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Potentials of BIM for Service Management - Identification of Specialized Use Cases Co-Working Services

Master Thesis

Master of Science in Construction and Real Estate Management

Joint Study Programme of HTW Berlin and Metropolia UAS

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from

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Conceptual Formulation
Master Thesis for Mr./Ms. Mohammad Emran Hossain
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Topic: **Potential of BIM in Service Management – Identification of Specialized Cases in Co-working Services.**

BIM (Building information modelling) is the most promising development in AEC Industry in the last two decades. BIM development is a continuous process in the AEC industry, where BIM has been adding new potential with its multi-dimensional modelling approach. BIM is already in practice for the complete lifecycle management of the built environment, such as planning, design, construction, operation, maintenance, and demolition of built assets. However, in most cases, BIM (Building Information Modelling) is implemented only in the planning, design, and construction phases of the built environment, whereas only in few projects BIM is implemented in the operational phase.

This study aims to find out the potential of BIM in the service management of the built asset, focusing on co-working service places. The floor plans and lists widely used for space management purposes, but two-dimensional floor plans fail to demonstrate the indoor complexity (Ma, Song and Shang, 2019). BIM provides the platform to present both graphical and non-graphical information of a built asset that helps make a pre-occupied simulation and evaluation of space (Shen, Shen and Sun, 2012). In the construction phase, more geometric detailing is required in the model to visualize the built structure and the seamless construction, but in the operational phase, an informative model is essential to perform the building services and required maintenance services. Several studies have been done to find out the benefits of BIM in service management from different perspectives. This study will investigate how BIM can help in the service management of the co-working service places.

The objective of this study:

- To identify the benefits of BIM in ultimate space utilization of built-asset.
- To find out the potential of BIM in indoor environment monitoring for user comfortability of co-working space.

- Prospective of BIM in automated utility services in co-working space, depending on user feedback.
- To identify the potential of BIM in energy-saving of working-space operation.
- To find out the advantages of BIM in marketing and promoting service of co-working spaces.
- To identify the advantages of BIM in the workplace management system.
- To identify the required level of information in BIM for service management from the co-working service perspective.

Methodology:

Case study and intensive literature review will be the primary technique to achieve the objective of the study.

Timescale:

This study will be ended within the summer semester of 2021 and presented in colloquium 2021.

Task Description	Date
First Draft	18th of August
Final Draft	5rd of August
Complete of Thesis work	6th of September
Submission	6th of September

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Signature of the Supervisor

Ma, G., Song, X. And Shang, S., 2019. BIM-based space management system for operation and maintenance phase in educational office building. Journal of civil engineering and management, 26(1), pp.29-42.

Shen, W., Shen, Q. and Sun, Q., 2012. Building Information Modeling-based user activity simulation and evaluation method for improving designer–user communications. Automation in construction, 21, pp.148-160.

Abstract

BIM (Building information modelling) is a revolutionary technology in AEC (Air Architecture, Engineering and Construction). The benefits of implementing BIM in the preconstruction phase and construction phase is already well established in the AEC industry. Moreover, BIM has been showing its potential in operational service management for the built asset with research studies and use cases for more than one decade. However, there is still academic and industrial discussion on how BIM adaption improves the operational service management of built assets from various perspectives such as asset management perspective, facility management perspective and real estate management perspective.

This thesis study aimed to investigate the potential of BIM in operational service management from the co-working service places perspective. Through intensive literature review and discussing three example case studies, this thesis study found that BIM can improve the operational service management of co-working service places, large-scale workplaces and educational campus places. However, along with the benefits, BIM adaption for operational service management of any built asset has some challenges. The benefits and challenges are summarized in the seventh chapter of the thesis work, which indicates that the ultimate benefits of BIM adaption for the built asset depend on some crucial factors.

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List of Abbreviations

BIM	Building Information Modeling
AIM	Asset Information Model
HVAC	Heating, ventilation, and air conditioning
FM	Facility Management
CAFM	Computer-aided facility management
GEFMA	German Facility Management Association
ESM	Energy management System
IoT	Internet of Things

1. Introduction

The 4th industrial revolution is going where information and technology are the most driven forces in this revolution. BIM (Building Information Modelling) has been changing the construction industry rapidly for the last two decades. The ongoing 4th industrial revolution approach in the construction industry increases the practice of digital theologies, sensor integration, intelligent system, and automation service where BIM is considered a central repository of all project data for the whole lifecycle (Maskuriy et al., 2019).

The potential of BIM in the AEC industry is well-established and already in practice in different parts of the world, mostly in developed countries. The benefits of BIM adaption in the operational phase of built assets have also been proved in research studies and limited practice cases. Currently, BIM adaption is widely accepted in the construction industry, and BIM has enough potential to be adopted in the facility management phase, but it is often misconceived (Naghshbandi, 2016).

The operational period of a built asset is the longest part of the whole life cycle and is responsible for the more significant part of the expenses of the building life cycle. The expenditure in the built asset's operational period can be minimised by implementing innovative technologies, proper space utilization, applying efficient energy management, and reliable maintenance management (Aktin and Bildste, 2017). Integration of BIM in the operational phase of the built asset to improve the various services in the operation and maintenance system can boost the efficiency of the current technologies. A survey, 'Facility management Awareness of BIM' conducted by Ashworth and Ticker, 2017 found that 74% of respondents believe that BIM has potential to make a significant impact in facility management of built assets (Ashworth and Ticker, 2017). In addition, research conducted by McGraw Hill construction in 2014 on the perceived value by owners of BIM for FM stated a prediction that approximately 98% of building owners in the UK would perceive value from BIM adaption (McGraw Hill, 2014).

The benefits of BIM in the operational phase of built assets is an interesting topic for the last few years. The number of studies published in the international journal from 2014 to 2018 is almost three times compared to the previous five years (Ashworth et al., 2019). This research aims to find the potential of BIM in different service management in the operational phase of the built asset from the perspective of co-working service place management. A co-working service place refers to the place where more than one group involves as the user.

Educational institutes and university campuses can be an example of a large scale co-working place, and commercial co-working office space is another huge co-working space sector. Service management in the operational phase of the built assets has similarities. However, some services are crucial in large-scale facilities and co-working places, such as space management, occupant's comfortability insurance, efficient energy management, and user-oriented utility services.

This thesis work consists of eight chapters; the first chapter is the Introduction chapter consisting of the general introduction, the background of the study, and the thesis work's methodology. The second chapter is written on the current practices of BIM in the operational phase of built asset management. The third chapter consists of discussion about the co-working service place and elaborative study regarding commercial co-working office space.

Intensive analysis has been done in the fourth and fifth chapters of this thesis to discover all information regarding research objectives. The fourth chapter has been organized to answer the researcher question through intensive literature review and practice case example evaluation related to the research aim. In the fifth chapter, case studies analysis has been done to validate the findings and understand the benefits and the challenges of BIM adaption in the operational phase of the built asset.

The sixth chