease the transfer of data(Kensek, 2015). Moreover, EcoDomus is an information technology firm focusing on improving the ways buildings are designed, built, managed, and retrofitted using BIM. EcoDomus is the leading global software provider, bringing the value of BIM-based Digital Twin to building owners and occupiers for an improved design and construction data collection and handover, facility management, operation, and maintenance. (EcoDomus, 2021).

2.9.4 Bexel Manager

BEXEL Manager Facility Maintenance is an intelligent and universal solution for centralized, model-based 6D facility maintenance planning and tracking, containing equipment data, documents, specifications, and materials. Besides this BEXEL Manager Facility Maintenance provides a comprehensive source for planning and tracking the use, performance, and maintenance of various systems, equipment, and other project assets, for the client and operations and maintenance teams (bexelconsulting, 2021). Moreover, BEXEL Manager is capable to identify over 20.000 clashes between model elements in a matter of seconds. BCF Manager allows reviewers to exchange identified issues (viewport, element IDs, issue description) in a file format that designers can directly import into the BIM Authoring tool, and promptly resolve the reported issues. One of the main qualities of BEXEL Manager is using predefined rules and templates, which enable to automatically create and update of specific sets of model elements(Crozdesk, 2022).

2.9.5 YouBIM

YouBIM is a Cloud-based Software (also available On-Prem), which extends the value of BIM through the Buildings Lifecycle by giving owners an integrated database and immediate access to location and asset information through an easy-to-navigate web-based 2D/3D-BIM interface(YouBIM, 2022). YouBIM attaches rich data and documents [PDFs, JPGs, Excels, etc.] to smart objects in the online BIM dataset. In addition, it seamlessly integrates with CMMS/EAM and CAFM systems like (IBM Maximo, Planon Software, ArchiBUS, Infor, etc…) and can integrate with BAS/BMS/IoT bringing live performance data to be displayed within the YouBIM environment(Greenhealthcanada, 2022).

The quality of BIM software for Built asset facility Management is the degree to which the system satisfies the stated and implied needs of its various stakeholders, and thus provides value. Those stakeholders' needs (functionality, performance, security, maintainability, etc.) are precisely what is represented in the quality model, which categorizes the product quality into characteristics and sub-characteristics. Therefore, based on ISO/IEC 25010 software quality standards and the desk study of different decisive features, the BIM software for Built Asset Facility Management is summarized shown in the table below:

Table 2- 9: BIM software for Built Asset Facility Management

Decisive features	BIM software for Built Asset Facility Management				
	CAFM	ARCHIBUS	ECODOMUS	BEXEL MANAGER	YouBIM
Cost	Midium	Midium	High	High	High
Functional Suitability	Medium	Medium	High	High	High
Performance efficiency(Capacity)	Low	Low	High	High	Midium

Compatibility(interoperability/integration)	Low	Low	High	High	Midium
Usability (Learnability, and Operability)	High	High	Medium	Medium	High
Reliability (Maturity based on a list of Features)	Low	Low	High	High	Medium
Security (Confidentiality and Accountability)	High	High	Medium	Medium	Medium
Maintainability (Analyzability and Testability)	High	High	Medium	Medium	Medium
Portability (Adaptability and Installability)	Fast	Fast	Fast	Fast	Fast

According to the comparison above, CAFM and ARCHIBUS mostly support semantic data and some O & M documents. However, ECODOMUS, BEXEL MANAGER, and YouBIM support all the required graphic data, non-graphic data, built asset O & M documents as well as the linked documents. Furthermore, based on the comparison of decisive features, ECODOMUS, BEXEL MANAGER, and YouBIM are more/less suitable for Built asset information Management. As a result, based on the list of fundamental features and integration with other design, construction, and FM software, BEXEL MANAGER excels in YouBIM and ECODOMUS. Therefore, the researcher recommends BEXEL MANAGER for building asset facility information Management in the public university. So, BEXEL Manager is an IFC2X3 certified BIM software solution for the management of construction projects that integrate the most important 3D/4D/5D/6D uses of BIM technology in one single software interface. Also, BEXEL MANAGER software allows a CDE for all relevant types of information. It gives a 3D view of facilities in an easy-to-use format for facility managers that links the Asset Information Model (in BIM) with real-time facility operations data acquired by meters and sensors technology BMS) and FM software. Furthermore, BEXEL Manager can integrate with any software that supports the IFC file format.

2.10 Research Gap

BIM applications for the planning, design and construction phases of a new building have been thoroughly discussed and researched. However, BIM for existing buildings and FM applications is still acknowledged as an emerging area for research and practice. The O & M phase of the built asset facilitates is the most expensive phase. Currently, most of the built asset information is paper-based and delivered to the owner lately(Patacas et al., 2015). Extensive data/information and documents are needed for built asset facility management. An efficient and effective system is needed to collect, access, and update existing built asset information(Teicholz,2013). Furthermore, the O & M phases of the built asset also require comprehensive and well-structured information (Yalcinkaya et al., 2016a). However, FM information systems in the market are not good to address the information requirements of FM (Liu and Issa, 2021). BIM has been widely adopted by the construction sector, though FM is still based on a variety of disparate FM systems. Therefore, the BIM system solves the challenges by incorporating the complete multifarious information from the planning to demolishing phase of the built asset. It is simple to integrate with existing FM systems(Nicał and Wodyński, 2016).

In Ethiopia, the implementation of BIM is still at an infant stage. Also, there is no clearly defined rule or regulation to implement BIM at the project delivery and end phase. Furthermore, The built asset facility management is also overlooked in the construction industry. Yet, nobody also specifies what data/information is needed for Built Asset O&M activities. The data/information is everything and critical for built asset management in public universities. The current practice of built asset information management systems in public universities utilizes a conventional method for data capturing, delivering, and managing the built asset. This brings inefficiencies of data/information, information loss, wasted time searching for the built asset data, inconsistencies of the available data, poor building maintenance management, loss of workforce productivity and re-work, inconvenience to end-user, and not meeting the intended purpose.

Due to this, substantial economic losses could occur. In summary, the construction industry grew rapidly and the ministry of education substantially lost its economy via the development of public universities. Thus, the essence of this study is to fill the gap in the literature and the current practice of built asset information management systems for Public Universities in Addis Ababa.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Introduction

In this chapter, information utilized to conduct this study including the research philosophy, research type, research approach, strategies, research data sources, sampling, method of data collection, method of data analysis, and research quality are discussed and justified.

Research methodology is a way to systematically solve the research problem. It may be understood as a science of studying how research is done scientifically (Kothari, 2004; Kumar, 2011 and Patel & Patel, 2019). It is also the path through which researchers need to conduct their research via formulating their problem, research objectives and finally presenting their results from the data obtained during the research period (Saunders, Lewis and Thornhill, 2009). The methodology for conducting research is grounded on a philosophical perspective on the nature of the issues to be investigated and the methods to investigate them.

Research philosophy is associated with the assumption, knowledge, and nature of the study. It deals with the specific way of developing knowledge(Danson, Taheri and Richards, 2018). Research philosophy also deals with the source, nature, and development of knowledge. In simple terms, research philosophy is the belief about how data about a phenomenon should be collected, analyzed, and used(Burrell and Morgan, 2019). Each research philosophy embodies its own set of ontological, epistemological, and axiological assumptions. The ontological assumptions about the nature of the studied phenomenon are highly abstract. The epistemological assumptions explain what is considered desirable, acceptable, legitimate, and valid human knowledge and how knowledge can be communicated to others. The epistemological assumptions are therefore more tangible than the ontological ones. The axiological assumptions explain how values and ethics should influence the research outline and the extent to which the researcher could remain detached from the collected data(Aliyu et al., 2015). Different research philosophies are distinguished from one another through two major dimensions: objectivism/subjectivism, and sociologies of regulation/radical change(Burrell and Morgan, 2019).

The aim of this study is to provide universally valid inferences about the phenomenon of BIM-enabled Built asset Facility information management systems. Ontologically, this study seeks ultimate objectivity, and epistemologically, research should seek, find, and present a hard fact. Furthermore, from an axiological standpoint, every effort has been taken to limit the influence of subjective evaluations. The current practice and the conceptual framework of BIM enabled Built asset facility information management system are derived from and closely linked to real-life practices. This research has formulated a research objective and established a research question to investigate the BIM-enabled Built asset facility information management system. Therefore, the research requires a mixed-method: both deductive and inductive research approach; both qualitative and quantitative data; and the data relies on behavioural responses and built asset facility documents. As a result, the pragmatic research philosophy has thus been adopted. As a research paradigm, pragmatism focuses on problems, practices, and relevance. As a contribution to solving the problem and informing the future practice, the researcher used the methodological approach that explored the research problem.

3.2 Types of Research

Research can be classified in a variety of ways depending on three different perspectives: applications of the findings of the research study; objectives of the study; mode of inquiry used in conducting the study. But, the classification of the types of a study based on these perspectives is not mutually exclusive(Kumar, 2011). Also, Research can be classified based on time, purpose, settings, place, and technique(Patel and Patel, 2019).

A research approach might be basic or applied depending on the application/purpose or value. While basic research seeks to expand knowledge by developing new theories and modifying existing ones, applied research seeks to provide practical solutions to specific problems via the analysis of empirical evidence. Based on the objectives of the study the research was classified into descriptive, exploratory and explanatory research types. Research is also classified into deductive and inductive based on the mode of inquiry used in conducting the study. The inductive approach at developing a theory while the deductive approach aims at testing an existing theory. In addition to that, research can be classified as quantitative and qualitative based on the data sources. Therefore, the research types based on the objectives of the study and that to answer research questions are discussed in this section.

- **Descriptive research:** As the name itself indicates, this research directly deals with description. The main character of this research is that the researcher does not have control over the variables (Patel and Patel, 2019). Descriptive research is concerned with specific predictions, with the narration of facts and characteristics concerning individuals, groups, or situations (Kothari, 2004). Furthermore, this research type focuses more on the “what” of the research subject than the “why” of the research subject(Clarke, 2014). The researcher has no power control over the variables but only reports what has happened or what is happening(Clarke, 2014 and Patel & Patel, 2019). Descriptive research studies also deal with collecting data and testing hypotheses or answering questions concerning the current status of the subject of study. It deals with the question of ‘what is of a situation(Clarke, 2014). Besides this, It focuses on answering the how, what, when, and where questions, rather than the why questions (Heath, 2021).
- **Exploratory research:** As the names suggest, this research is intended to merely study, examine, analyze, or investigate something(Stebbins, 2014). Exploratory research studies are also termed formative research studies. The main purpose of such research is that of formulating a problem for more precise investigation or of developing the working hypotheses from an operational point of view(Kothari, 2004). it is designed to explore ideas and insights in order to obtain a proper definition of the problems at hand. it is appropriate for the early stage of the decision-making process. it is designed to obtain a preliminary investigation of the situation with a minimum expenditure of time and cost(Stephenson and Slesinger, 2018). Exploratory research is carried out at the very beginning when the problem is not clear or is vague(Heath, 2021). Accordingly, Explanatory research is a research type that is developed to investigate a phenomenon that had not been studied before or had not been well explained previously in a proper way(Denscombe, 2010). The results of exploratory research are not usually useful for decision-making by themselves, but they can provide significant insight into a given situation. Although the results of qualitative exploratory research can give some indication as to the "why", "how" and "when" something occurs, it cannot tell us “How often" or "how many". In other words, the results can neither be

generalized; they are not representative of the whole population being studied(Stebbins, 2014).

- **Explanatory research:** The research Studies that establish causal relationships between variables. The emphasis here is on studying a situation or a problem to explain the relationships between variables(Saunders et al., 2013). it is a research method that explores why something occurs when limited information is available. It can help you increase your understanding of a given topic, ascertain how or why a particular phenomenon is occurring, and predict future occurrences (Kumar, 2011). In general, Explanatory research is conducted to help researchers to study the problem in greater depth and understand the phenomenon efficiently. The main use for explanatory research is problem-solving by finding the data that went overlooked or had never been investigated before; while it might not bring out conclusive data(Denscombe, 2010).

In conclusion, according to the preceding discussion in this research exploratory and descriptive research type has been adopted which are in line with the research objective and questions. BIM-enabled Built Asset Facility Information Management at Public Universities has not been having not yet been studied is why the researcher chose an exploratory research type. Also, the researcher has limited influence to control variables that report only what has happened or what is happening so that is why the researcher chose descriptive research. Additionally, the current practices of built asset information management systems in the public universes are described in what question and explored in how question. This study is much more basic research than applied research.

3.3 Research Approach

Research approaches are plans and the procedures for research that span the steps from broad assumptions to detailed methods of data collection, analysis, and interpretation(Creswell, 2014). The research involves the use of theory. That theory may or may not be made explicit in the design of the research, although it usually is made explicit in the presentation of the findings and conclusions. The extent to which the research is concerned with theory testing or theory-building raises an important question regarding the design of the research. The three research approaches are deductive; inductive and abductive(Saunders et al., 2019). Moreover, the reasoning is the process of using existing knowledge to draw conclusions, make predictions, or construct explanations. Three methods of reasoning are the deductive, inductive, and abductive approaches(Garg and Former, 2013). Therefore, A deductive research approach is aimed and testing theory and an inductive approach are concerned with the generation of new theories emerging from the data. An abduction approach is a form of logical inference which goes from an observation to a theory that accounts for the observation(Yu, 2006; Melnikovas, 2018; Patel & Patel, 2019). In addition, the research approach is a way of thinking that researchers adopt about how the research design is made and how the research will be conducted. In this way, the research approach is categorized as qualitative, quantitative, and mixed approaches (Bottomley, 2016).

- **Qualitative research approach:** it is a research approach concerned with the subjective assessment of attitudes, opinions, and behavior. Research in such a situation is a function of the researcher's insights and impressions(Kothari, 2004 and Garg & Former, 2013). Research in a qualitative way uses narrative data with words to answer questions or problems. It aims to answer a problem descriptively. In a qualitative method, the researchers are instruments. Usually, this research is done through individual interviews or with focus group discussions(Bottomley, 2016).
- **Quantitative research approach:** This research is mainly concerned with the measurement of a phenomenon in terms of quantity(Patel and Patel, 2019). The research approach also involves the generation of data in a quantitative form which can be subjected to rigorous quantitative analysis formally and rigidly. This approach can be further sub-classified into inferential, experimental, and simulation approaches to research(Kothari, 2004 and Garg & Former, 2013). Furthermore, this research must be based on facts that are clear and can be proven empirically. This method tests the truth of theory and concepts and this study begins with a detailed hypothesis. This method searches for facts and causes and wants to know a lot about a number of variables so that it can identify the differences. To collect data, the quantitative approach uses a structured survey or interview(Bottomley, 2016).

In short, according to the preceding analysis and discussion in this research Mixed method approach was used. Mixed method research is an approach to an inquiry involving collecting both quantitative and qualitative data, integrating the two forms of data, and using distinct designs that may involve philosophical assumptions and theoretical frameworks(Saunders et al., 2015). Accordingly, the researcher also used both deductive and inductive research approaches for theory built/testing, as well as the data analysis process.

3.4 Research Strategy

A research strategy is “a way of investigating an empirical topic by a set of pre-specified procedures” (R. K. Yin, 2003). There have been several research strategies established and used for descriptive, explanatory, and exploratory research. Some of these strategies are used in the deductive approach, while others are used in the inductive approach (Benbasat et al., 1987). According to, Saunders et al. (2015) research strategies are categorized as an experiment, surveys, case studies, grounded theory, ethnography, and action research. Accordingly, Yin (2003) the type of research strategies are slightly different from others such as case studies, surveys, experiments, archival documents, and history. But, grounded theory and ethnography should be considered as research methods rather than research strategies since they offer no theoretical proposition. The research questions and research objectives, the available time to conduct the study, the extent of knowledge, the collection of data, the philosophical underpinning, and other available resources all influence the selection of a research strategy. Furthermore, these strategies are not mutually exclusive and do not guarantee an exact answer to the research question (Crossan, 2003). Moreover, Rowley (2002) identifies three criteria to consider when selecting a research strategy: the types of questions to be addressed, the degree of control over behavioural occurrences, and the degree of focus on contemporary rather than historical events.

Table 3- 1: Summary for selection of research strategy

Research strategy	**Type of research question**	**Requires control of behavioural events?**	**Focuses on contemporary events?**
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
Case Study	How, why?	No	Yes

Action Research	what, how?	Yes	Yes
Grounded Theory	How, what, why?	No	No
Ethnography	Who, what, where, how many, how much?	No	Yes/No

In conclusion, considering the extent of control the researcher has over actual behaviour, the degree of focus on contemporary issues, the nature of the problem, the specific objective, and the availability of data, this study necessarily requires a comprehensive contextual investigation of the context of public universities in Addis Ababa. Therefore, a case study is selected as a research strategy in this study.

A case study is a common research strategy involving an empirical investigation of a particular contemporary phenomenon in a real-life context(Wedawatta et al., 2011). The study strategies enable a researcher to closely examine the data within a specific context. In most cases, a case study method selects a small geographical area or a very limited number of individuals as the subjects of study. Case studies, in their true essence, explore and investigate contemporary real-life phenomena through detailed contextual analysis of a limited number of events or conditions, and their relationships(Zainal, 2015). Besides, the Case study research method is an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used(Yin, 2003).

3.4.1 Justification of the Selected Strategies: A case study research Strategy

The case study research method is an empirical inquiry that investigates a contemporary phenomenon within its real-life context; when the boundaries between phenomenon and context are not clearly evident; and in which multiple sources of evidence are used(R. K. Yin, 2003). The case study research strategy allows in-depth, multi-faceted explorations in reputation as an effective methodology to investigate and understand complex issues in real-life settings(Harrison et al., 2017). The case study method enables a researcher to closely examine the data within a specific context. In most cases, a case study method selects a small geographical area or a very limited number of individuals as the subjects of study. Case studies, in their true essence, explore and investigate contemporary real-life phenomena through detailed contextual analysis of a limited number of events or conditions, and their relationships(Zainal, 2015). Furthermore, Yin (2003) mentions the three conditions for adopting a case study as the research strategy:

- When the research type is exploratory, descriptive, and explanatory;
- when the researcher has little control over the studied phenomenon; and
- When the studied phenomenon is contemporary.

As discussed in section 3.2 the selected research type in this study is a mixed type of exploratory and descriptive. According to the nature of the problem, the specific objective, and the availability of data, this research requires a detailed contextual investigation within the selected public universities' context in Addis Ababa. Also, due to the multidisciplinary nature of the research, the researcher rarely controls it. Moreover, the research phenomenon is contemporary. Therefore, those entire reasons are used to select a case study as a research strategy. Hence, the researcher's judgment to use a case study as a research strategy is understandable.

- **Design of case study**

Researchers can adopt either a single-case or multiple-case design depending on the issue in question. In cases where there are no other cases available for replication, the researcher can adopt the single-case design. The multiple-case design, on the other hand, can be adopted with real-life events that show numerous sources of evidence through replication rather than sampling logic(Zainal, 2015). Yin (2009) proposes four main types of case study design each of which needs to be selected on the basis of particular sets of conditions. This shows that case studies can be based upon single or multiple-case designs and on single or multiple units of analysis. Four main types of cases are:

- **Single Case Study, Holistic:** In this type of study, only a single case is examined, and at a holistic level. A single case study should be chosen when it can play a significant role in testing a hypothesis or theory. Therefore, researchers in this case study conduct a single case and draw a single analysis.
- **A single Case, Embedded:** In this type of study, only a single is examined but a number of different units of analysis may be conducted. Thus, researchers in this case study conduct a single case and draw a multiple analysis.

- **Multiple Case, Holistic:** Where the multiple case study approach is needed (say, to improve the reliability or generalizability of the study) but it is not possible to identify multiple units of analysis, then a more holistic approach can be taken. The aim here is not to increase the size of the sample, but to replicate the findings of one case across a number of cases. In this sense, the approach is not very dissimilar to that of experimentation, where an attempt is made to replicate the findings of one experiment over a number of instances. Therefore, researchers in this case study conduct multiple cases and draw a single analysis.
- **Multiple Cases, Embedded:** The problems faced by holistic case studies can be reduced if multiple units of analysis are used which allows for more sensitivity and for any slippage between research questions and the direction of the study to be identified at a much earlier stage. But one of the dangers of embedded designs is that the sub-units of analysis may become the focus of the study itself and divert attention away from the larger elements of analysis. Therefore, researchers in this case study conduct multiple cases and draw a multiple analysis.

Hence, based on the above analysis and discussion of multiple cases, a holistic case study design type is used in this study.

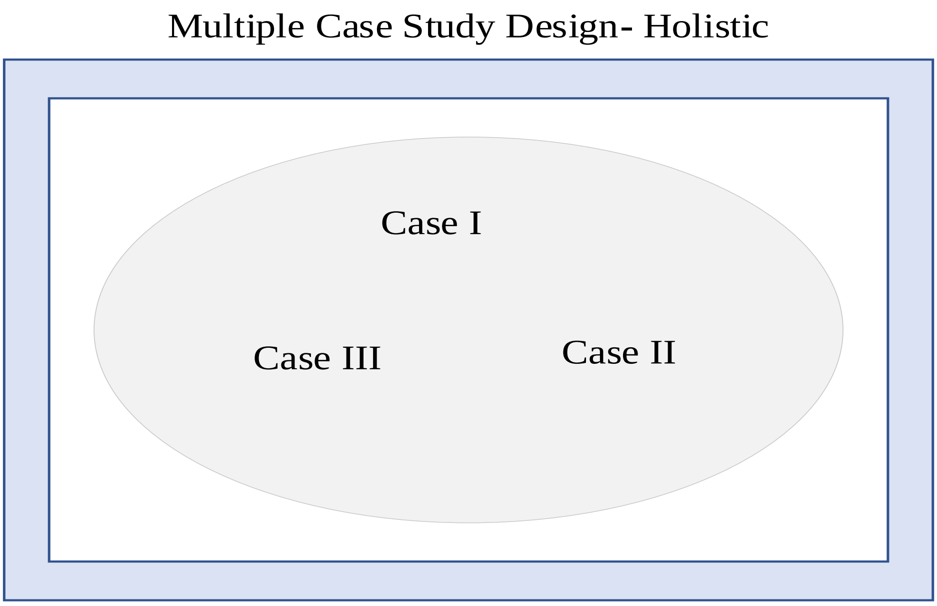


Figure 3- 1: Case Study Design for this study

3.4.2 Sample sizes of the case and Case Selection criteria

Sample sizes in case studies are typically small, which is common in most qualitative research. But, there are no precise rules as to the number of cases that should be selected in multiple case study research(Fletcher and Plakoyiannaki, 2000). Eisenhardt (1989) suggests that four to ten cases well, with fewer than four it is difficult to generate theory, and with above its difficult to manage data. Yin(2018) argues that using a single case under a situation where a critical case is observed and analogous to single testing after all increases the sample size for replication logic. Moreover, typically a case study has a sample of one (i.e., the bounded case, but note that sampling can also occur within the case) unless the research project is a multiple-case study. In a multiple-case study, having three to four distinct cases for comparison is probably the most case that one can realistically handle. When using multiple cases or sampling within a case, it is effective to use a selection method known as purposeful sampling(Patton, 2003). In general, a case study requires selecting the best-fit case(s) based on predefined selection criteria to address a specific interest and theoretical consideration.

There are five public universities in Addis Ababa, and researchers minimize the sample size to three cases due to the following reasons: to conduct in-depth investigations; to increase the accuracy of findings, as well as time and cost constraints. Hence, the following criteria are used to select three cases among form the five public universities in Addis Ababa;

- Year of establishment
- No of campus
- No and types of a built asset in the universities
- No of the staff and students enrolled
- Public university plot area
- Technology implementation

3.5 Sources of Data and Method of Collection

Data is the basis of data analysis that was undertaken during the research process(Thakur, 2020). Data are organized into two broad categories: qualitative and quantitative. Qualitative data are mostly non-numerical and usually descriptive or nominal in nature but quantitative data is numerical in nature and can be mathematically computed(Buchanan, 1981). Besides this, the data are categorized into primary and secondary data: primary data is original data collected for a specific research goal but secondary data is data collected from a source that has already been published(Hox and Boeije, 2005). Those data are collected from primary and secondary data sources (Thakur, 2020).

- **Primary data sources:** A primary source contains original information that is not derived from interpretation, summarizing, or analyzing someone else's work(Lombard, 2010 and Ajayi, 2017).
- **Secondary data sources:** Secondary sources are work that has been based on primary (or other secondary) sources. They are usually an interpretation, a summary, an analysis, or a review (Lombard, 2010 and Ajayi, 2017).

The mixed-methods approach is used in this study, so primary data are collected using primary data sources such as semi-structured interviews and document analysis. Secondary data, on the other hand, are collected via a critical literature review. Additionally, both qualitative and quantitative data are collected from primary data sources by using the data collection method.

- **Interview:** An interview is a face-to-face conversation with the respondent. In an interview, the main problem arises when the respondent deliberately hides information otherwise it is an in-depth source of information(Buchanan, 1981). Therefore, In management and social science research studies, there are three types of interviews: structured, unstructured, and semi-structured. Structured interviews are more commonly used in survey strategies for gathering quantitative data in a study. Informal and in-depth interviews are referred to as unstructured interviews. These interviews are used to investigate a specific topic or area of research, and the interviewee is not asked any predetermined questions (Saunders et al.,2015). Semi-structured interviews are non-standardized interviews that are used as a qualitative data collection method in research. The interviewer has a list of predetermined themes or questions to cover in this type of interview, but they may not get a chance to ask all of them(Hox and Boeije, 2005).

In summary, interviews are the best research instrument in the inductive research approach. Therefore, in this study semi-structured interviews were conducted by selected interviewees from the university FM Directorate and Project offices Directorate via considering their experience in built asset facilities management and construction project management respectively. All the interviews were recorded by the researcher, with participant consent, for transcription at a later time. All the participants were given the same semi-structured interview questions. To avoid any confusion, the names of public universities were assigned Codes of Case I, Case II, and Case III. Furthermore, for personal identification, participants' names were assigned codes ranging from P1 to P4, with P1 indicating participant #1 and P4 indicating participant #4.

Table 3- 2: Interviewee's information

Cases	Interviewees/ Participants	Roles
Case 1	P1	Vice President for Institutional Development and Business
	P2	Project office Directorate
	P3	FM Directorate
	P4	Maintenance team leader
Case 2	P1	FM Directorate
	P2	Senior Civil Engineer in the project office
	P3	Civil Engineer in the project office
Case 3	P1	Project office Directorate
	P2	FM Directorate

Interviews helped in the collecting of detailed information about:

- Perceptions, experiences, ideas, and concepts are deeply rooted in the Built asset information management system. Also, the opinions and perceptions of study participants to get practical information about the built asset facility information management system.
- Current built asset facility information management strategies, tools, and technologies were explored through this method, from the opinions of the FM team.
- Practical information about built asset information requirements for BIM-enabled FM.
- Extracting expert practitioners' knowledge about the built asset information management system; the required information for BIM-enabled FM. The extracting knowledge was used to develop the conceptual framework of a BIM-enabled built asset facility information management system.

In this study both qualitative and quantitative methods were used, this covered the depth of the topic of BIM-enabled built asset information management system and cross-verification was done through replication logic, document analysis, and observation to bring reliability and validity to the research. So that document analysis is a valuable source of information to understand central phenomena and for cross-verification.

3.6 Data Analysis Technique

Analyzing data is the heart of building theory from case studies, but it is the most difficult and the least codified part of the process(Eisenhardt, 1989). The purpose of this study was to investigate the BIM-based built asset facility information management system. To this end, this study focused on the current practice of built asset information management systems in public universities and the required information for BIM-enabled FM. The researcher also focused on the data to develop a conceptual framework. Therefore, the author of the study has chosen both thematic analysis for qualitative data and descriptive analysis for quantitative data. However, the analysis of the multiple case studies is based on the comparisons between the empirical evidence with the theoretical propositions developed at the initial stages of the study and involves detailed case study write-ups for each case. The overall idea is to become intimately familiar with each case as a stand-alone entity. This process allows the unique patterns of each case to emerge before pushing towards generalized patterns across cases. In addition, it gives rich familiarity with each case which, in turn, accelerates cross-case comparisons.

- **Cross case patterns:** The strategies are driven by the fact that people are poor at information processing (Eisenhardt, 1989). They jump to conclusions based on limited data, are swayed by clarity, ignore the basic statistical properties, and occasionally dismiss contradictory evidence. As a result of these information-processing biases, there's a risk that a researcher will reach an incorrect or premature conclusion. As a result, the key to a successful cross-case comparison is to counteract these tendencies by examining the data in a variety of different ways. The study's cross-case study utilizes a process called replication logic, or pattern matching, by Yin (2003), which is similar to that used in multiple experiments.

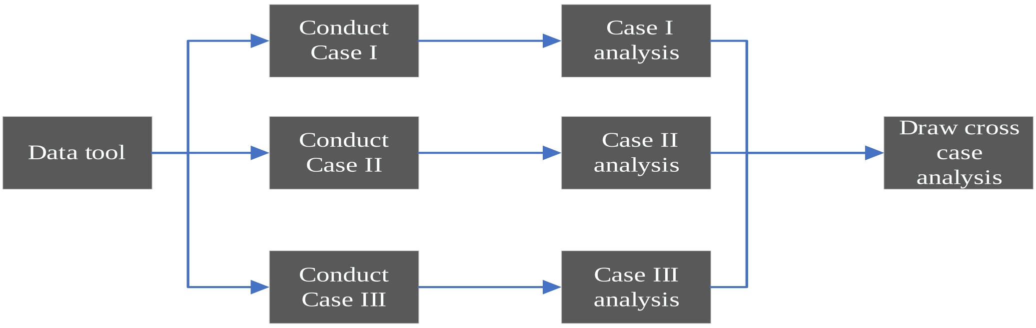


Figure 3- 2: Data analysis Flow chart of the study

3.7 Research Quality

Reliability and validity are concepts used to evaluate the quality of research. Reliability and validity are closely related, but they mean different things. So, Reliability is about the consistency of a measure, and validity is about the accuracy of a measure. Furthermore, A measurement can be reliable without being valid. However, if a measurement is valid, it is usually also reliable(Brent and Leedy, 1990). According to, Yin(2003), construct validity, internal validity, external validity, and reliability are the four research quality measurements that can be used to judge the quality of any given case design.

- **Construct validity**: investigates the extent to which the research tool used can put the research theory or hypothesis to the test. It can be addressed by ensuring logical connections between the chosen research paradigm, research type, approach, and design(Amaratunga and Baldry, 2000; Rowley, 2002 and Yin, 2003).
- **Internal validity:** Internal validity (for explanatory or causal studies only, and not for descriptive or exploratory studies) to demonstrate a causal relationship between two variables (Amaratunga and Baldry, 2000; Rowley, 2002 and Yin, 2003).
- **External validity:** establishing the domain to which a study's findings can be generalized. Also, discusses the results' relevance outside of the investigated situation (Amaratunga and Baldry, 2000; Rowley, 2002 and Yin, 2003).
- **Reliability:** demonstrating that the operations of a study such as the data collection produced can be repeated with the same results. This is achieved through thorough documentation of procedures and appropriate recording keeping(Amaratunga and Baldry, 2000; Rowley, 2002 and Yin, 2003). Moreover, Yin (2009) defines that the logic of replication is critical to reliability. the two types of replication logic are literal replication and theoretical generalization. According to Yin (2018), literal

replication ensures the occurrence of similar findings, whereas theoretical replication implies the presence of opposing findings across multiple case analyses.

Table 3- 3: Validity and reliability in the case study research [Source: Yin(2003)]

Tests	Case study tactic	Consideration in this study
Construct validity	• Use of multiple sources of Evidence • Establish a chain of evidence • Have key informants review the draft case study report	• Use of multiple sources of Evidence • Establish a chain of evidence
Internal validity	• Do pattern matching • Do explanation building • Do time-series analysis	
External validity	• Use replication logic in multiple case studies	• Use replication logic in multiple case studies
Reliability	• Use case study protocol • Develop a case study database	• Use case study protocol • Develop a case study database

Construct validity, literal replication logic, and document analysis are adopted to check the research quality in this study.

3.8 Research Framework

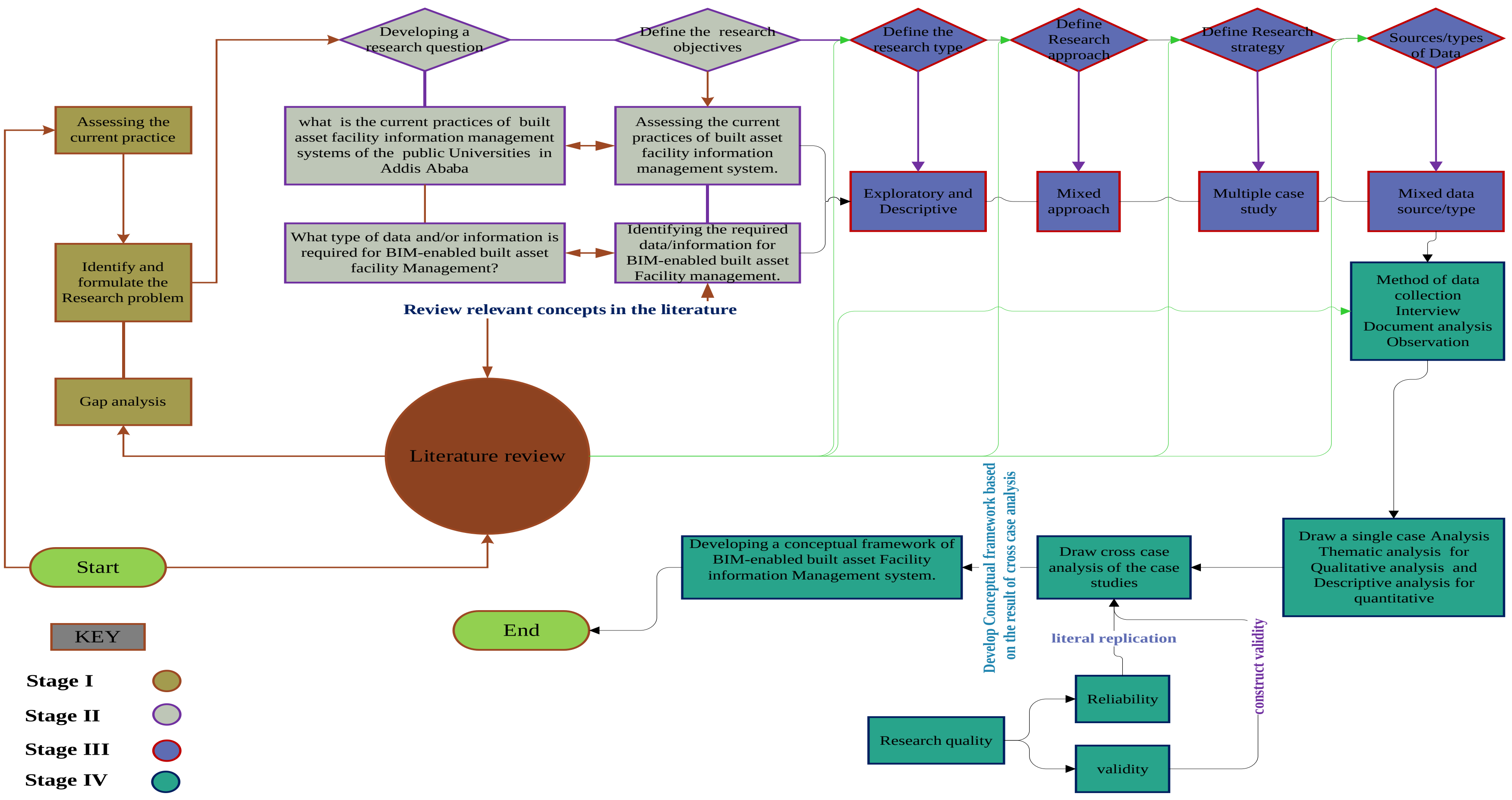


Figure 3- 3: Research Framework

CHAPTER FOUR: RESULT AND DISCUSSION

In this chapter, the analysis and results of the study are presented and discussed. As stated in section 3.4.2 three cases are selected in this study and holistically multiple case studies were conducted. In each case study, data were obtained primarily by face-to-face semi-structured interviews, the reliability of the data was verified by the document analysis of each case and finally, multiple-case replication logic was adopted in this study. The findings of a single case interview and document analysis were used to draw the final cross-analysis.

The chapter is divided and structured into six parts, which are corresponds to the three research objectives. The first part is an introduction, the second is a case description, the third part is interviewees' information, and the fourth part is current practices of Built Asset Facility data/information management system in Public Universities, which has 12 sub-sections/themes. The required data/information for BIM-enabled Built Asset facility management is the fifth part, and the conceptual framework for BIM-enabled Built Asset facility information management is the sixth and final part of this study.

4.1 Case Description

Table 4- 1: Case I description

https:// google. earth.com/web/search/case university, Addis Ababa

Location	Addis Ababa
Year of established	2011 E.C
No. of administrative staff	391
No. of Academic staff	472
No. of Undergraduate student	8000
No. of Postgraduate student	7000
Total covered land area	130 Ha
No. of campus	1
No. of building Block	60

The public university was established under the Directive of the Council of Ministers No. 216/2011. It is one of the two science and technology universities in Ethiopia. The conception of the public university has a direct and reasonable connection with the Growth and Transformation Plan of the government of the Federal Democratic Republic of Ethiopia (FDRE). The University has been given a bold nationwide mission of transferring the agriculture-led economy to an industry lead economy. The public university has been working in Engineering and Science fields taking into account the country's prioritized needs. The University is led by a President who is assisted by four Vice Presidents. Hence, the Facility Directorate and the Project Development Office report to the Institutional Development & Business V/President. The project office is responsible for the new construction and development of new facilities, whereas the facility directorate is responsible for the maintenance and operation of existing building facilities and general services. The university facilities include academic facilities (lecture halls, laboratories, and libraries), residential facilities (Student Dormitory), office/administrative facilities, sport/leisure facilities, commercial facilities, Student Cafeteria, and other supporting facilities like water, power, and ICT facilities.

Table 4- 2: Case II description

https://earth.google.com/web/search/Addis Ababa

Location	Addis Ababa
Year of established	1950 E.C
No. of administrative staff	4,346
No. of Academic staff	3110
No. of health professionals	1253
No. of Undergraduate student	29,872
No. of Postgraduate student	17,738
No. of campus	14

The public university is the oldest and the largest higher learning and research institution in Ethiopia. Since its inception, the University has been the leading center in teaching-learning, research, and community services. The public University has 14 campuses 10 colleges, 4 institutes that run both teaching and research, and 6 research institutes. Within these departments, there are 55 departments, 12 centers, 12 schools, and 2 teaching hospitals. The University is led by a President who is assisted by four Vice Presidents and one Executive Director: Academic Vice President, Vice President for Research and Technology Transfer, Vice President for Administration and Student Services, Vice President for Institutional Development and the Executive Director of the College of Health Sciences (with the rank of Vice President). Office of Facility Management is Administration and Student Services and is responsible for planning, coordinating, directing, and controlling general services. Construction Office develops and maintains risk management and emergency response mechanism for the university. The University has multiple facilities on each campus like have research, library, laboratories, cultural building and social activities, residential facilities (Student and staff hostel), office/administrative, commercial facilities, Student Cafeteria, Student's health facilities, and other supporting facilities like water, power, and ICT facilities.

Table 4- 3: Case III description

<table>
<tr><td rowspan="7">
http://www.case university.edu.et/</td><td>Location</td><td>Addis Ababa</td></tr>
<tr><td>Year of established</td><td>1996 E.C</td></tr>
<tr><td>No. of administrative staff</td><td>1000</td></tr>
<tr><td>No. of Academic staff</td><td>280</td></tr>
<tr><td>No. of student</td><td>7,000-7,999</td></tr>
<tr><td>No. of Postgraduate student</td><td>7000</td></tr>
<tr><td>No. of campus</td><td>3</td></tr>
<tr><td colspan="3">The public university started operation in 1995 but was formally established in February 1996. The need for the establishment of the University arose from the acute need for manpower with the new form of government structure. The University has been able to make a tremendous contribution to capacity building through the provision of short-term courses and specialized undergraduate and postgraduate programs. It has three campuses in different parts of Addis Ababa. The University is led by a President who is assisted by four Vice Presidents. The vice president's office for administration and development is working to improve efficiencies at the university in the areas of Administration, Finance, Facilities, Procurement, and Property administration. Technique and facility directorate is established as a Directorate, by separating the maintenance service part of the electric, building and water and sewerage line of the university from the General Service directorate on Aug 7, 2017. But the Projects Coordination Directorate under the president and responsible for the new construction and development of new facilities support Techniques and facility directorate. The university facilities include academic facilities (lecture halls, laboratories, and libraries), residential facilities (Student Dormitory), office/administrative facilities, Sports and Recreational facilities, commercial facilities, Student Cafeteria, Student health facilities, and other supporting facilities like water, power, and ICT facilities.</td></tr>
</table>

4.2 Information of interviewees

The information of interviewees such as roles, years of experience, and the time it took to conduct the interview is stated in the table below.

Table 4- 4: Detail Information of interviewees

Cases	Interviewees/ Participants	Roles	Years of Total experience	Years of specific experience	Interview Duration
Case 1	P1	Vice President for Institutional Development and Business	Above 20	4	20 min
	P2	Project office Directorate	13	2	50 min
	P3	FM Directorate	12	3 above	61 min
	P4	Maintenance team leader	6	4	61 min
Case 2	P1	FM Directorate	12	4	61 min
	P2	Senior Civil Engineer in the project office	12	5	102 min
	P3	Civil Engineer in the project office	8	3	102 min
Case 3	P1	Project office Directorate	16	4	51 min
	P2	FM Directorate	12	4	51 min

The interviewees have extensive construction industry knowledge as well as specific work experience. As shown in the figure below,56 % of the interviewees have 11–15 years of work experience, while 22 % have more than 16 years. As a result, the interviewees' work experience indicates that they are well-versed in the research knowledge area and current practices. They are also familiar with how information loss affects built asset facility management practices. Besides, 89 % of interviewees have worked in a specific field for more than 3 years. As a result, interviewees are familiar with the new project and built asset facility management practices, the effects of a lack of data information, and the types of data and information required for built asset facility management. Furthermore, the project office professionals understand the challenges of collecting the data/information at each stage of project life, as well as how to collect and generate the data/information at each phase of the project that uses for built asset facility Management.

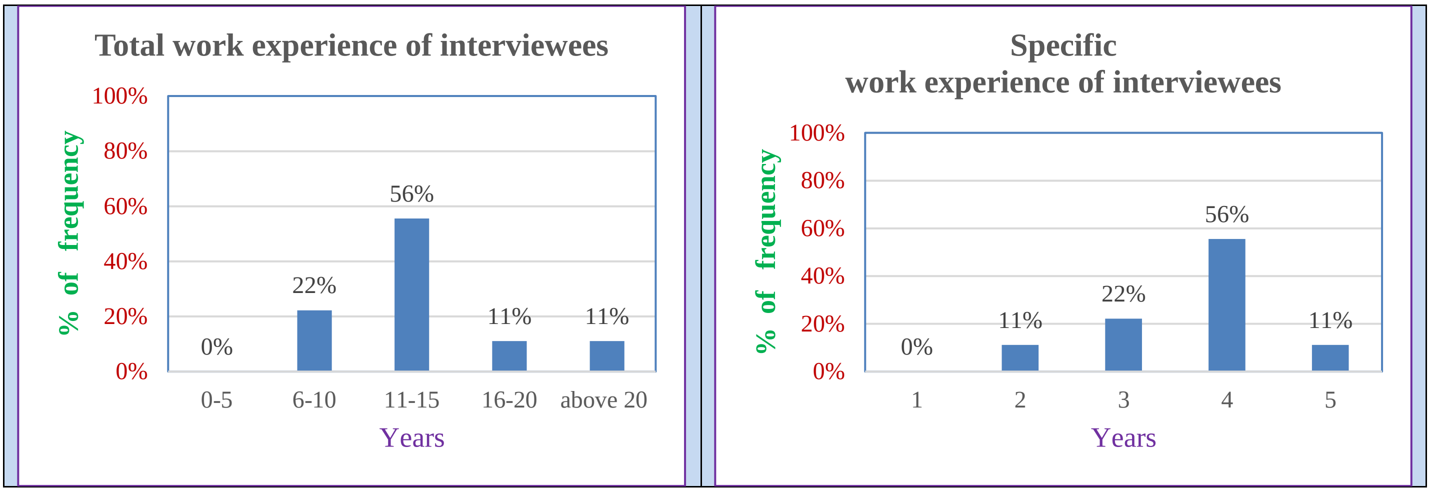


Figure 4- 1:Interviewees' work experiences

4.3 The current practices of the Built asset facility data/information management system of the public universities in Addis Ababa.

To collect enough data the main research question was divided into twelve (12) summarized sub-questions/themes to address the specific objectives, "What type of built asset facilities data/information management system is currently practised in public universities?". Hence, the current practice of built asset facilities information management systems is discussed for each selected public university and finally, the conclusion of multiple case results is presented by comparing with the facts in published literature and existing data.

4.3.1 Case I analysis

How many built assets (building blocks) are there in your university?

The purpose of the question was to draw attention to know the public university's asset registry and managing practice during and after the handing-over phase of the project. Based on the analysis result, three participants are unaware of the number of Building Blocks in the University. P3, on the other hand, mentioned that the university has 60 building blocks, and the participant was more familiar with the names and functions of those facilities. Hence, the participant is a senior professional in the university who is responsible for built asset registering and managing built assets as well as the construction project. In general, the results indicated that public university hasn't asset registry database to store the built asset data/information and its documents.

Does your department have data/information and documents of the built assets?

The question was developed to assess whether or not the FM office has data/information on the built assets. The three participants appear to have similar cognitive patterns on the FM offices have no the data/information and documents of the built asset. P2, on the other hand, stated that some building blocks have drawing documents, but almost none of them relate to the built asset. Generally, the result indicates that almost all built assets have no data/information and documents.

Does your office have as-built models/drawings/designs of the built asset facilities?

This question was intended to find out that does the FM department/office has as-built models/drawings/designs of built asset facilities, and if so, how to store and manage them. Furthermore, to assess whether the FM department/office uses those as-built design documents for maintenance purposes after construction and also to verify the document's relevance. Pondering over the answers, there seemed to be similar patterns of ideas observed between the three participants, specifically that there is no as-built model/drawings/design of the built asset facilities. Furthermore, P1 mentioned that securing the as-built model/drawings/design of the built asset is exceedingly difficult due to contract termination issues because of poor performance of the developer and the project's developer, owner, and consultant changes from time to time until the handover phase of the project. However, P2 stated that the project office has as-built drawings/design documents for some building blocks, but that the author has not yet really seen any as-built documents.

Does your office have a database to store and manage data/information and relevant documents of the Built Asset?

The purpose of the question was intended to find out whether the FM department/office has a database to manage and store data/information and relevant documents of Built Asset. After analyzing the responses, four participants seem to have similar patterns of understanding on FM department/office lacks a database to store and manage data/information and related Built Asset documentation. All participants mentioned that there is no database to manage the built asset information. So, this problem contributes to greater complexity and an unclear picture of where data is stored. Moreover, P3 mentioned that by considering the impact of the lack of a database the FM department currently intends to collaborate with the university's IT department is being tried to develop a simple maintenance database system.

Which data /information and document management system currently do you use?

This question was aimed to find out about the current practice of built asset facilities O & M data/information and document management system in the FM department. Pondering over the responses, there seemed to be similar patterns of thought between the four participants that there is no organized information and documents of the built asset. However, some maintenance records/maintenance schedules, as well as facility and equipment conditions, are managed manually (a paper-based file system) to a limited extent. P2 also mentioned that softcopy and Portable Document Format (PDF) of the building block drawings were stored, edited, and managed using a computer database.

Figure 4- 2: Case I Current practices of Built asset O & M data and Information Management system (Source: Picture Taken from the case I FM offices, 2021)

Does your office have a data/information/ file structure and data classification system?

The purpose of this question was to assess whether the FM department/office has a data/information file structure and a building classification system, as well as to know the participants' perspectives on the universities or individuals' interest to use the data structure and classification system. Therefore, four participants stated that the FM office has no data/information structure or classification system. However, all participants have interested to adopt the standard data model and building a classification system to manage the information of the built asset. Hence, to manage the data/information and documents of built assets properly the owner/FM team should categorize their facilities according to the standard data model and building classification system.

How do you manage and process O & M work orders request?

This question was aimed to find out the current O & M work orders request management and process practices in the FM office. Accordingly, four participants seem to have similar thoughts on the work order request. Therefore, the FM office was using the paper-based work order requests and practiced mobile applications (to some extent,) for conversations about the O&M problems and reports.

How do you capture and visualize data /information of built asset facilities for O&M activities?

The purpose of the question was to intend to know the current practice of built assets data/information capturing and visualization system used in the FM office. Accordingly, four participants seem to have a similar thought so the FM office uses the traditional (manually) data capturing and visualizing technique. The FM use tape measures for as-built data/ information capturing and for visualizing the data using direct onsite observations. Besides, P1 and P3 mentioned the traditional data/information capturing and visualizing technique is time-consuming, labour-intensive, and highly error-prone, with is difficult to change and visualize the data especially when the geometry of a facility or building is complex.

What is your level of agreement regarding the current practice of data/information exchange format from developer to user/FM team?

The purpose of this question was to know the level of agreement regarding the current practice of data/information transfer format from developer to user/FM team in the public universities. After analyzing four participants' responses shown figure below; printed paper documents (hardcopy), scanned documents (pdf format), AutoCAD documents (in DWG, DXF format), word documents (in DOC, DOCx format), and Excel documents (in

XLS format) are the pervasive data/information transfer formats from developer to facility owner/FM operator during project delivery phase.

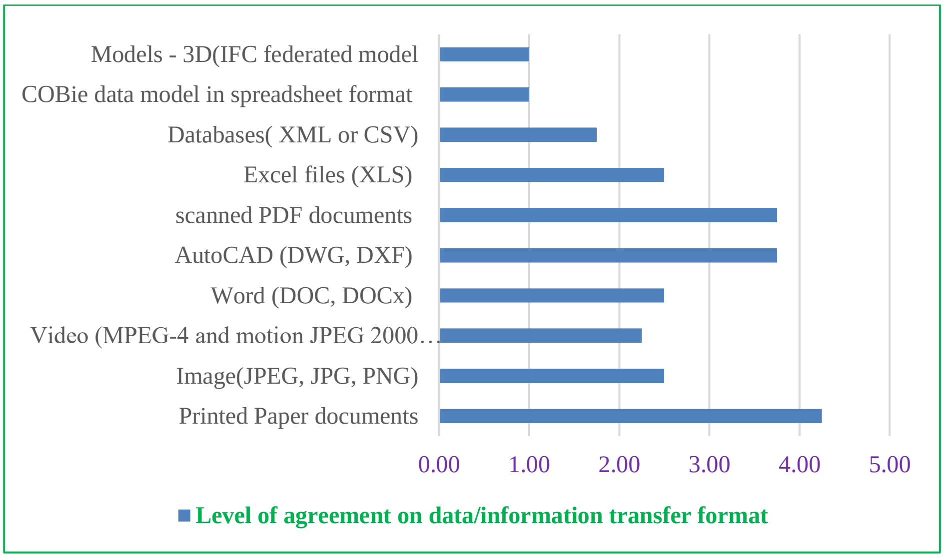


Figure 4- 3: Case I current practice of data/information transfer format from developer to user/FM team

Do you think that lack of data/information has an impact on the cost, schedule, and duration of O&M?

The purpose of this question was to identify the effect of lack of data/information has an impact on the cost, schedule, and duration of O&M. Accordingly, four participants seemed to have the same perspectives on the lack of data/information has an impact on the cost, schedule, and duration of O&M. Furthermore, P1 mentioned that reworking due to a lack of information has an impact on the built asset's O&M costs, schedule, and duration. Also, wasting time to gather, capture, and visualize data/information of the built asset O & M. The researcher concludes that costs are related to performing unnecessary redundant activities, such as resurveying, re-measuring, re-work, and/or manually re-entering data, and costs arising from information inaccessibility problems, such as delayed and idle O & M whereas to find staff, validate, or expects accurate facilities information, all of which are costs due to a lack of data/information about the built asset and also affect the O & M schedule, and duration.

Do you think that lack of data/information affects the process of monitoring and controlling built assets, as well as maintenance performance and user satisfaction?

The purpose of this question was to see how a lack of data/information affects the process of monitoring and controlling built assets, as well as a maintenance performance and user satisfaction. Based on participants' responses, lack of data/information affects the process of monitoring and controlling built assets, as well as maintenance performance and user satisfaction. Additionally, rework on the maintenance activities due to lack of information have an impact on user satisfaction and maintenance performance.

What do you think to enhance the current built asset information management system and do you believe it is required for Built asset facility management?

The purpose of this question was to identify the ways of improving current practices and to know participants as well as university higher officials' perspectives to enhance the current built asset information management system. Accordingly, the four participants' perspectives are believable to improve current practice by adopting new technology of built asset information management system throughout the project's life cycle. Furthermore, the author concludes that to improve current built asset facility information management system practices, the public university must adopt new technologies such as BIM-enabled FM technologies. The BIM-enabled Built asset facility information management system contains all of the detailed information about the built asset, the interconnected systems, and their associated parts, manuals, and other relevant documents that are also related to the university goal. In addition to that, improve and achieve whole-life cycle performance efficiencies from their physical assets, set an appropriate Maintenance plan and duration by allocating the optimal O&M cost. The facility manager can also immediately identify the source of the problem and the necessary steps to resolve it.

Summary

The FM office in this case the public university hasn't had an asset registry database to store and manage the data/information and documents of built assets. Additionally, almost all built assets facilities in the university have no data/information and documents. Hence, due to a lack of data/information and documents on the built asset facility the cost, schedule, and duration of O&M activities are affected. Also, it impacts the process of monitoring and controlling built assets, as well as a maintenance performance and user satisfaction. Currently, the FM office utilizes the traditional (manual) method to capture, visualize and manage the built asset facilities data. Similarly, Printed paper documents (hardcopy), scanned documents (pdf format), AutoCAD documents (in DWG, DXF format), word documents (in DOC, DOCx format), and Excel documents (in XLS format) are practiced as the pervasive data/information transfer formats from developer to facility owner/FM operator during project delivery phase. Besides this, the FM office has no standard data model and building a classification system to manage the built asset facilities information. So, to improve current practices of the built asset facility information management system the public universities must adopt FM technologies.

4.3.2 Case II analysis

How many built assets (building blocks) are there in your university?

The purpose of the question was to draw attention to know that the public university's practice in asset registry and management after the handing-over phase of the project. Hence, none of the three participants remembered how many existing building Blocks are there in the university. However, P1 stated that the university has 16 campuses, each with its own library, laboratory, student and staff residential building, lecture and meeting hall, office, and other built assets. Also, the university has a staff residential building outside of the university compound. Hence, the participant is a senior professional in the university who is responsible for asset registering and managing built assets as well as the construction project. In general, the results indicated that public university hasn't registered the built asset and also hasn't Asset registry database to store the built asset data/information and documents.

Does your department have data/information and documents of the built assets?

The question was developed to assess whether or not the FM department has data/information on the built assets. Therefore, P2 and P3 mentioned that the project office has blueprint as-built drawings of the recently completed projects, but there is no data/information and documents for the oldest built asset in the university. Additionally, P1 stated that the FM office has not built asset data /information and documents but the office has documents to record the O & M expanse and work order request. In general, the results indicate that almost all of the university's-built assets are longstanding so there is no data/information or document for such assets.

Does your office have as-built models/drawings/designs of the built asset facilities?

This question was intended to find out that does the FM department/office has as-built models/drawings/designs of built asset facilities, and if so, how to store and manage them. Furthermore, to assess whether the FM department/office uses those as-built design documents for maintenance purposes after construction also to verify the document's relevance. Pondering over the answers, there seemed to be similar patterns of ideas observed between three participants, specifically that there is no as-built model/drawings/design of the longstanding-built asset facilities. However, P2 and P3 stated that the project office has as-built drawings/design documents for recently completed projects.

Does your office have a database to store and manage data/information and relevant documents of the Built Asset?

The purpose of the question was intended to find out whether the FM department/office has a database to manage and store data/information and relevant documents of Built Asset. Accordingly, three participants mentioned that the FM department/office lacks a database to store and manage data/information and documents. The lack of a structured database in the university was recognized by all participants as a major challenge in registering and managing data/information and documents of the university-built assets.

Which data /information and documents management system currently do you use for built asset O&M?

The purpose of this question was to know more about the FM department's current built asset O&M data/information and document management systems. As a result, three participants stated that the built asset's information and documentation are not organized. However, As-built drawings, equipment conditions, and maintenance records/maintenance schedules are stored in a paper-based file system to a limited extent. P3 also mentioned using a computer to store, edit, and manage the recently completed project documents and that document is necessary for the O & M.

Figure 4- 4: Case II Built asset O & M data / Information Management system*(Source: Picture Taken from the case II project offices, 2021)*

Does your office have a data/information/ file structure and data classification system?

The purpose of this question was to assess whether the FM department/office has a data/information file structure and a data classification system, as well as to know the participants' perspectives to inspire the university and individuals to use standard data structure and classification system. Accordingly, the three participants mentioned that the FM office has no data/information structure and classification system. Moreover, all participants are interested to adopt a standardized data /information structure and classification system for built asset information management. Hence, to manage the data/information and documents of built assets properly the owner/FM team should categorize /structure /classify their facilities based on the standard data model format.

How do you manage and process O & M work orders request?

This question was aimed to find out the current management and process O & M work order request practices in the FM office. Therefore, three participants mentioned that the FM office currently practiced using paper-based requests, and use mobile applications for simple discussion and reporting.

How do you capture and visualize built asset facilities' O&M data/information?

The purpose of the question was intended to know the current practice of built assets data/information capturing and visualization system used in the FM department /office. Therefore, the three participants declared that the FM office uses the traditional (manual) as-built data/information capturing and visualizing techniques. The FM office use tape measures for data capturing and direct onsite observations for visualizing as-built data. Besides, all participants mentioned the traditional ways of capturing and visualizing as-built information are time-consuming, labour-intensive, and highly error-prone, with difficulty in changing and visualizing the data.

What is your level of agreement regarding the current practice of data/information exchange format from developer to user/FM team?

The purpose of this question was to know the level of agreement regarding the current practice of data/information exchange format from developer to user/FM team in this public university. After analyzing three participants' responses shown figure below printed paper documents (hardcopy), scanned documents (pdf format), AutoCAD documents (in DWG, DXF format), and word documents (in DOC, DOCx format) are currently practiced data/information exchange formats from developer to owner/FM team during project delivery phase.

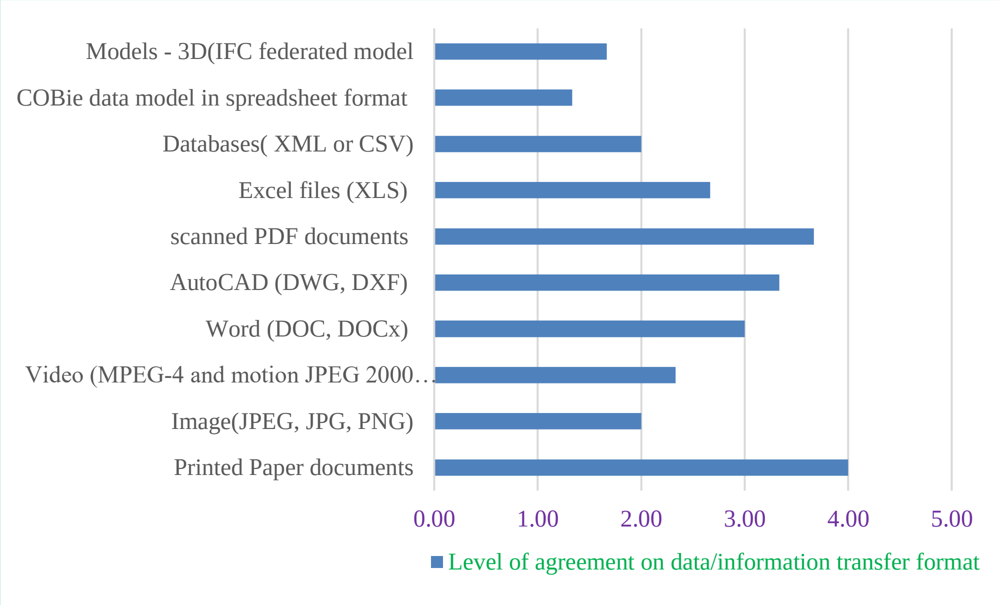


Figure 4- 5: Case II current practice of data/information exchange format from developer to user/FM team

Do you think that lack of data/information has an impact on the cost, schedule, and duration of O&M?

The purpose of this question was to identify the impact of lack of data/information has an impact on the cost, schedule, and duration of O&M. therefore, the three participants mentioned that lack of data/information has an impact on the cost, schedule, and duration of O&M. Moreover, P1 mentioned that during the maintenance time of MPE rework was expected due to a lack of information about the exact location of the MPE system in the built asset that which ultimately affects the O&M costs of the built asset. Furthermore, the time is wasted visualizing the critical points of damaged MPE systems that affect O&M costs indirectly. Besides, P2 and P3 stated that lack of information leads to insufficient O & M of a built asset, which has an indirect impact on O&M costs schedule and duration, and a low return on investment. Information is everything, a lack of it affects not only O&M costs but also quality. The researcher concludes that costs are related to performing unnecessary redundant activities and costs arising from information inaccessibility problems are all of which are costs due to a lack of data/information about the built asset.

Do you think that lack of data/information affects the process of monitoring and controlling built assets, as well as maintenance performance and user satisfaction?

The purpose of this question was to see how a lack of data/information affects the process of monitoring and controlling the built assets, as well as maintenance performance and user satisfaction. According to participants' responses, lack of data/information affects the process of monitoring and controlling built assets, and also influences maintenance performance and user satisfaction. Furthermore, due to a lack of information, rework on maintenance tasks has an impact on user satisfaction and maintenance performance.

What do you think to enhance the current built asset information management system and do you believe it is required?

The purpose of this question was to know the participants' as well as university higher officials' perspectives to improve the current built asset information management system and identify the ways of improving current practices. Therefore, three participants mentioned that to improve the current practice of the built asset information management system via new technology throughout the project's life cycle and organizing ourselves to do so. The researcher concludes that to improve current practices of the built asset information management system the public university must adopt a BIM-enabled built asset information management system. Besides, BIM-enabled FM platforms contain all the detailed information about the built asset, the interconnected systems, and their associated parts, manuals, and other relevant documents. In addition to that, improve and achieve whole-life cycle performance efficiencies from their physical assets, set an appropriate Maintenance plan and duration by allocating the optimal O&M cost.

Summary

The FM office in this case the public university hasn’t an asset registry database to store and manage the data/information and documents of the built asset. So, the FM office has no as-built model/drawings/design of the longstanding-built asset facilities. But to some extent, the project office has as-built drawings/design documents for recently completed projects. Moreover, almost all built assets facilities in the university have no data/information and documents. Hence, due to a lack of data/information and documents of the built asset facilities the cost, schedule, and duration of O&M activities are affected.

Also, it impacts the process of monitoring and controlling built assets, as well as a maintenance performance and user satisfaction. Currently, the FM office utilizes the traditional (manual) method to capture, visualize and manage the built asset facilities data. Similarly, printed paper documents (hardcopy), scanned documents (pdf format), AutoCAD documents (in DWG, DXF format), and word documents (in DOC, DOCx format) formats are currently being practiced as the pervasive data/information transfer formats from developer to facility owner/FM operator during project delivery phase. Besides this, the FM office has no standard data model and building a classification system to manage the built asset facilities information. So, to improve current practices of the built asset facility information management system the public universities must adopt BIM-enabled FM technologies.

4.3.3 Case III analysis

How many built assets (building blocks) are there in your university?

The purpose of the question was to draw attention to know that the public university's practice in asset registry and management after the handing-over stage of the project. Accordingly, the two participants were unsure how many Buildings Blocks the university possessed. Yet, P2 stated that the university has around 34 building blocks, although this is unconfirmed. The Building Blocks are being served as a library, laboratory, student residential building, lecture and meeting hall, and office. Hence, the participant is a senior professional in the university who is responsible for asset registering and managing built assets as well as the construction project. In general, the results indicated that public university hasn’t an Asset registry database and didn't register the built asset data/information and documents.

Does your department have data/information and documents of the built assets?

The question was developed to assess whether the FM department had data/information about the built assets. As a result, the two participants stated that the FM office lacked data/information and documents for all built assets. However, the project office does have a blueprint document for some recently completed projects. In general, the results show that practically almost all built assets in the university haven’t been organized data/information and documents.

Does your office have as-built models/drawings/designs of the built asset facilities?

This question was intended to find out that does the FM department/office has as-built models/drawings/designs of built asset facilities, and if so, how to store and manage them. Furthermore, to assess whether the FM department/office uses those as-built design documents for maintenance purposes after construction and also to verify the document's relevance. Accordingly, the two participants that there is no as-built model/drawings/design of the all-built asset facilities. Yet, P1 and P2 stated that the project office has as-built drawings/design documents for some recently completed projects.

Does your office have a database to store and manage data/information and relevant documents of the Built Asset?

The purpose of the question was intended to find out whether the FM department/office has a database to manage and store data/information and relevant documents of the Built Asset. As a result, the two participants stated that the FM department/office does not have a database to store and manage data/information and documents. Additionally, The lack of a structured database was identified as a major issue in registering and managing data/information and documents of the built assets.

Which data /information and documents management system currently do you use for built asset O&M?

The purpose of this question was to know more about the current practice of FM offices-built asset O&M data/information and document management systems. As a result, two participants stated that the FM office hasn't any organized data /information and documents of the built asset. However, to a limited extent, maintenance records/schedules, as-built drawings, and facility and equipment conditions are managed in an exceedingly paper-based filing system.

Figure 4- 6: Case III Current Built asset O & M data / Information Management system

(Source: Picture Taken from the case III FM and project offices, 2021)

Does your office have a data/information/ file structure and data classification system?

The purpose of this question was to assess whether the FM office has a data/information structure and classification system, as well as to know the views of the participants for adopting the standard data structure and classification system. Accordingly, P1 and P2 stated that the FM office does not have a data/information structure and classification system. Furthermore, all participants are interested in adopting a standardized data/information structure and classification system for managing built asset data/information. Hence, to properly manage the data/information and documentation of the built assets, the owner/FM team must structure/classify their facilities based on the standard data model format and classification system.

How do you manage and process O & M work orders request?

This question was aimed to find out the current management and process O & M work order request practices in the FM office. Therefore, P1 and P2 mentioned that the FM office currently practiced Manual (paper-based) work order requests.

How do you capture and visualize built asset O&M data/information?

The purpose of the question was intended to grasp the current practice of built assets data/information capturing and visualization system utilized in the FM department /office.

Therefore, the two participants declared that the FM office uses the traditional (manual) capturing and visualizing techniques so as-built data/information capturing and visualizing through tape measures and direct onsite observations respectively. But, the traditional ways of capturing and visualizing as-built information are time-consuming, labor-intensive, and highly error-prone, with difficulty in changing and visualizing the data.

What is your level of agreement regarding the current practice of data/information exchange format from developer to user/FM team?

The purpose of this question was to grasp the level of agreement regarding the current practice of data/information exchange format from developer to user/FM team in the public universities. After analyzing participants' responses shown figure below the printed paper documents (hardcopy), scanned documents (pdf format), AutoCAD documents (in DWG, DXF format), word documents (in DOC, DOCx format), and Excel documents (in XLS format) are currently practiced data/information transfer formats from developer to facility owner/FM operator during project delivery phase.

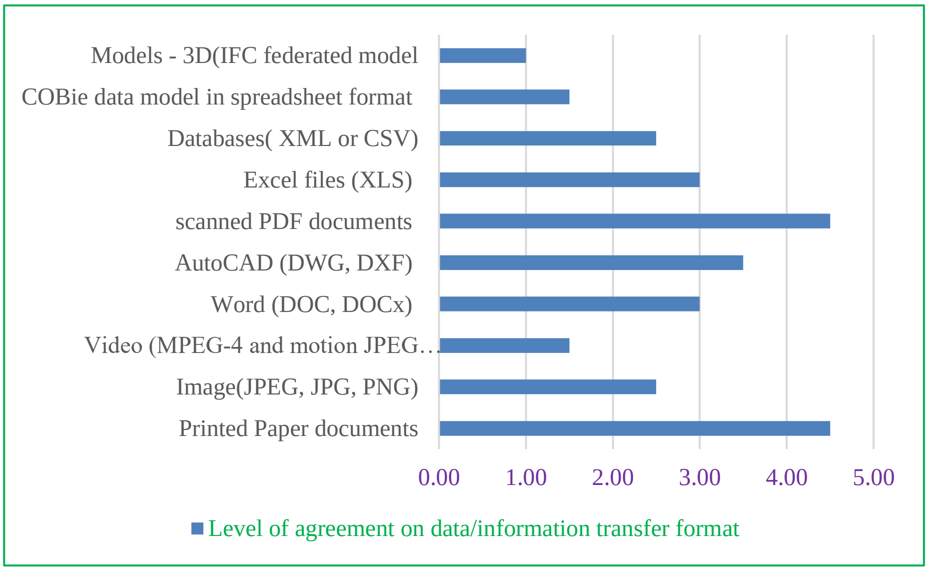


Figure 4- 7: Case III current practice of data/information exchange format from developer to user/FM team.

Do you think that lack of data/information has an impact on the cost, schedule, and duration of O&M?

The purpose of this question was to identify the impact of lack of data/information has an impact on the cost, schedule, and duration of O&M. Accordingly, the P1 and P2 mentioned that lack of data/information has an impact on the cost, schedule, and duration of built facility O&M. Moreover, the time is wasted to visualize the exact points of damaged electrical and sanitary systems that also affect the schedule, duration, and O&M costs indirectly. Besides, two participants stated that lack of information leads to insufficient O & M of the built asset which has an indirect impact on O&M costs schedule and duration, and a low return on investment.

Do you think that lack of data/information affects the process of monitoring and controlling built assets, as well as maintenance performance and user satisfaction?

The purpose of this question was to assess whether the lack of data/information affects the process of monitoring and controlling the built assets, as well as maintenance performance and user satisfaction. Accordingly, P1 and P2 stated that lack of data/information affects the process of monitoring and controlling built assets, and also impacts maintenance performance and user satisfaction. Furthermore, due to a lack of information, rework on maintenance tasks has affected user satisfaction and maintenance performance.

What do you think to enhance the current built asset information management system and do you believe it is required?

The purpose of this question was to grasp the participant's and university higher officials' point of view to enhance the current built asset information management system and identify the ways of improving it. Therefore, P1 and P2 mentioned that to enhance the current practice of the built asset information management system by implementing new technology throughout the project's life cycle. The researcher concludes that to improve current practices of built asset information management the public university must adopt a BIM-enabled Facility information management system. Besides, BIM-enabled FM platforms contain all the detailed information about the built asset, the interconnected systems, and their associated parts, manuals, and other relevant documents.

Summary

The FM office in this case of the public university hasn't an asset registry database to store and manage the data/information and documents of the built asset. So, the FM office has no as-built model/drawings/design of the longstanding-built asset facilities. But to some extent, the project office has as-built drawings/design documents for recently completed projects. Moreover, almost all built assets facilities in the university have no data/information and documents. Hence, due to a lack of data/information and documents of the built asset facilities the cost, schedule, and duration of O&M activities are affected. Also, it impacts the process of monitoring and controlling built assets, as well as a maintenance performance and user satisfaction. Currently, the FM office utilizes the traditional (manual) method to capture, visualize and manage the data/information of built asset facilities. Similarly, Printed paper documents (hardcopy), scanned documents (pdf format), AutoCAD documents (in DWG, DXF format), word documents (in DOC, DOCx format), and Excel documents (in XLS format) are practiced as the pervasive data/information transfer format from developer to facility owner/FM operator during project delivery phase. Besides this, the FM office has no standard data model and building a classification system to manage the built asset facilities information. So, to improve current practices of the built asset facility information management system the public universities must adopt BIM-enabled FM technologies

4.3.4 Cross Case analysis and summary

As discussed the FM office in the selected public university has no asset registry database to store and manage the built asset data/information and its documents in all of the cases studied. In detail, the FM office also has no as-built model/drawings/design of the built asset facilities. On the other hand, Case II and III project offices have as-built drawings and design documents for recently completed projects to some extent. Moreover, the FM office in the three cases has no data/information and documents of the built asset and facilities, and almost all built assets facilities in the university lack data/information and documents, and that challenges the O & M of the built asset facilities. Therefore, complete, accurate, and reliable information is helpful to manage the built asset of public universities. Love (2015), also stated that appropriate and reliable information about an asset is critical for built asset management to support decision-making, planning, and execution of O & M activities. Furthermore, Built asset management is demanded comprehensive sets of information about the built asset facility(Yalcinkaya *et al.*, 2016a).

In all selected cases the built asset facility is to lack data/information and documents the built asset facilities so the cost, schedule, and duration of O&M activities are affected. Also, it impacts the process of monitoring and controlling built assets, as well as a maintenance performance and user satisfaction. The O&M stage is the most expensive phase during the life cycle of a building(Guzman and Ulloa, 2020). Additionally, Eastman et al., (2011) put the percentage at 60 %, Teicholz(2013) at 60 -75%, and Miettinen et al.(2018) even higher up to 85%. Accordingly, these costs are borne by owners and operators, which incur most of these costs during ongoing facility O & M. In addition to the costs quantified, there are additional costs due to inefficiency, lack of data/information and data/information loss associated with interoperability problems.

The FM office in all cases utilizes the traditional (manual) method to capture, visualize and manage the data/information of built asset facilities. Similarly, Printed paper documents (hardcopy), scanned documents (pdf format), AutoCAD documents (in DWG, DXF format), word documents (in DOC, DOCx format), and Excel documents (in XLS format) are practiced in Case I and III as the pervasive data/information transfer format from developer to facility owner/FM operator during project delivery phase also in case I except Excel documents (in XLS format) all exchange formats are practiced. Besides this in the three cases, the FM office has no standard data model and classification system to manage the data/information of the built asset facilities. Therefore, all data /information transfer formats practiced in the selected multiple cases are proprietary formats. Clearly, all of the data is not entered into one model or one system. This, therefore, requires the interoperability of systems so that data can be communicated from upstream systems for downstream use. During O & M activities executed the FM data, as well as the graphic data required for the next FM use so that the information must be updated to reflect the changes. Once again, interoperability is the key. Gallaher *et al.*(2004), stated that $15.8 billion in annual interoperability costs were quantified for the capital facilities industry. Of these costs, two-thirds are borne by owners and operators, which incur most of these costs during ongoing facility O & M.

The current built asset management practices rely on conventional systems. So the built asset management requires new technologies. Due to that the FM office has interested in adopting a BIM-enabled built asset information management system. Marmo et al.,(2019) also stated that current facility management practice relies on different systems which require new technologies to integrate and manage information more easily. Additionally, technology can provide powerful strategic and tactical tools to manage the information of the built asset facilities(Aziz, Nawawi, and Ariff, 2016). In general, the emergence of technologies is used to record the information throughout the facilities lifecycle to improve FM efficiency(Dawood *et al.*, 2013). Likewise, Hossain and Yeoh (2018) stated as BIM-based FM platforms/software can play a significant role in better O &M and built asset Management.

4.4 The required data/information for BIM-enabled Built Asset facility management.

The required information for BIM-enabled Built Asset Facility Management is identified in this part of this study. The required information is generated from the project information model and, on the other hand, from organizational information requirements in a BIM-based project. The required information: Basic, technical, managerial, commercial, financial, and legal are first identified from the literature. Finally, the selected multiple case studies were conducted to identify the required information for built asset facilities management. Semi-structured interviews were used to collect data from the FM department and project office. During the project start delivery phase and the project end delivery phase, the two offices are responsible for the required information for Built asset management. As a result, the results of a single case analysis were analyzed further and used to inform the final cross-analysis of multiple cases. Therefore, to achieve this objective in this study, the author used a ten-point rating scale, with (1) indicating extremely irrelevant and (10) indicating extremely relevant. As a result, in order to define cutoff points, the researcher used the concept of statistics to convert the ungrouped 10-point rating scale into grouped five Categories. Moreover, the researcher computes the overall mean score for the items of that variable of interest based on the raw data from the interview. After determining the mean value of the research completed cutoff points using the formula (Class interval = Maximum-Minimum / n = (10-1)/5 =1.8). were as;

- Maximum refers to the highest score on the given rating scale
- Minimum refers to the lowest score on the rating scale
- n refers to the number of CATEGORIES the researcher intends to create weighted mean;

So that, information is Not Relevant (1 -2.8), Slightly Relevant (2.9 – 4.6), Fairly Relevant (4.7 – 6.4), Relevant (6.5 – 8.3), and Very Relevant information (8.3 – 10).

4.4.1 Case I analysis

In this case, almost all of the information is Very Relevant for BIM-based Built Asset Facilities Management. However, project contract type and delivery system, technical characteristics of the built asset and commissioning dates, and submitted data also are relevant as shown in the table below.

Table 4- 5: The required data/information for BIM-enabled built asset Facility management of Case I

The required data/information for BIM-enabled built asset Facility management			
Sn.No	**Information Requirements**	**weighted mean**	**Level of data/information Relevance**
1	**Basic Project information**		
1.1	Name of Asset	9.25	Very Relevant
1.2	Location	8.75	
1.3	Name of Employer	9.25	
1.4	Name of Contractor	8.75	
1.5	Name of consultant	9.25	
1.6	Year of Built Asset start	8.75	
1.7	Year of Built Asset handover	9.25	
1.8	Built Asset cost at completion	8.75	
1.9	No of floors	9.25	
1.1	Contract type	8.25	Relevant
1.11	Project of delivery system	8.25	
1.12	Built asset function	8.75	Very Relevant
1.13	Technical Characteristics (Classic ,Modern and contemporary)	8.25	Relevant
2	**Technical information**		
2.1	Software platforms	8.75	Very Relevant
2.2	Data and Exchange Formats	8.5	
2.3	Visualization format(in 3D IFC Federated model)	9	
2.4	Classification of BIM DATA(Uniclass, Omniclass,Master format ,uniformat and etc)	8.75	
2.5	Co-ordinates	9	

2.6	Level of development (Level of Detail +level of information)	8.75	
2.7	Mechanical, Electrical and Plumbing (MEP) Systems information	8.5	
2.8	Training details	8.5	
2.9	Engineering data and design parameters	8.75	
2.10	Details of asset dependencies and interdependencies	9	
2.11	Commissioning dates and Submitted data	8.25	Relevant
2.12	Operational data including performance characteristics and design limits	8.75	Very Relevant
3	**Managerial information**		
3.1	Type of asset	9	
3.2	Photograph	9	
3.3	Identification numbers (specification number, product number, serial number)	8.5	
3.4	Location	9.25	
3.5	Floor area	9.25	
3.6	Space management information	9	
3.7	Warranties and guarantee periods	9.25	
3.8	Access planning and work schedules	9	
3.9	Maintenance and inspection schedules and records	8.75	
3.10	Operation and Maintenance manual	8.75	
3.11	Outstanding tasks	9	Very Relevant
3.12	Record of planned and unplanned maintenance	9.25	
3.13	Standards, processes, and procedures	9.25	
3.14	Hazardous contents or waste	8.75	
3.15	End of the life cycle of the asset	9.25	
3.16	Emergency plans	9.25	
3.17	The presence of any hazardous contents and waste	9.25	
3.18	Details of emergency plans including responsibilities and contact details	9.25	
3.19	Linked Data information related to specific building asset.	9.25	
3.20	User's Manual	9	
4	**Commercial information**		
4.1	Description of the asset	8.5	
4.2	The function of the asset	8.75	
4.3	Details of supplier	8.75	
4.4	Lead time	8.75	
4.5	Facilities and Equipment condition	8.75	
4.6	Key performance indicators	8.75	Very Relevant
4.7	Performance targets or standards	9	
4.8	Non-conformance criteria and actions to be taken	9	
4.9	The criticality of assets and spaces to the organization	8.75	

5	**Financial information**		
5.1	Original purchase/leasing Cost	9.5	Very Relevant
5.2	Operating cost	9.5	
5.3	Planned maintenance cost	9.5	
5.4	Historical maintenance cost	9.25	
5.5	Replacement value	9	
6	**Legal information**		
6.1	Details Ownership	9.5	Very Relevant
6.2	maintenance demarcation	9.5	
6.3	Contractual information	9.25	
6.4	Property boundaries	9.75	
6.5	Work instructions	9.5	
6.6	Legal obligations (H&S, etc.)	9	
6.7	Risk assessments and control measures	9	

4.4.2 Case II analysis

In this case, all of the information is Very Relevant for BIM-enabled Built Asset Facilities Management as shown in the table below.

Table 4- 6:The required data/information for BIM-enabled built asset Facility management of Case II

The required data/information for BIM-enabled built asset Facility management			
Sn.No	**Information Requirements**	**weighted mean**	**Level of data/information Relevance**
1	**Basic Asset information**		
1.1	Name of Asset	9.67	Very Relevant
1.2	Location	9.67	
1.3	Name of Employer	9.67	
1.4	Name of Contractor	9.33	
1.5	Name of consultant	9.33	
1.6	Year of Built Asset start	9.33	
1.7	Year of Built Asset handover	9.67	
1.8	Built Asset cost at completion	9.67	
1.9	No of floors	9.67	
1.1	Contract type	8.67	
1.11	Project of delivery system	9.00	
1.12	Building function	9.33	
1.13	Technical Characteristics (Classic, Modern and contemporary)	9.33	

2	**Technical information**		
2.1	Software platforms	8.67	Very Relevant
2.2	Data and Exchange Formats	8.33	
2.3	Visualization format (in 3D IFC Federated model)	8.33	
2.4	Classification of BIM DATA(Uniclass, Omniclass,Master format ,uniformat and etc)	8.67	
2.5	Co-ordinates	8.67	
2.6	Level of development (Level of Detail +level of information)	9.00	
2.7	Mechanical, Electrical and Plumbing (MEP) Systems information	9.33	
2.8	Training details	9.00	
2.9	Engineering data and design parameters	9.33	
2.10	Details of asset dependencies and interdependencies	9.33	
2.11	Commissioning dates and Submitted data	9.00	
2.12	Operational data including performance characteristics and design limits	9.33	
3	**Managerial information**		
3.1	Type of asset	9.33	Very Relevant
3.2	Photograph	8.67	
3.3	Identification numbers (specification number, product number, serial number)	8.33	
3.4	Location	8.67	
3.5	Floor area	9.33	
3.6	Space management information	9.33	
3.7	Warranties and guarantee periods	9.33	
3.8	Access planning and work schedules	9.00	
3.9	Maintenance and inspection schedules and records	8.67	
3.10	Operation and Maintenance manual	8.33	
3.11	Outstanding tasks	9.33	
3.12	Record of planned and unplanned maintenance	9.00	
3.13	Standards, processes, and procedures	9.33	
3.14	Hazardous contents or waste	8.67	
3.15	End of the life cycle of the asset	9.00	
3.16	Emergency plans	9.33	
3.17	The presence of any hazardous contents and waste	9.00	
3.18	Details of emergency plans including responsibilities and contact details	9.00	
3.19	Linked Data information related to specific building asset.	9.33	
3.20	User's Manual	8.67	
4	**Commercial information**		
4.1	Description of the asset	9.00	Very Relevant
4.2	The function of the asset	8.33	
4.3	Details of supplier	9.00	
4.4	Lead time	9.67	
4.5	Facilities and Equipment condition	8.67	
4.6	Key performance indicators	9.33	

4.7	Performance targets or standards	9.00	
4.8	Non-conformance criteria and actions to be taken	9.33	
4.9	The criticality of assets and spaces to the organization	9.00	
5	**Financial information**		
5.1	Original purchase/leasing Cost	8.67	Very Relevant
5.2	Operating cost	9.00	
5.3	Planned maintenance cost	9.33	
5.4	Historical maintenance cost	9.00	
5.5	Replacement value	9.33	
6	**Legal information**		
6.1	Details Ownership	9.67	Very Relevant
6.2	maintenance demarcation	9.33	
6.3	Contractual information	9.00	
6.4	Property boundaries	9.00	
6.5	Work instructions	9.00	
6.6	Legal obligations (H&S, etc.)	9.33	
6.7	Risk assessments and control measures	9.00	

4.4.3 Case III analysis

In this case, all of the information is very Relevant for BIM-enabled Built Asset Facilities Management as shown in the table below.

Table 4- 7: The required data/information for BIM-enabled built asset Facility management of Case III

The required data/information for BIM-enabled built asset Facility management			
Sn.No	**Information Requirements**	**weighted mean**	**Level of data/information Relevance**
1	**Basic Project information**		
1.1	Name of Asset	10	Very Relevant
1.2	Location	10	
1.3	Name of Employer	10	
1.4	Name of Contractor	10	
1.5	Name of consultant	10	
1.6	Year of Built Asset start	10	
1.7	Year of Built Asset handover	10	
1.8	Built Asset cost at completion	10	
1.9	No of floors	10	
1.10	Contract type	9.5	
1.11	Project of a delivery system	9.5	
1.12	Building function	9.5	
1.13	Technical Characteristics (Classic, Modern and contemporary)	9.5	

2	**Technical information**		
2.1	Software platforms	9	Very Relevant
2.2	Data and Exchange Formats	9	
2.3	Visualization format (in 3D IFC Federated model)	9	
2.4	Classification of BIM DATA(Uniclass, Omniclass,Master format ,uniformat and etc)	9	
2.5	Co-ordinates	9	
2.6	Level of development (Level of Detail +level of information)	9.5	
2.7	Mechanical, Electrical and Plumbing (MEP) Systems information	10	
2.8	Training details	10	
2.9	Engineering data and design parameters	10	
2.10	Details of asset dependencies and interdependencies	10	
2.11	Commissioning dates and Submitted data	10	
2.12	Operational data including performance characteristics and design limits	10	
3	**Managerial information**		
3.1	Type of asset	10	Very Relevant
3.2	Photograph	10	
3.3	Identification numbers (specification number, product number, serial number)	10	
3.4	Location	10	
3.5	Floor area	10	
3.6	Space management information	10	
3.7	Warranties and guarantee periods	9.5	
3.8	Access planning and work schedules	9	
3.9	Maintenance and inspection schedules and records	9	
3.10	Operation and Maintenance manual	9	
3.11	Outstanding tasks	9	
3.12	Record of planned and unplanned maintenance	9	
3.13	Standards, processes, and procedures	9.5	
3.14	Hazardous contents or waste	9.5	
3.15	End of the life cycle of the asset	9.5	
3.16	Emergency plans	9.5	
3.17	The presence of any hazardous contents and waste	9.5	
3.18	Details of emergency plans including responsibilities and contact details	9.5	
3.19	Linked Data information related to specific building asset.	10	
3.20	User's Manual	10	
4	**Commercial information**		
4.1	Description of the asset	9.5	Very Relevant
4.2	The function of the asset	9.5	
4.3	Details of supplier	9.5	
4.4	Lead time	9.5	
4.5	Facilities and Equipment condition	9.5	
4.6	Key performance indicators	9.5	

4.7	Performance targets or standards	9	
4.8	Non-conformance criteria and actions to be taken	9.5	
4.9	The criticality of assets and spaces to the organization	9.5	
5	**Financial information**		
5.1	Original purchase/leasing Cost	9.5	Very Relevant
5.2	Operating cost	9.5	
5.3	Planned maintenance cost	9.5	
5.4	Historical maintenance cost	9.5	
5.5	Replacement value	9.5	
6	**Legal information**		
6.1	Details Ownership	10	Very Relevant
6.2	maintenance demarcation	10	
6.3	Contractual information	9	
6.4	Property boundaries	9.5	
6.5	Work instructions	9	
6.6	Legal obligations (H&S, etc.)	9.5	
6.7	Risk assessments and control measures	9	

4.4.4 Cross Case Analysis and Summary

In this study, all the basic, technical, managerial, commercial, financial, and legal information are extremely relevant for built asset management. That information is relevant for built asset management that is stated under the standard Publicly Available Specifications (PAS) 1192-3:2014/ BS EN ISO 19650-3 asset management standard(Trust, 2018) and (BIM WiKi, 2021). To manage the built asset Munir, et al.(2020) also categorized information based on individual assets as building details, energy data, contract details, planning details, and performance optimization. Furthermore, physical resources, support services, human resources and Business information are relevant for Built asset management(Teicholz, 2013). But, there is a lack of standards about the optimal level of information that is relevant for built asset management(Kaya, 2011b). The result also indicated that there is a data/information shortage of built asset management in the FM offices and project offices of selected public universities. Also, currently, the shortage and a lack of information are the challenges in the FM offices and project offices of public universities. Hence, when the information is properly transferred and managed those issues will be solved. After that jargon data will be a big issue in the FM office. As a result of the constant searching, categorizing, validating, and recreating of information due to jargon data time and money will lose. Therefore, the data/information relevance rating scale is necessary to manage the data/information of the built asset for the decision-making process.

Accordingly, due to jargon data issues and time loss from constantly searching for, categorizing, validating, and recreating information, Infrastructure Asset Managers use the Moscow rating scale (where M – Must have information; S – Should have information; C – Could have information; W – Would eventually have information if time and money were available)(Jackson, 2018). As a result, must-have information that is critical for built asset management such as asset unique ID, inception, and Life Cycle. Should-have information is also critical, but may not be as time-sensitive as the must-have information. so that the information related to currency, Suitability for information use functional and technical performance specifications. Could have information is wanted or desirable but less important and Less impact if left out. The information such as location-geospatial, Linear and Space, topological relationship and location, Geometric construction, Dimensions Relationship to other assets and groupings such as networks, Entities, Facilities, Systems, and Assemblies, Reference to Work Breakdown Structure, Material, Energy embedded, etc. are could have information.

Built asset facilities management in the public university requires complete and reliable information. Similarly, Nicał and Wodyński (2016) operational phase requires a comprehensive set of well-structured information regarding the built asset. Currently, built asset management in public universities is challenging due to the lack of comprehensive data/information on the built asset. So, FM teams often waste time and effort collecting information to do O & M activities. Accordingly, Matarneh *et al.*(2018) stated that during the operations and maintenance phase, FM teams often spend a considerable amount of time and effort collecting information in the form of electronic data and hardcopy documents. Employees also engage in constant redundant activity searching for, sorting, validating, and recreating information. In this regard, BIM can serve as a catalyst to improve Facilities Management processes where it is demonstrated in identifying more precise and accurate information throughout the design and construction process(Muhammad and Mustapa, 2020). Therefore, BIM-enabled FM is imperative for improving the quality and accuracy of built asset information. This avoids also data entry costs and generates higher-quality data(Teicholz, 2013).

4.5 The conceptual framework for a BIM-enabled constructed asset Facilities information Management system

The built asset FM is frequently erratic, and slow, and it uses complicated procedures. Moreover, the data/information transferred from the developer to the owner is in printed document format and challenged. Decisions are not verified by statistically relevant information and knowledge-driven method from consistently composed data. The Built asset facility management in Addis Ababa public universities is problematic due to the lack of data, information, and documents. The FM office in the public Universitas in Addis Ababa has no database to manage built asset facilitates and a heavy reliance on a paper-based approach. Accordingly, the FM office in the public universities also needs a single platform to improve the current built asset information management system and project data delivery process. So, to solve the problem the researcher developed the Conceptual Framework. To develop the Conceptual Framework various standards and specifications have been used as a reference which could streamline the development of a Built asset facility information management system, through the structured development of owner and facility managers' information requirements, and their validation against various data/information sources. The ISO 19650 series specifications are an important contribution to achieving this specific research objective. The author of this research believes that the study output will contribute knowledge and practical application in the proper implementation of the system in public universities. In particular, ISO 119650-3 sets out key requirements for information management during the operational phase of facilities, considering the use of several different data/information sources and IT systems. Several fundamental concepts are introduced to accomplish this objective such as the Public University Management system, Level of decision, OIR, AIR, PIR, EIR, PIM, AIM, Enterprise system, COBie, IFC and Built asset maintenance process. In general, as shown in the figure `below the conceptual framework has seven main parts: Public University Management system; information requirements; Asset information model; linked data systems; level of decision; built asset Facility administration and Built Asset Maintenance process.

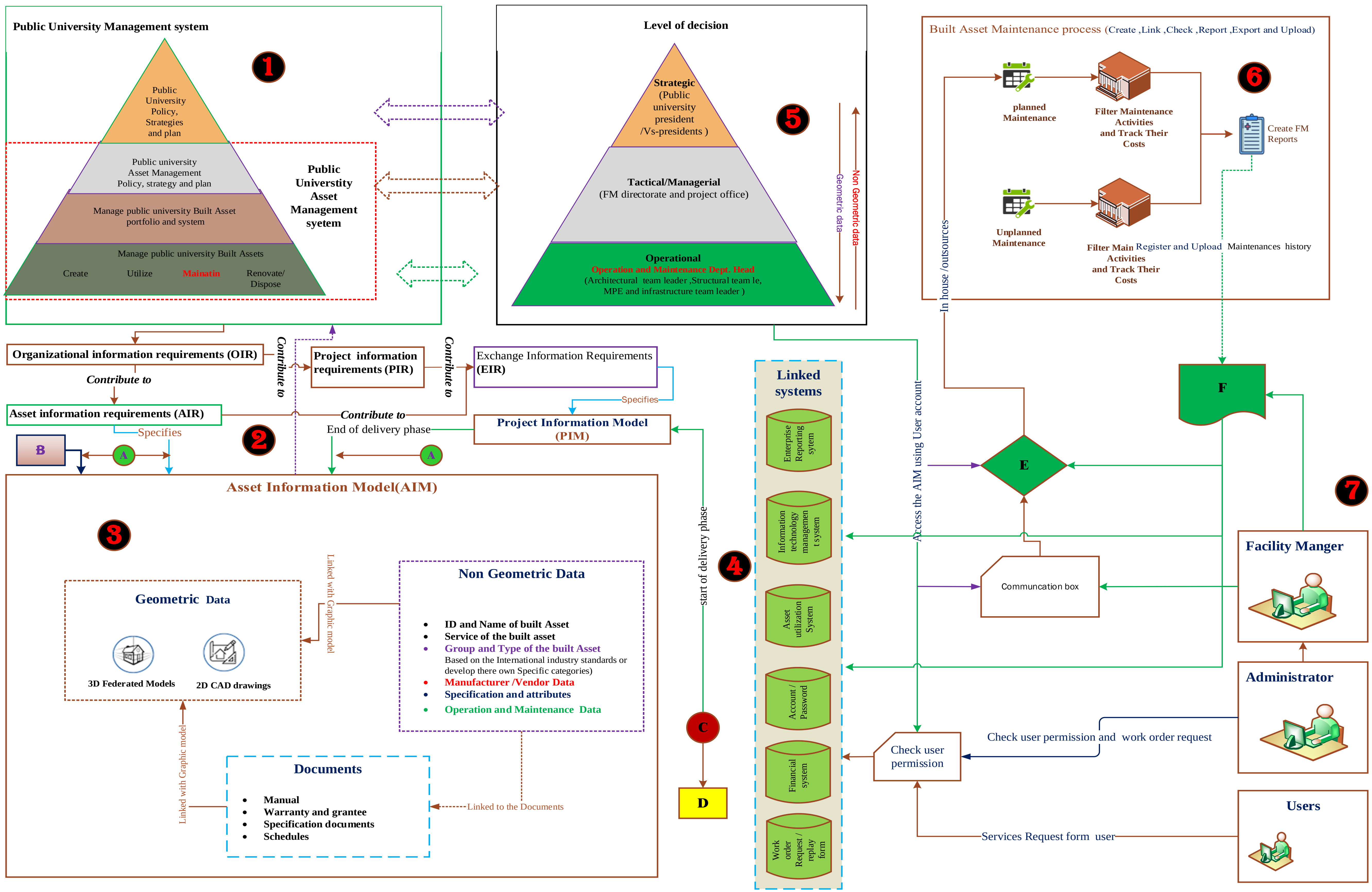


Figure 4- 8: BIM-enabled built asset Facility information Management system conceptual framework

The number that used in the conceptual framework are discussed as follows:

1. **Public university's management layer:** Includes the asset management strategy, policy, and plan. Asset management policy and plan are used to manage the built asset facility via crate, use, maintain, and renovate/dispose of.
2. **Information requirements layer:** Data/information is arranged and processed into meaningful patterns and put into context. Asset information should be controlled by a management system incorporating the requirements, processes, and governance, suitable for the public university's needs and/or for the needs of its users.
3. **Asset information model layer:** The Proposed AIM is considered the university's requirements. The information and data are transferred from existing organizational systems into the AIM; reorganizing or relabeling and storing the existing data or information as part of the AIM in the form of data, documents, and models. AIM collects new or updated information or data from the capture o surveys of the built asset. Information exchanges shall be carried out in accordance with the requirements of the AIR. The AIR shall define the structure, process, and content of information to be exchanged. So, IFC and COBie data models shall be used for graphic and semantics data/information exchange respectively.
4. **Linked data enterprise systems layer:** The interface between the AIM and the existing enterprise systems shall be implemented through a two-way connection. The interface shall push authorized data and information from the AIM to the appropriate enterprise systems as determined by the University’s requirements.
5. **Level of decision layer:** Decision-making in the public university is classified into three categories.
6. **Built Asset Maintenance process layer:** After the decision is made between the Facility manager and decision-makers the planned and unplanned Built Asset Maintenance will be performed.
7. **The user and Administration layer:** In this layer, the user request the services; the Administrator controls the overall data/information security and direct relationship with the Facility manager. The facility manager controls the technical parts of the AIM and the management of the built asset. The facility manager shall be discussed with decision-makers.

A. Information verification and validation process and if has been accepted to be stored in the AIM. But, if verification and validation are not achieved then the information and data should be rejected, passed to the Archive area for record purposes, and returned to the originator for resubmission.

B. Use appropriate data capturing technology and generate the data/information of the built asset.

C. Data/Information Searching, Filtering, and sorting box.

D. **AIM** direct links to simple FM software (i.e CAFM and CMMS) for easy reference.

E. The shared area is a sub-set of the client shared area.

F. Decision box: The facility manager shall be discussed with decision-makers the scope of the built asset services. Finally, the Facility manager accept and proved the service and registered and Upload the Maintenances history.

Terms

OIR: The OIRs describe the information required by an organization for asset management and operation and other organizational functions at a strategic level.

AIR: The asset-related information that the asset owner/operator needs, either for themselves or for their stakeholders. Once the business needs are understood, more detailed AIRs can be defined.

EIR: Known as client's BIM requirements) is a document that defines the client's project and BIM objectives. The EIR generally outlines the information to be delivered, together with any associated standard and process to be adopted by the project delivery teams.

BIM Execution Plan (BEP): A document to explain in detail how the project team plan to meet the requirements specified by the building/facility owner.

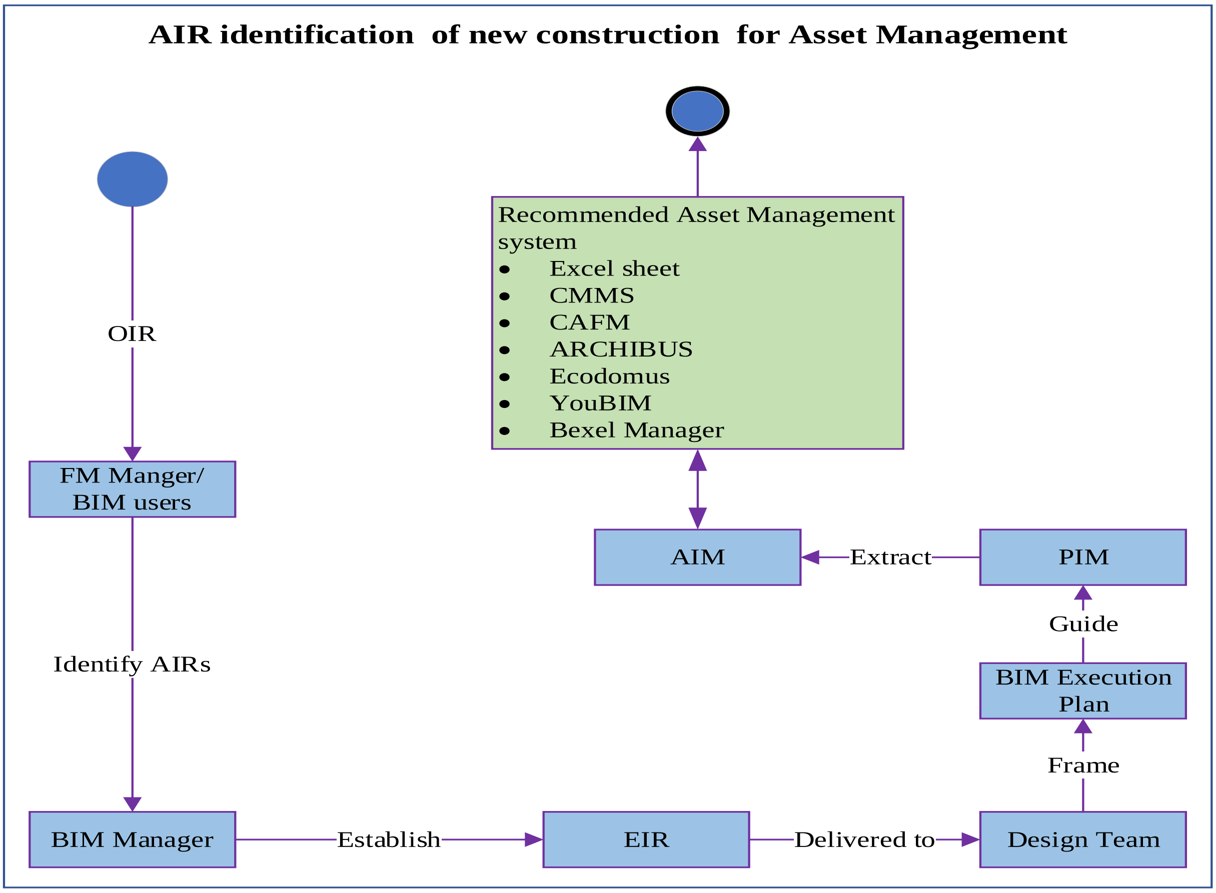
PIM: The information model developed during the design and construction stage of a project.

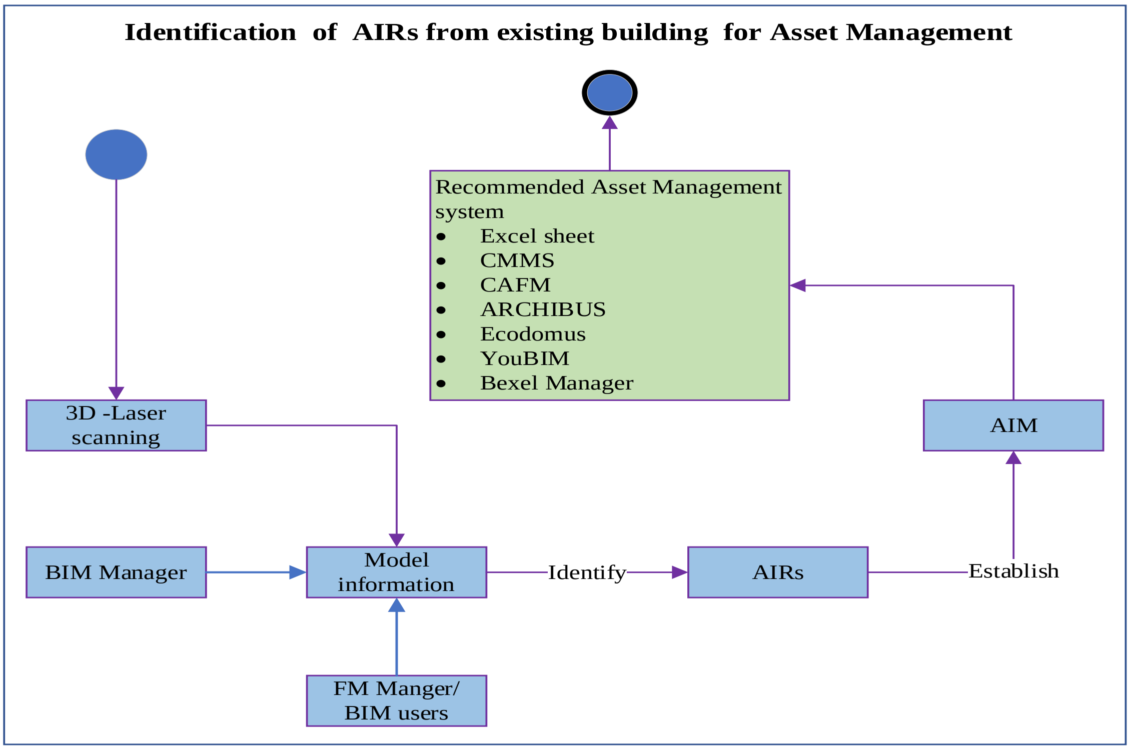
As-Built BIM Model: This Model should capture the condition and relevant information at the end of the construction stage for the new building and for the existing building to capture the condition and relevant information using data capturing technology.

AIM: The Model is derived from the As-Built BIM model and created from non-BIM built assets where only information specified in the AIR is to be retained.

Detailed Framework to use BIM for Built Asset Management

The key to effective BIM for built asset management (BIM-BAM) is to understand the asset information requirements which are critical for the O&M phase. Built asset management is about managing assets to achieve better O&M and the life cycle of critical assets. Hence building/facility owners must ensure building asset information is captured accurately during the design as well as construction stages. To ensure this is done proficiently, it is important to define the information requirements at the start of the project.





In conclusion, in the first stage, the built asset facility data is captured using appropriate data capturing technologies and data is extracted from that technology and fed into the AIM Model. Then, the data are extracted from AIM to the external database using the open standard schema IFC and COBie COBie spreadsheets. The data/information are then used for built asset management, FM decision-making process also an input for the public university management system. Besides, the data are then manipulated to identify the required FM information. In the second stage, the required information related to maintenance schedules is extracted from two sources: the industry standards; and the proposed web-based interface that allows different stakeholders to enter maintenance data directly into the same external database. At the final stage, data from AIM using IFC federated model and data collected from various sources using the COBie spreadsheet are presented; then data are imported from the COBie spreadsheet into CAFM/CMMS software. A seamless data flow is achieved by connecting different data/information sources into a single external database system. The data exchange process will be improved by having a seamless data flow that collects data automatically from various sources, reducing the time and effort required for a conventional system and manually entering the built asset data into FM systems. Moreover, Furthermore, this will provide

FM teams with the highly demanded regarding built asset components, allowing them to more efficiently respond to various O & M issues.

BIM-enabled built asset Facility information Management system conceptual framework was validated by incorporating the FM and project office professionals from the selected public universities, experts from the industry and the academia. The developed conceptual framework was distributed for participants to review and comment on it. An individual interview and discussion were made with six professionals from the public universities; three from the industry and three from the academia. The framework was validated based on the clarity, simplicity, comprehensiveness, relevance, and applicability of the developed framework in the public university.

- **Framework clarity:** 58.33% of the respondents strongly agree with the developed framework clarity, 33.33% of the respondents also agree with the framework clarity; while 8.33% of the respondents neither agree nor disagree.
- **Framework simplicity:** 50.00% of the respondents strongly agree with the developed framework clarity, 41.67%of the respondents also agree with the framework simplicity; while 8.33% of the respondents neither agree nor disagree.
- **Framework comprehensiveness:** 66.67% of the respondents strongly agree with the developed framework clarity and 41.67%of the respondents also agree with the framework comprehensiveness.
- **Framework relevance:** 75.00% of the respondents strongly agree with the developed framework clarity and 25 %of the respondents also agree with the framework relevance.
- **Framework applicability in the public university:** 58.33% of the respondents strongly agree with the developed framework clarity and 41.67% of the respondents also agree with the framework applicability.

Table 4- 8: BIM-enabled built asset Facility information Management system conceptual framework validation analysis

Description	Strongly Agree	Agree	Neither agree nor disagree	Disagree	Strongly Disagree
The Framework is clear	7	4	1	0	0
The framework is simple to understand	6	5	1	0	0
The framework is comprehensive	8	4	0	0	0
The framework is relevant	9	3	0	0	0
The framework is applicable in the public universities	7	5	0	0	0

4.6 Summary

The study established case selection criteria and used non-behavioural sources of data; hence, the subjectivity and observer's error and bias are minimized. In this study, the document review and literal replication of multiple cases grant the data and research reliability respectively. The nature of the research requires a mixed method: both deductive and inductive research approaches; both qualitative and quantitative data. Therefore, the pragmatic research philosophy has thus been adopted. The research objectives, as well as the research question, also claim the research type, approach, and design that should be designed. In this regard, no previous local studies have assessed and examined the current practices. Hence, in this study exploratory and descriptive research types were adopted. Accordingly, this study believed in the selected research strategies. Therefore, the research has been constructively validated.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

As stated in the first chapter, this study started with the specific objectives of assessing the current practice of built asset facility information management systems and identifying the required data/information for BIM-enabled built asset Facility management. This chapter concludes the major findings and forwarded recommendations based on the research findings. The recommendation is based on research findings integrated with the application of BIM tools in the built asset management at the O&M phase and the way how to improve the current built asset facility information management system. Finally, the chapter presents recommendations for future studies.

5.1 Conclusion

FM office in public universities needs multiple information to efficiently operate and maintain built asset facilities. Current FM information systems in public universities are conventional /paper-based/ that lack interoperability capabilities, which results in poor data management. One critical measure of building operations and maintenance is data accuracy and availability; however, capturing, storing and exchanging data within a multifaceted built asset facility is cumbersome and requires standardized processes. This study assessed the current practices of built asset information management systems in public universities and identified the required information for BIM-enabled built asset facility management. Also, the data analysis confirmed the importance of having a standardized built asset facilities information management system.

The results also revealed the FM office in the public university does not have a built asset facility registry database to store and manage data/information and documents of the built asset. Besides, almost all the public universities have no data, information or documents about the built asset’s facilities. The lack of data/documents on the built asset impacts the cost, schedule, and duration of O & M activities. This, in turn, has an impact on the process of monitoring and controlling the built assets, maintenance and user satisfaction. The FM office in the public universities currently uses the conventional system to capture, visualize and manage the data/information of built asset facilities that are not used as-built BIM models and/or COBie spreadsheets such as maintenance data. The data /information transfer formats practised in the selected public university are proprietary. Also, the built asset data are not entered into one model or one system. Therefore, FM teams required the interoperability of systems so that data can be communicated from upstream systems for downstream use/emerging technology to manage built asset facilities. All the basic, technical, managerial, commercial, financial, and legal information are extremely relevant for built asset management in public universities. The result confirmed there is a shortage /lack of data/information on the built asset in the FM offices as well as in the project offices. According to Kaya(2011b), there is no common standard to know the optimal level of information that is relevant for built asset management in the decision-making process. However, the Moscow rating scale is a superlative rating scale to solve the jargon data problem and identify the relevance of data/information (where M -Must have information; S - Should have information; C -Could have information; W -Would eventually have information if time and money were available).

Due to these results, BIM-Enabled Built Asset Facility Information Management System conceptual framework is proposed for built asset facility management and seamless information exchange between various data sources including as-built BIM models and FM systems using an open-data format to overcome interoperability problems. The proposed framework is presented in seven different layers within three summarized stages. In the first stage, built asset facility data is captured using appropriate data capturing technologies and data is extracted from that technology and fed into the AIM Model. Finally, the data are extracted from AIM to the external database using the open standard schema IFC and COBie COBie spreadsheets. The data/information are then used for built asset management, FM decision-making process also an input for Public university management system. Besides, the data are then manipulated to identify the required FM information. In the second stage, the required information related to maintenance schedules is extracted from two sources: the industry standards; and the proposed web-based interface that allows different stakeholders to enter maintenance data directly into the same external database. At the final stage, data from AIM using IFC federated model and data collected from various sources using the COBie spreadsheet are presented; then data are imported from the COBie spreadsheet into CAFM/CMMS software. A seamless data flow is achieved by connecting different data/information sources into a single external database system. The data exchange process will be improved by having a seamless data flow that collects data automatically from various sources, reducing the time and effort required for a conventional system and manually entering the built asset data into FM systems. Moreover, Furthermore, this will provide FM teams with the highly demanded regarding built asset components, allowing them to more efficiently respond to various O & M issues.

5.2 Recommendation

Based on the findings of the study, in order to improve the current practice of built asset facilities information management systems, the following points are recommended:

Recommendation For Public universities

- Public universities should develop built asset registry databases to store and manage built asset data/information and related documents. On the other hand, public universities can adopt simple FM software (CAFM and CMMS).
- The FM office in the public universities has no sufficient data/information to manage the built asset facility. To get the required information for built asset management the public universities should be adopted the data capturing techniques of their choice. Thus, should be non-contact such as Image-based techniques, range-based techniques, and combined and contact capturing techniques such as EDM and manual tap measurements. Also, extract the required data properly and import it to Built asset information management tools.
- The Public universities incorporated different types of built asset Facilities in their compound also the expansion of institutions will be continuous. Public universities should adopt BIM Enabled built asset information management systems for existing and new buildings. So, they can adopt BEXEL Manager as a BIM-enabled FM software/tool.
- FM practice, BIM implementation in the project life cycle, and integration of BIM with FM are currently at the infant stage. Furthermore, the built-in asset information management system has not been widely researched. As a result, further research is needed to apply BIM for construction and FM in public universities.

Recommendations for future work

In the infant stage of BIM implementation in the project life cycle and FM practice in the public universities as well as the construction industry; the bulky nature of the issues addressed and the lack of previous studies on the built asset facility information management system are the major challenges of this study. In addition, due to the current situation of the country, the research geographic area is limited in Addis Ababa is the limation of this study. In this study, research objectives are addressed fully and finally, the proposed conceptual framework is developed. However, the proposed conceptual framework is not implemented in the practice. This has an inevitable weakness of not addressing issues in detail and being implemented in the public universities. As a result, it could be helpful to start further research and contribute knowledge.

In this study, the required information for BIM-enabled built asset facility management is identified based on selected public universities in Addis Ababa as a case. Therefore, it needs further research by incorporating other public universities in Ethiopia. In addition, future studies could identify the information requirements of BIM-enabled Built asset Facility management in the construction industry by using case studies and surveys method. The proposed Conceptual framework was developed based on the analysis result of the study in selected public universities in Addis Ababa. Therefore, the proposed framework should be further developed and implemented by incorporating other public universities. Finally, the author of this study recommends next research could investigate the benefits of BIM -FM integration for the O & M process of a project and finally develop the AIM of the built asset facility.

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APPENDICES

Appendix 1: Publishable Manuscript

DEVELOPING BIM-ENABLED BUILT ASSET FACILITY INFORMATION MANAGEMENT SYSTEM: A CASE OF PUBLIC UNIVERSITIES IN ADDIS ABABA

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ABSTRACT

Facilities management (FM) is a discipline comprising various processes, activities, and maintenance services to support the main functions of built asset facilities. It demands sets of comprehensive information. Lack of information is one of the major challenges in the O & M phase of the built asset. The emergence of Building Information Modelling (BIM) systems, helped to solve the issue and improve the efficiency of built asset facilities management. Currently, the public universities have no data/information and related documents of the built asset facilities and have a major difficulty. Therefore, this study aims to explore the current practice of built asset facility information management systems in three selected public universities and identify the required information for BIM-enabled built asset management. Finally, this study aims to develop the conceptual framework of a BIM-enabled built asset facilities information management system. A multiple-case study was conducted on the three public universities in Addis Ababa. The study findings indicated that the FM office in public universities didn't have the data or information of the old built asset facilities but to some extent, they have as-built drawings for recently completed projects. So, the lack of information has an impact on the time and the cost of the O & M process of the built asset. The FM office practised the conventional method to capture, visualize, transfer and manage the built asset information. Currently, all the basic, technical, managerial, commercial, financial, and legal information are extremely relevant for built asset management in the selected public universities. Accordingly, to manage the built asset information, the FM office in public universities needs a single platform. As a result, a BIM-enabled FM conceptual framework was developed. The results obtained from this study further indicated that it needs further research by incorporating other public universities in Ethiopia.

Keywords: ***Built asset facilities, FM, BIM, BIM-FM Integration, Information requirement, information management system***.

BACKGROUND

The construction industry in Ethiopia is one of the major sources of economic growth[1]. The construction industry has grown significantly in recent years. The construction's GDP expanded 30 times from 15,130 million ETB in 2010 to 495,283 million ETB in 2019, according to national accounts statistics in the African Statistical Yearbook [2]. However, the percentage share of the construction sector to GDP at the constant basic price has decreased from 11.3% in 2007/08 to 9.9% by 2019/20[3]. Despite this, the expansion of economic infrastructure (buildings, roads, railways, telecom, power, irrigation) is critical to achieving the country's Growth and Transformation Plan (GTP). Also, a significant amount of the country's budget is allocated to economic development through financing infrastructures for the development of education and power projects, the construction of railways, and road projects [4]. However, Ethiopia's construction industry has been facing numerous challenges such as policy implementation; corruption; weak capacity of contractors and consultants; lack of collaboration and professionalism; and lack of benchmarking construction industry development (CID) practice from the role of government, resource-related variables, and the nature of the construction industry itself[5-6]. The existing buildings in Ethiopia have a lot of shortages in providing appropriate services due to a lack of proper FM. Also, the FM practice is at the infant stage but it is expected to boom due to its benefits during the O & M phase of a building. Accordingly, for the successful O & M of a building in the city, the development of FM and improvement of existing FM practices, and, the enhancement of technology-aided practices are recommended [7]. One of the requirements for a coordinated FM practice is information logistics[8]. The built asset FM requires an information management system that automatically captures, stores, and integrates the data to support the decision-making process[9]. The recent steady uptake of digital technologies, such as BIM implemented in the D&C phase has been accompanied by an expectation that this would enable the better transfer of information to the O&M phase [10]. Built asset management in public universities is frequently erratic, and slow, and it uses complicated procedures. Moreover, the data/information transferred from the developer to the owner is in printed document format. Decisions are not verified by statistically relevant information and knowledge-driven method from consistently composed data. Furthermore, the believable scenario is an information management system in public universities has not been sufficiently captured, researched, and documented and BIM provides a robust platform for FM information management. So, those are major issues to explore the BIM-Enabled Built asset information Management system of the public universities in Addis Ababa as case studies.

Research Question

This research addresses the following research questions:

- What is the current practice of built asset facility information management systems in the public Universities in Addis Ababa?
- What type of data and/or information is required for BIM-enabled built asset facility Management?
- What Kind of conceptual framework can be developed to respond to the challenges of built asset Facility Information Management system?

Research Objectives

The general objective of this study is to investigate BIM-enabled built asset information management systems of the Public Universities in Addis Ababa. But, the specific objectives of this study are:

- Assessing the current practice of built asset facility information management systems of the public Universities in Addis Ababa.
- Identifying the required data/information for BIM-enabled built asset Facility management.
- Final to develop the conceptual framework for BIM-enabled built asset Facility information Management system.

LITERATURE REVIEW

CONSTRUCTION INDUSTRY

The construction industry significantly contributes to the economic growth and social development of the nations. It also plays a key role in satisfying a wide range also an activity that creates all types of new buildings, engineering structures, as well as the operation and maintenance activities of the existing facilities[11]. In Ethiopia the level of Construction project management practices in terms of adopting advanced general project management procedures (such as risk, time, safety, etc.), functions, tools, methods, and techniques are unsatisfactory and very low[12]. Despite these challenges, the country's infrastructure development and FM of big infrastructures such as university buildings, highway projects, rail projects, dam construction, and real estate development are still in the infant stage also there is no well-organized CID policy[7].

FACILITY MANAGEMENT (FM)

FM is multi-disciplinary services and activities that have integration between people, place, process, and technology[13]. FM is the Science and Art of managing the integrated process from operational to strategic levels to ensure the functionality, comfort, safety, and efficiency of a built environment by integrating People, Place, Process, and Technology. FM is also a process that identifies business needs; develops FM Policy and Strategy; creates and implements business support activities; implements support infrastructure and capability; and maintenance and operation support infrastructure[14]. FM also focuses on the integration of primary activities at the strategic and operational levels. All most all FM organizations have the same management levels [15]. However, information requirements at each level are different [16].

BUILDING INFORMATION MODELING (BIM)

The concept of BIM was first proposed by Professor Chuck Eastman at the Georgia Institute of Technology in late 1970 [17] and [18].BIM is a set of integrated policies, processes, and technologies[19]. BIM is also a system that integrates all of the geometric and non-geometric information, functional requirements and capabilities in a single system of the building project over its lifecycle[20]. BIM has enormous potential for building O&M and FM. However, the benefits of BIM in O&M and FM have not been fully realized yet. In fact, most existing buildings do not have a BIM, and creating a BIM for an existing building is challenging[21]and [22]. On the other hand, the use of BIM for new buildings is easy to start with a fresh, clean file, and layout everything as we need precisely where it is supposed to be[23]. For existing buildings, the building information is insufficient. To collect data about a building, data capturing techniques are required.

BIM-FM INTEGRATION

Built Asset management entails balancing costs, opportunities, and risks against the desired performance of assets to meet an owner's goals. The owner/FM office has had appropriate and reliable information about an asset is critical for asset management to support decision-making, planning, and execution of asset activities and tasks, during the operations and maintenance phase of the asset[24]. In the O & M of the built asset, FM teams often spend a considerable amount of time and effort collecting information in the form of electronic data and hardcopy documents. Also, employees engage in constant redundant activity for searching, sorting, validating, and recreating information[25]. Accordingly, BIM is one of the most prominent initiatives frequently addressed by scholars and practitioners as a game-changer in the construction industry in general and FM in particular[26]. BIM- FM data integration has come with issues related to establishing an effective process to extract, store, and distribute data/information of the asset to ensure interoperability of the system [27] and [9]. In general, automated data processing and information transfer from the early stages of a project to the operation and maintenance phases of the project, as well as increasing the efficiency of work orders and decision-making processes by access to real-time data and previously-stored graphical and non-graphical data, are the benefits of BIM-FM integration practices[28]. The data generated by software may be classified as either proprietary or open data. Open data is information that is freely available to the public and may be used, re-used, republished, and redistributed by anyone. To put it another way, everyone can access open data, but proprietary data can only be read by specific software solutions[29]. Industry Foundation Classes (IFC) is a vendor-neutral data model for the exchange of building information among software and companies[26]. Construction Operations Building information exchange (COBie) that a widely used model view definition for facility management information handover also used to identify and exchange information about facility assets, throughout the lifecycle of facilities [30]. BIM Collaboration Format is also an alternate information transfer format that is commonly used during the design process for minor information transfers between actors[29]. Information interoperability and data mapping are essential for exchanging seamless information between BIM and FM systems. Besides this interoperability is simply the ability that data generated by any one party can be properly interpreted by all other parties[26]. Interoperability is critical in managing data loss issues in fully integrated systems. A robust BIM adoption and implementation can be possible via solving interoperability problems. Interoperability enables heterogeneous software and hardware systems to collaborate in an integrated manner, allowing for integrated project delivery [31]. Common Data Environment (CDE) is an important central repository to solve the interoperability issue. Therefore, CDE is a central repository where built asset information is housed. The contents of the CDE are not limited to assets created in a 'BIM environment' and it will therefore include documentation, graphical model, and non-graphical assets data[32].

INFORMATION REQUIREMENT

Information requirements are the sets of information that support some of the process activities in the particular phase of the product life cycle [33]. At the critical phases of a project, the information requirements are released by the client's assessment and approval [34]. In UK BIM standard PAS 1192-3 and BS EN ISO 19650-D provides information requirements are inputs for the whole information management system, which includes organizational information requirements (OIR), asset information requirements (AIR), project information requirements (PIR), and employer/exchange information requirements (EIR). Hence, the owner of the facility in defining and translating strategic information requirements (OIR) into operational information requirements (AIR and PIR) and how it may be included in the tender specification (EIR)[35],[36] and [37]. OIRs are the information required by an organization for asset management and operation to inform decision-making about high-level strategic objectives[35] and [38].

AIR is a part of the BIM process that incorporated the required graphical and non-graphical data/ information, and documents of the built asset at the O&M phase [39]. According to, BS EN ISO 19650 - Guidance Part D standard, AIR is an information requirement specification for "what", "when", "how", and for "whom" information is to be produced. As well, PAS 1192-3/ BS EN ISO 19650-3 defines AIR as data and information requirements of the organization in relation to the basic, technical, managerial, financial, commercial and legal information of the built asset. AIR is a subset of the overall project brief [36]. The AIR specifies the Asset Information Model (AIM) requirements [40]. AIR is managed mainly in AIM in the form of **Documentation**, **Non-Graphical Data**, and **Geometry/Graphical Models**. As a result, critical decisions can be made by the client and their supply chain, based on timely and accurate information[41].

- **Documentation:** Drawings and PDFs from manufacturers, such as Safety Data Sheets, etc. that are usually handed over to clients and their facilities management teams via Operation and Maintenance Manuals.
- **Non-Graphical Data:** For BIM Level 2 that is in line with the British Standard BS1192-4 which utilizes the Data exchange format COBie.
- **Geometry, Graphical Models:** 3D Federated models of the building and the systems and components within it.

PIR is a set of high information requirements derived from OIR. PIR focuses on the information required by the Appointing Party at key decision points during the design and construction phase of the project [42]. Project information requirements are under ISO 19650-1 clause 5.4 and ISO 19650-2 clause 5.1.2[43] and [42].

- **Project task information:** Negotiate funding and PIR of the area/occupancy information and visualizations required at key decisions to demonstrate to funders what the facility will look like.
- **Project business plan information:** The facility must earn the turnover in the first year, and PIR of retail department area/occupancy information and benchmark sales figures per m2 to be provided at key decision points.in addition to that, the investment target cost of the project must be defined and PIR of Project cost information to be provided at each key decision point.
- **Statutory information:** The project task is a land registry application and the PIR is information about the site's location and surrounding area.
- **Procurement information:** Project task information is issuing invitations to tender for the design team, main contractor, and ordering the necessary quantity as well as PIR of the tender package information for key decision points.
- **Design information:** Project task information of the facility's Strategic brief and PIR evidence that performance and capacity requirements are required at each key decision point.

The EIR, which was created by the UK BIM Task Group, sets out the information deliverables as well as the standards and processes to be adopted in the supply chain. Hence, the term ‘exchange information requirements' from ISO 19650-1 has the same meaning as the term ‘employer’s information requirements’ from ISO 19650-2[36]. In addition, ISO 19650-2, Specification for information management for the capital/delivery phase of construction projects using building information modelling specifies the requirements of level 2 BIM and specifies the employer's information requirements. EIR known as the Employer’s BIM requirements is a document that outlines the project and BIM objectives of the client[35]. Technical information (details of software platforms, CDE, CAFM systems used by the Client, etc.); Managerial information (details of information management processes to be adopted), and Commercial information (details of information deliverables, timing of information exchanges, and definitions of information purposes) are a type of EIR [44]. Therefore, information requirements should define based on the purposes and objectives of the built asset. Information requirements as a whole tell the story of the organizations.

The inappropriate data exchange format selection is affecting the built asset data/information management system. However, accessibility, longevity, accuracy, completeness and interoperability are the selection criteria for data exchange forms and formats [45] and [46]. However, interoperability is a key to the standardization of BIM methods and usage. OpenBIM data standards such as IFC and specifications such as COBie provide the capability to capture FM data requirements in a structured manner from the early stages of project development[47]. Moreover, to ensure that data is trustworthy, it is important to validate, check and understand the dimensions of data quality. Similar to the way that data quality expectations for operational or analytical data silos are specified, master data quality expectations are organized within defined data quality dimensions and information deliverables to simplify their specification and measurement. Hence the typical information deliverables are the BIM execution plan (BEP) Project Information Model(PIM) and Asset Information Model (AIM)[35].

An AIM can be created from existing asset information systems, from new information and information in a PIM that was created for the construction of a new asset. In summary, ISO 19650-3 presented the relationship between elements of BIM-based information management such as EIR, OIR, AIR, PIM, and Asset Information Model AIM. These are shown in the Figure below, whilst their connection to the asset's lifecycle. The process starts with the OIR, where the asset owner probes the business needs to identify the data and information required from the BIM-based processes to meet the needs of its AM system and other business functions[48].

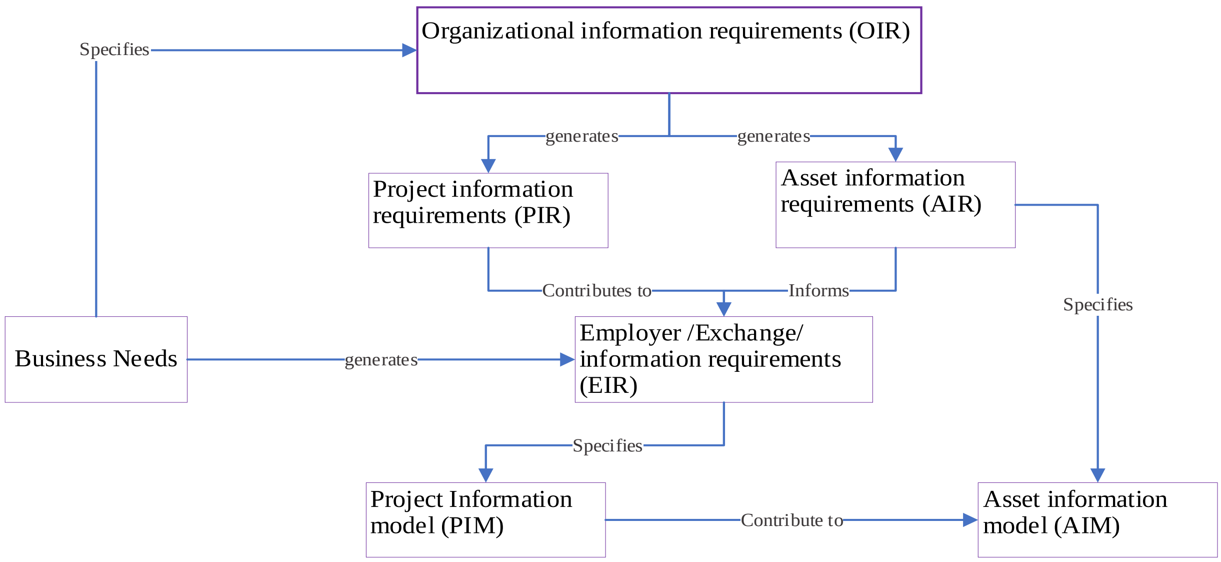

Figure 1: Elements of BIM-based information management Elements of BIM-based information management adapted from PAS1192-3[48]**.**

GAP IDENTIFICATION

The O & M phase of the built asset facilitates is the most expensive phase. The O & M phases of the built asset also require comprehensive and well-structured information [49]. However, the existing FM information systems are not well addressed the information requirements of Built asset Management [50]. BIM solves the challenges by incorporating the complete multifarious information from planning to demolishing phase of the built asset. It is also simple to integrate with existing FM systems[51]. In Ethiopia, the practice of FM and the implementation of BIM at the project delivery and end phase is still at an infant stage. Furthermore, the built asset facility management was not emphasized by the construction industry. Yet nobody specifies what data/information is needed for built asset O &M Management. The data/information is everything and critical for built asset management in public universities. The current practice of built asset information management systems in public universities utilizes a conventional method for data capturing, delivering, and managing the built asset. This brings inefficiencies of data/information, information loss, wasted time searching for the built asset data, inconsistencies of the available data, poor building maintenance management, loss of workforce productivity and re-work, inconvenience to end-user, and not meeting the intended purpose. Due to this, substantial economic losses could occur. In summary, the construction industry grew rapidly and the ministry of education substantially lost its economy via the development of public universities. Thus, the essence of this study is to fill the gap in the literature and the current practice of built asset information management systems of Public Universities in Addis Ababa.

METHODOLOGY

Research methodology is a way to systematically solve the research problem [52] and [53].it is also the path through which researchers need to conduct their research via formulating their problem, and research objectives and finally presenting their results from the data obtained during the research period [54]. The objective of the research is to conduct an in-depth investigation of the BIM-Enabled Built Asset Facility Information Management System of the public universities in Addis Ababa. The study adopts both descriptive and exploratory types of research. A multi-case study was conducted on the three public universities in Addis Abeba. The case study research strategy is an empirical inquiry that investigates a contemporary phenomenon within its real-life context [52]. The public universities were selected based on the year of establishment; no campus and types of built assets in the universities; plot area and technology implementation. The research approach of this study is both deductive and inductive research. Both quantitative and qualitative data are collected form primary and secondary data sources by document analysis, observation and semi-structured interviews of the FM office and project office representatives of each public universities. All the semi-structured interviews, document analysis, and observation data were analyzed using the thematic and statistical analysis method.

RESULT AND DISCUSSION

The findings from the study indicated that the FM office in public universities didn’t have the data or information of the old built asset facilities but to some extent, they have as-built drawings for recently completed projects. So, the lack of information has an impact on the time and the cost of the O & M process of the built asset. The FM office practiced the conventional method to capture, visualize, transfer and manage the built asset information. Currently, all the basic, technical, managerial, commercial, financial, and legal information are extremely relevant for built asset management in the selected public universities. Accordingly, to manage the built asset information, the FM office in public universities needs a single platform. As a result, a BIM-enabled FM conceptual framework was developed.

Case Description

Table 9: Case I description

Location	Addis Ababa
Year of established	2011 E.C
No. of administrative staff	391
No. of Academic staff	472
No. of Undergraduate student	8000
No. of Postgraduate student	7000
Total covered land area	130 Ha
No. of campus	1
No. of building Block	60

Table 10: Case II description

Location	Addis Ababa
Year of established	1950 E.C
No. of administrative staff	4,346
No. of Academic staff	3110
No. of health professionals	1253
No. of Undergraduate student	29,872
No. of Postgraduate student	17,738
No. of campus	14

Table 11: Case III description

Location	Addis Ababa
Year of established	1996 E.C
No. of administrative staff	1000
No. of Academic staff	280
No. of student	7,000-7,999
No. of Postgraduate student	7000
No. of campus	3

The current practices of the Built asset facility data/information management system of the public universities in Addis Ababa.

The current practice of public universities-built asset facilities information management systems is discussed for each selected case and finally, a cross-case analysis is conducted from the results of the multiple cases.

Case Study I

The Case I public university FM office hasn't an asset registry database to store and manage the data/information and documents of the built asset. Almost all built assets facilities in the university have no data/information and documents. However, to some extent, the maintenance records/maintenance schedules data, as well as facility and equipment conditions data are managed manually (a paper-based file system). Drawings of some of the building blocks were stored, edited, and managed in computer database form of Portable Document Format (PDF). The FM office also uses the traditional (manual) document management system and practiced conventional methods to capture and visualize the built asset facilities data.

Figure 9: Case I Current practices of Built asset O & M data and Information Management system (Source: Picture Taken from the case I FM offices, 2021)

The FM office has practiced Printed paper documents (hardcopy), scanned documents (pdf format), AutoCAD documents (in DWG, DXF format), word documents (in DOC, DOCx format), and Excel documents (in XLS format) as the pervasive data/information transfer formats from developer to facility owner/FM office during project delivery phase.

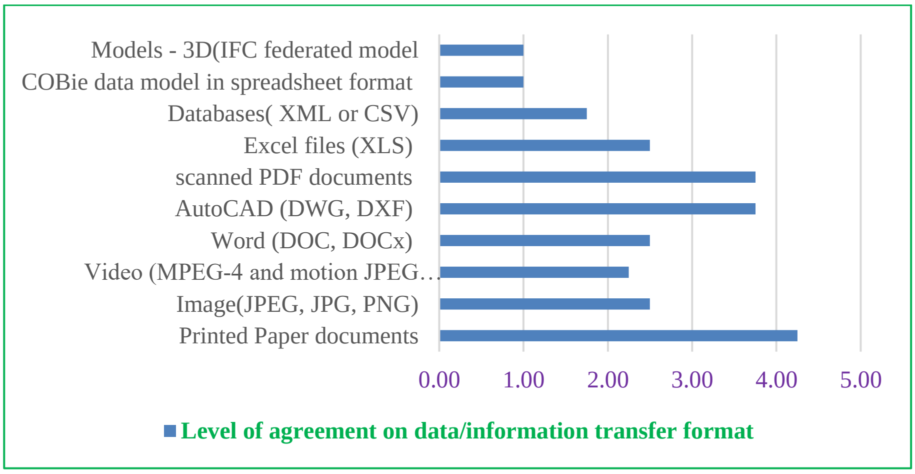

Figure 10: Case I current practice of data/information transfer format from developer to user/FM team

The cost, schedule, and duration of O&M activities are affected due to a lack of data/information and documents of the built asset facilities. Lack of information also affects the process of monitoring and controlling the built assets, as well as maintenance performance and user satisfaction. The FM office also has not a standard data model and building a classification system to manage the built asset facilities information. But they need a single platform to manage built asset facilities.

Case Study II

The Case II public university FM office hasn't an asset registry database to store and manage the data/information and documents of the built asset. It implies that the FM office has no as-built model/drawings/design of the longstanding-built asset facilities. Almost all built assets facilities in the university have no data/information and documents. But to some extent, the project office has as-built drawings/design documents for recently completed projects. The FM office in the selected public university practiced the conventional document management system and built asset facilities data capturing and visualizing method.

Figure 11: Case II Built asset O & M data / Information Management system ***(Source: Picture Taken from the case II project offices, 2021)***

The FM office has practiced printed paper documents (hardcopy), scanned documents (pdf format), AutoCAD documents (in DWG, DXF format), and word documents (in DOC, DOCx format) as pervasive data/information transfer formats from developer to facility owner/FM team during project delivery phase.

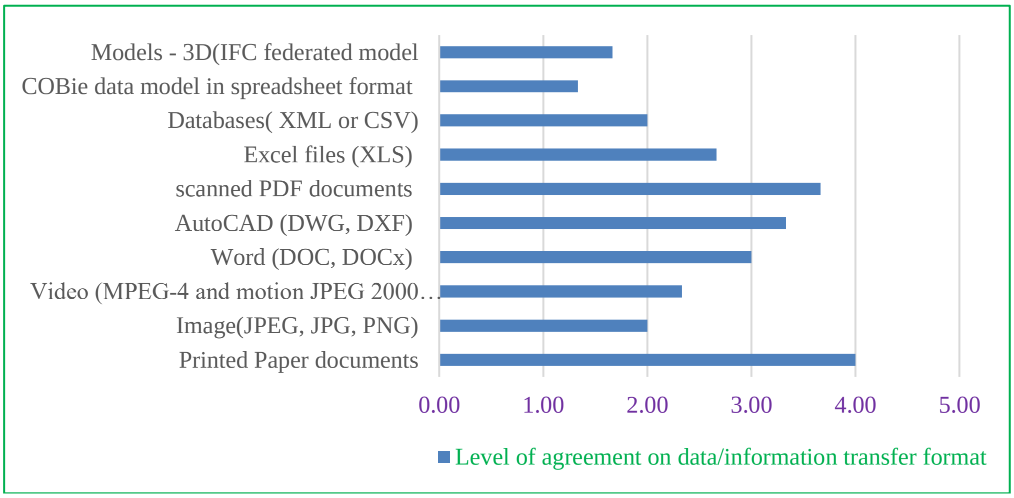

Figure 12: Case II current practice of data/information exchange format from developer to user/FM team

The cost, schedule, and duration of O&M activities are affected due to a lack of data/information and documents on the built asset facilities. The lack of information also affects the process of monitoring and controlling built assets, as well as a maintenance performance and user satisfaction. The FM office also has no standard data model and building a classification system to manage the built asset facilities information. But they need a single platform to manage built asset facility information.

Case Study III

The Case I public university FM office hasn't an asset registry database to store and manage the data/information and documents of the built asset. The FM office also has no as-built model/drawings/design of the longstanding-built asset facilities. But, some of the recently completed projects have as-built drawings/design documents. In summary, almost all built assets facilities in the university have no data/information and documents. The FM office in the selected public university practiced the conventional document management system and built asset facilities data capturing and visualizing method.

Figure 13: Case III Current Built Asset O & M data / Information Management system ***(Source: Picture Taken from the case III FM and project offices, 2021)***

The FM office has practiced Printed paper documents (hardcopy), scanned documents (pdf format), AutoCAD documents (in DWG, DXF format), word documents (in DOC, DOCx format), and Excel documents (in XLS format) as the pervasive data/information transfer format from developer to facility owner/FM office during project delivery phase.

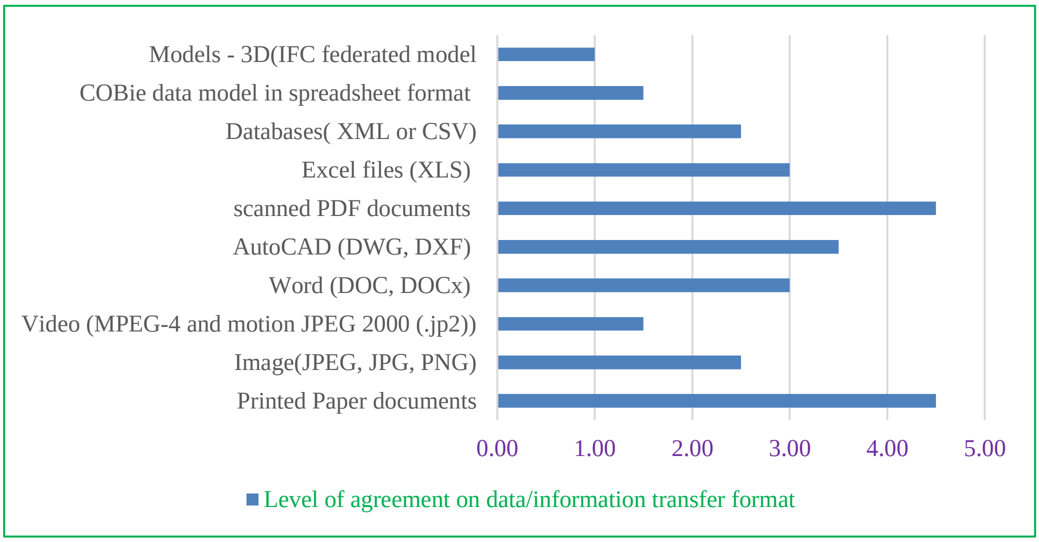

Figure 14: Case III current practice of data/information exchange format from developer to user/FM team.

The cost, schedule, and duration of O&M activities are affected due to a lack of data/information and documents of the built asset facilities. Lack of information also affects the monitoring and controlling process of built assets, as well as maintenance performance and user satisfaction. The FM office also has not the standard data model and building a classification system to manage the built asset facilities information. But they need a single platform to manage built asset facility information.

In summary ,in the built asset life cycle the O&M phase is the most expensive phase and it takes higher expanse that the other phase of the project [55].The O&M cost of the built is around 60 -75% of the project cost [56] and [57]. Sometimes it is also higher than 85%

of the project cost[58]. Most of these costs were incurred during O & M of the built facility. The O & M costs are also generated by the owner's and operator's faults. In addition, the O & M costs are generated due to inefficiency, lack of data/information and data/information loss associated with interoperability problems. Accordingly, the FM office in the three cases has no data/information and documents of the built asset facilities. Consequently, the cost, schedule, and duration of O&M activities are affected due to a lack of data/information and document on the built asset facilities and literature also supports the result.

The required data/information for BIM-enabled Built Asset facility management.

The required data/information is generated from the organizational information requirements and project information model in a BIM-based project. In detail, the required data/information for BIM-enabled built asset facility management are basic, technical, managerial, commercial, financial, and legal information of built assets. That data/information is first identified from the literature.

The finding from the study indicated that almost all basic, technical, managerial, commercial, financial, and legal information are extremely relevant for BIM-enabled built asset management. In accordance with BS EN ISO 19650-3 asset management standards [59] and [39] the above-mentioned information is relevant to form-built asset management. Furthermore, physical resources, support services, human resources and business need information are relevant for Built asset management[57]. But, there is a lack of standards to identify the optimal level of information relevancy for built asset management[60]. The result also indicated that there is a data/information shortage of built asset management in the FM offices and project offices of selected public universities. Also, currently, shortages and a lack of information are challenging in the FM offices and project offices of public universities. Hence, when the information is properly transferred and managed those issues will be solved. After that jargon data will be a big issue in the FM office. As a result of the constant searching, categorizing, validating, and recreating of information due to jargon data time and money are will lose. Therefore, the data/information relevance rating scale is necessary to manage that data/information of the built asset for the decision-making process.

Accordingly, due to jargon data issues and time loss from constantly searching for, categorizing, validating, and recreating information, Infrastructure Asset Managers use the Moscow rating scale (where M – Must have information; S – Should have information; C – Could have information; W – Would eventually have information if time and money were available)[61]. As a result, must-have information that is critical for built asset management such as asset unique ID, inception, and life cycle cost. Should-have information is also critical, but may not be as time-sensitive as the must-have information. The information related to currency, Suitability for information use functional and technical performance specifications are categorized under the Should have information. Could have information is wanted or desirable but less important and Less impact if left out. The information such as location-geospatial, Linear and Space, topological relationship and location, geometric construction, dimensions relationship to other assets and groupings such as network, entities, facilities, systems, and assemblies, reference to work breakdown structure, material, the energy embedded, etc. are could have information. They would have information are will depend on the life cycle stage of the built asset.

Built asset facilities management in the public university requires complete and reliable information. The O & M phase requires a comprehensive set of well-structured information regarding the built asset. FM teams often spend a considerable amount of time and effort collecting information in the form of electronic data and hardcopy documents. Employees also engage in constant redundant activity searching for, sorting, validating, and recreating information. So, BIM is a catalyst to improve Facilities Management processes where it is demonstrated in identifying more precise and accurate information throughout the design and construction process[62]. Therefore, BIM-enabled FM is imperative for improving the quality and accuracy of asset information. This avoids also data entry costs and generates higher-quality data[57]. Hence, to solve the data /information loss and the interoperability issue BIM-enabled built asset facilities information management system is essential.

Conceptual framework Development for a BIM-enabled constructed asset Facilities information Management system

The built asset FM is frequently erratic, and slow, and it uses complicated procedures. Moreover, the data/information transferred from the developer to the owner is in printed document format and challenged. Decisions are not verified by statistically relevant information and knowledge-driven method from consistently composed data. The Built asset facility management in Addis Ababa public universities is problematic due to the lack of data, information, and documents. The FM office in the public Universitas in Addis Ababa has no database to manage built asset facilitates and a heavy reliance on a paper-based approach. Accordingly, the FM office in the public universities also needs a single platform to improve the current built asset information management system and project data delivery process. So, to solve the problem the researcher developed the Conceptual Framework. To develop the Conceptual Framework various standards and specifications have been used as a reference which could streamline the development of a Built asset facility information management system, through the structured development of owner and facility managers' information requirements, and their validation against various data/information sources. The ISO 19650 series specifications are an important contribution to achieving this specific research objective. The author of this research believes that the study output will contribute knowledge and practical application in the proper implementation of the system in public universities. In particular, ISO 119650-3 sets out key requirements for information management during the operational phase of facilities, considering the use of several different data/information sources and IT systems.

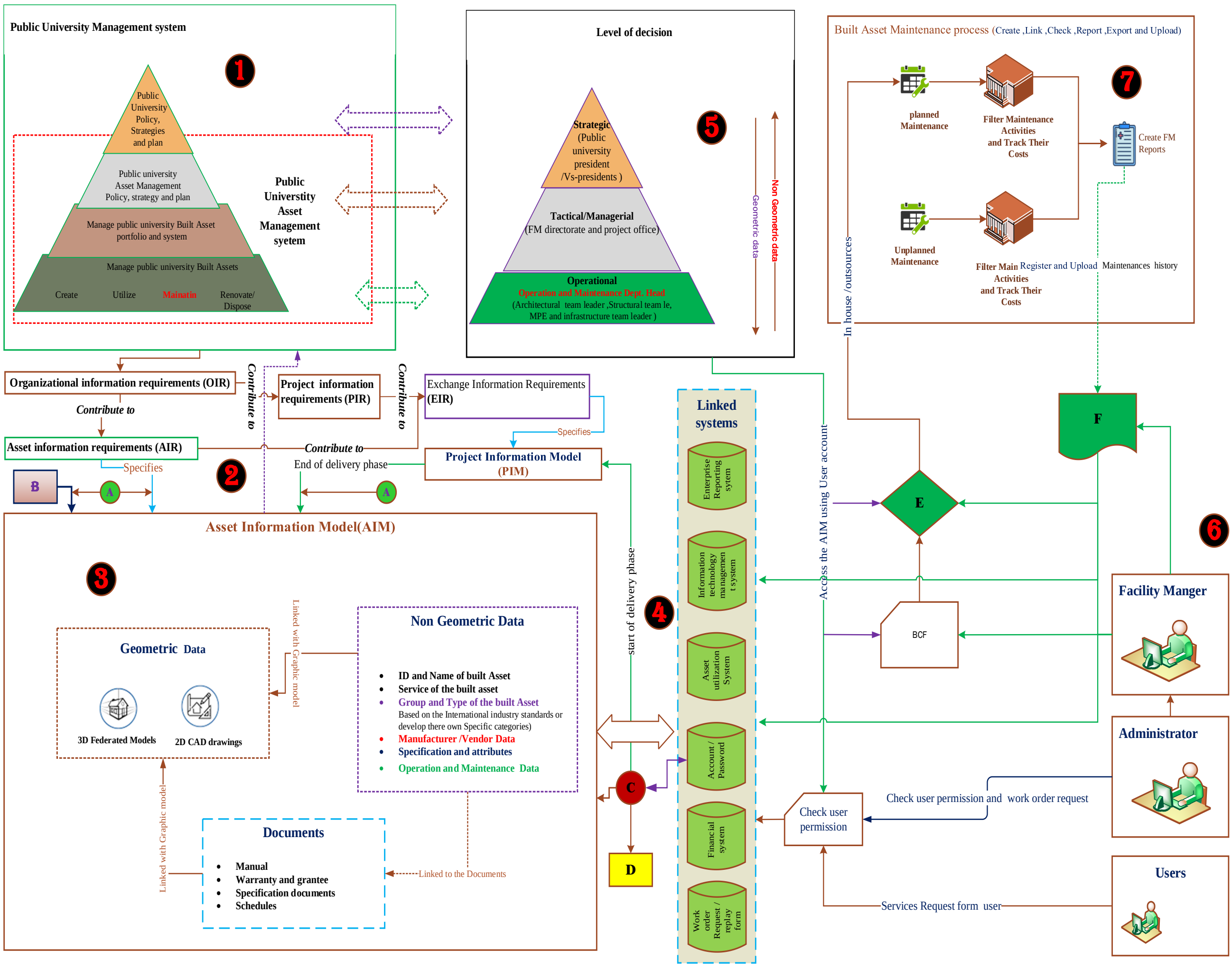

Figure 8: BIM-enabled built asset Facility information Management system conceptual framework.

Framework legend

1. **Public university's management layer:** Includes the asset management strategy, policy, and plan.
2. **Information requirements layer:** Data/information is arranged and processed into meaningful patterns and context
3. **Asset information model layer:** The information and data are transferred from existing organizational systems into the AIM.
4. **Linked data enterprise systems layer:** The interface between the AIM and the existing enterprise systems shall be implemented through a two-way connection
5. **Level of decision-making layer:** Decision Making in the public university is classified into the three categories such from operational, tactical and strategic levels.
6. **Built Asset Maintenance process layer:** After the decision is made between the Facility manager and decision-makers the planned and unplanned Built Asset Maintenance will be performed.

7. **The user and Administration layer:** In this layer, the user request the services; the Administrator controls the overall data/information security and direct relationship with the Facility manager.

A. Information verification and validation box.
B. Data capturing technology that generate the built asset data/information.
C. Data/Information Searching, Filtering, and sorting box.
D. **AIM** direct links box to simple FM software (i.e CAFM and CMMS) for easy reference.
E. The data/information Searching area.
F. Decision box: The facility manager shall be discussed with decision-makers about the scope of the built asset services.

Detailed Framework to use BIM for Built Asset Management

The key to effective BIM for built asset management (BIM-BAM) is to understand the asset information requirements which are critical for the O&M phase. Built asset management is about managing assets to achieve better O&M and the life cycle of critical assets. Hence building/facility owners must ensure building asset information is captured accurately during the design as well as construction stages. To ensure this is done proficiently, it is important to define the information requirements at the start of the project and after data capturing of the existing building.

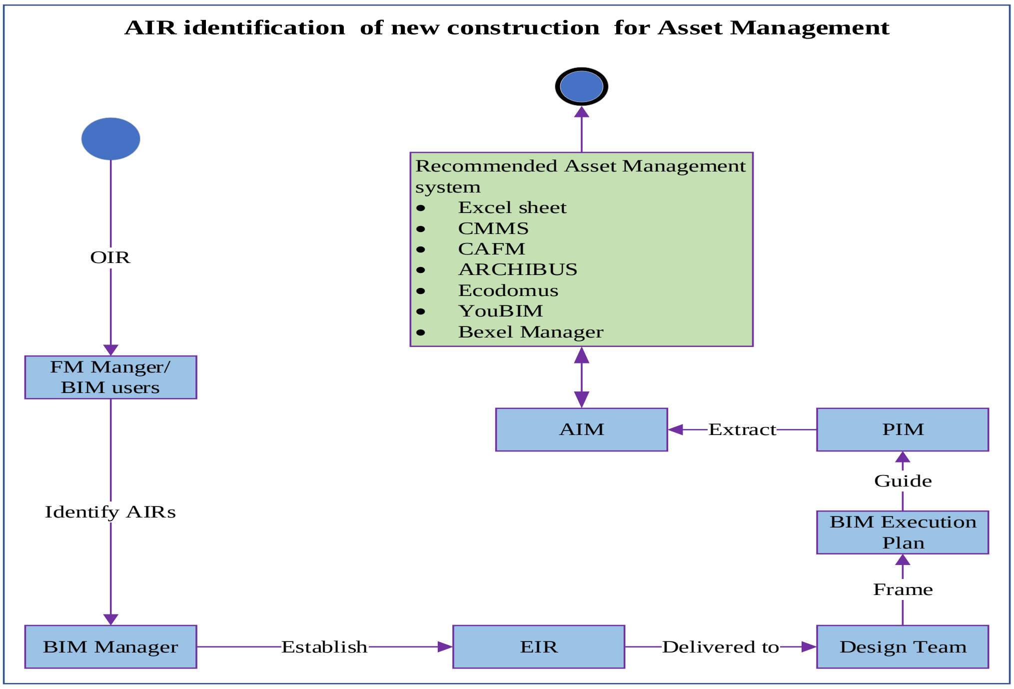

Figure 9: AIR identification of new construction for Asset Management.

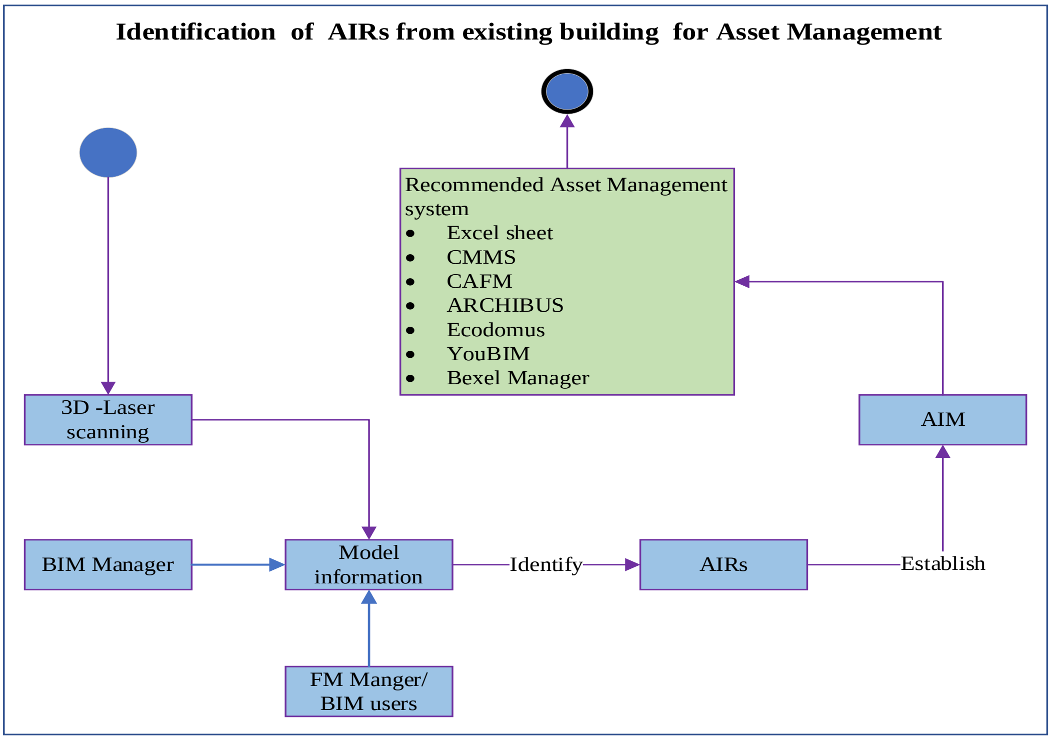

Figure 10: Identification of AIRs from existing building for Asset Management.

CONCLUSION

FM office in public universities needs multiple information to efficiently operate and maintain built asset facilities. The FM information systems in public universities are conventional /paper-based/ that lack interoperability capabilities, which results in poor data management. One critical measure of building operations and maintenance is data accuracy and availability; however, capturing, storing and exchanging data within a multifaceted built asset facility is cumbersome and requires standardized processes. The finding of this study indicated that the FM office in the public university does not have a built asset facility registry database to store and manage data/information and documents of the built asset. So, it indicates the public universities have no data, information and documents of the built asset's facilities. The lack of data/documents of the built asset impact the cost, schedule, and duration of O & M activities. All the basic, technical, managerial, commercial, financial, and legal information are extremely relevant for built asset management in public universities. The result validates there is a shortage /lack of data/information of the built asset in the FM offices as well as in the project offices. To solve the aforementioned challenges, the conceptual framework for a BIM-enabled Built Asset Facility Information Management System has been developed.

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Appendix 2 : Case study Interview questions

Part I: Respondent's Background

1.1. Name of the University:

1.2. Your Professional Background:

1.3. Educational Level:

1.4. Total Professional experience:

1.5. What is your Position:

1.6. Year of Experience in current position:

Part II: The current practices of the Built asset facility data/information management system of the public universities in Addis Ababa

2.1. Total Number of Students:

2.2. Total Number of Staff:

2.3. How many built assets (building blocks) are there in your university?

2.4. Does your department have data/information and documents of the built assets?

2.5. Does your office have as-built models/drawings/designs of the built asset facilities?

2.6. Does your office have a database to store and manage data/information and relevant documents of the Built Asset? If yes, which data store as a data/information in the database to be used for Maintenance Activities?

2.7. If no, which data /information and document management system currently do you use?

2.8. Does your office have a data/information/ file structure and data classification system?

2.9. How do you manage and process O & M work orders request?

2.10. How do you capture and visualize data /information of built asset facilities for O&M activities? (Paper-based checklists or Automatic).

2.11. Do you think that lack of data/information has an impact on the cost, schedule, and duration of O&M?

2.12. What is your level of agreement regarding the current practice of data/information exchange format from developer to user/FM team?

Information /Data Transfer format	Strongly disagree	Disagree	Neither agree or disagree	Agree	Strongly agree
Printed on paper documents.	☐	☐	☐	☐	☐
Word (DOC, DOCx format)	☐	☐	☐	☐	☐
AutoCAD (DWG, DXF format)	☐	☐	☐	☐	☐
Scanned PDF documents	☐	☐	☐	☐	☐
Excel files (XLS) format.	☐	☐	☐	☐	☐
Databases (XML or CSV)	☐	☐	☐	☐	☐
COBie data model in spreadsheet format.	☐	☐	☐	☐	☐
Models - 3D (IFC federated model)	☐	☐	☐	☐	☐
Image (JPEG, JPG, PNG) format	☐	☐	☐	☐	☐
Video (MPEG-4 and motion JPEG)	☐	☐	☐	☐	☐

2.13. Do you think that lack of data/information affects the process of monitoring and controlling built assets, as well as a maintenance performance and user satisfaction?

2.14. What do you think to enhance the current built asset information management system and do you believe it is required for Built asset facility information management?

Part III: *The data and /or information that might be required for BIM-Enabled for BIM-enabled Built Asset facility management for Public University Building Facilities in Addis Ababa.*

What is your level of agreement in the data/information relevancy for Built Asset facility management in your university?

n.No	Information Requirements	Available file format in	Preferred File format in	Level of data/information Relevance									
				Very Relevant									Not Relevant
		Paper, DWG, PDF, DOC, JPEG	Paper, DWG, PDF, DOC. JPEG, IFC2*3, COBie	10	9	8	7	6	5	4	3	2	1
1	**Basic Project information**												
1.1	Name of Asset												
1.2	Location												
1.3	Name of Employer												
1.4	Name of Contractor												
1.5	Name of consultant												
1.6	Year of Built Asset start												
1.7	Year of Built Asset handover												
1.8	Built Asset cost at completion												
1.9	No of floors												
1.1	Contract type												
1.11	Project of delivery system												
1.12	Building function												
1.13	Technical Characteristics (Classic ,Modern and contemporary)												
2	**Technical information**												
2.1	Software platforms												

2.2	Data and Exchange Formats												
2.3	Visualization format(in 3D IFC Federated model)												
2.4	Classification of BIM DATA(Uniclass, Omniclass,Master format ,uniformat and etc)												
2.5	Co-ordinates												
2.6	Level of development (Level of Detail +level of information)												
2.7	Mechanical, Electrical and Plumbing (MEP) Systems information												
2.8	Training details												
2.9	Engineering data and design parameters												
2.10	Details of asset dependencies and interdependencies												
2.11	Commissioning dates and Submitted data												
2.12	Operational data including performance characteristics and design limits												
3	**Managerial information**												
3.1	Type of asset												
3.2	Photograph												
3.3	Identification numbers (specification number, product number, serial number)												
3.4	Location												
3.5	Floor area												
3.6	Space management information												
3.7	Warranties and guarantee periods												

3.8	Access planning and work schedules												
3.9	Maintenance and inspection schedules and records												
3.10	Operation and Maintenance manual												
3.11	Outstanding tasks												
3.12	Record of planned and unplanned maintenance												
3.13	Standards, processes, and procedures												
3.14	Hazardous contents or waste												
3.15	End of the life cycle of the asset												
3.16	Emergency plans												
3.17	The presence of any hazardous contents and waste												
3.18	Details of emergency plans including responsibilities and contact details												
3.19	Linked Data information related to specific building asset.												
3.20	User’s Manual												
4	**Commercial information**												
4.1	Description of the asset												
4.2	The function of the asset												
4.3	Details of supplier												
4.4	Lead time												
4.5	Facilities and Equipment condition												
4.6	Key performance indicators												
4.7	Performance targets or standards												

4.8	Non-conformance criteria and actions to be taken												
4.9	The criticality of assets and spaces to the organization												
5	**Financial information**												
5.1	Original purchase/leasing Cost												
5.2	Operating cost												
5.3	Planned maintenance cost												
5.4	Historical maintenance cost												
5.5	Replacement value												
6	**Legal information**												
6.1	Details Ownership												
6.2	maintenance demarcation												
6.3 6.4	Contractual information Property boundaries												
6.5	Work instructions												
6.6 6.7	Legal obligations (H&S, etc.) Risk assessments and control measures												

Appendix 3: Framework validation questionnaires

Chair of Construction Management, Ethiopia Institute of Architecture Building Construction and City Development (EiABC), Addis Ababa University.

Subject: Requesting your sincere assistance in participating as key respondents to validate the framework.

Research title: Developing BIM-Enabled Built Asset Facility Information Management System: A Case of Public Universities in Addis Ababa.

Dear /Sir

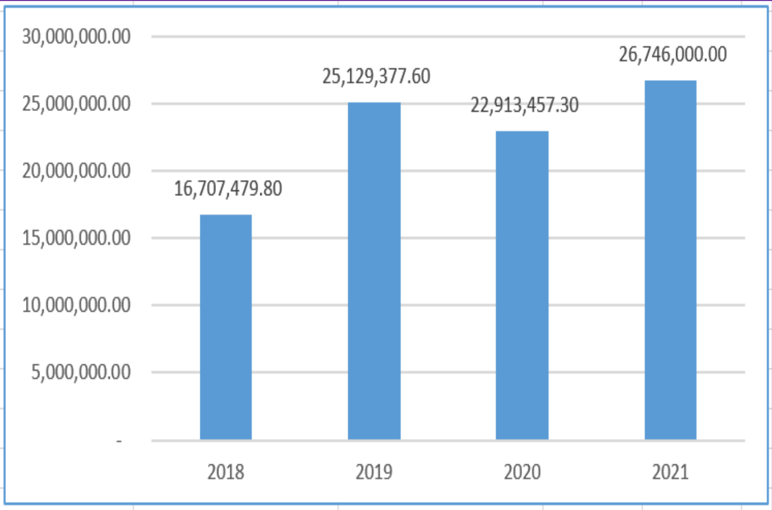
This MSc research aims to develop a conceptual framework for BIM-Enabled Built Asset Facility Information Management systems for the Public Universities in Addis Ababa by critically assessing the current practice of Built Asset Facility Information Management systems and identifying the required information for BIM-enabled Built Asset Facility Management (FM). The built asset FM is frequently erratic, and slow, and it uses complicated procedures. Moreover, the data/information transferred from the developer to the owner is in printed document format. decisions are not verified by statistically relevant information and knowledge-driven method from consistently composed data. The Built asset facility management in public universities is problematic due to the lack of data, information, and documents. The FM office in the public Universitas has no database to manage built asset facilitates and a heavy reliance on a paper-based approach. Accordingly, the FM office in the public universities also needs a single platform to improve the current built asset information management system and project data delivery process. So, to solve the problem the researcher developed the Conceptual Framework. To develop the Conceptual Framework various standards and specifications have been used as a reference which could streamline the development of a Built asset facility information management system, through the structured development of owner and facility managers' information requirements, and their validation against various data/information sources. The PAS 1192 /ISO 19650 series specifications are an important contribution to achieving this specific research objective. The author of this research believes that the study output will contribute knowledge and practical application in the proper implementation of the system in public universities.

With this brief background and the discussed legend framework. I kindly request you to respond to the survey to validate the framework, which will be highly valuable and necessary for the attainment of the research objectives. The rating system ranges from 1 (Strongly Disagree) to 5 (Strongly Agree). Please indicate your responses by ticking (X or √) mark at the appropriate box/es.

	Strongly Agree (5)	Agree (4)	Neither agree nor disagree (3)	Disagree (2)	Strongly Disagree (1)
The Framework is clear					
The framework is simple to understand					
The framework is comprehensive					
The framework is relevant					
The framework is applicable in the public universities /industry					

Appendix 4: Summary of govern Capital Expenditure for construction projects in the public universities for the last four years

Year	ETB (BLN)
2018	16,707,479.80
2019	25,129,377.60
2020	22,913,457.30
2021	26,746,000.00



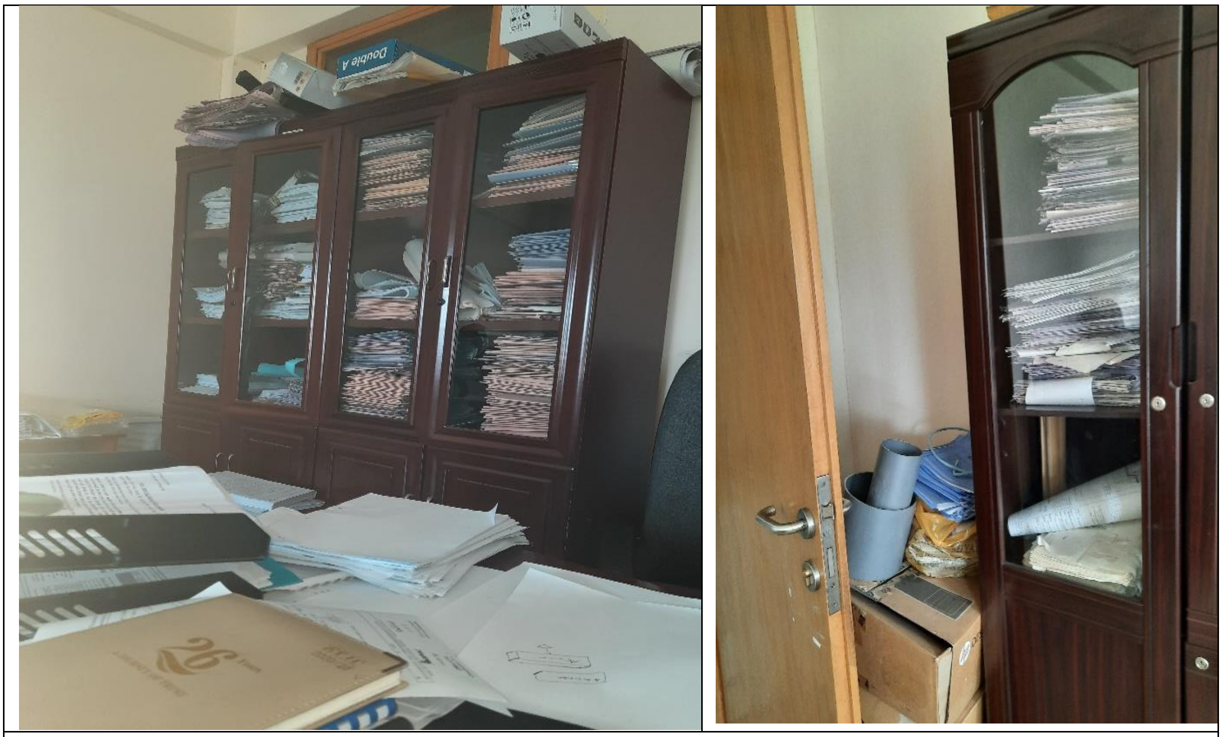
Appendix 5: Built asset Condition and Document management practices

Case I Built Asset Condition and Document Management Practice

Built Asset Condition

Built asset document management practice and Work order request form

Built Asset Condition



Built asset document management practice

Case III Built Asset Condition and Document Management Practice

Built Asset Condition

Built asset document management practice and Work order request form

Appendix 6 : BIM Expert input to developed a Framework to use BIM for built asset management

BIM experts have an input to validate conceptual framework and to developed a Framework to use BIM for built asset management. The figure below is a freehand sketch of a flow chart showing how to use BIM for built asset management for new and existing buildings.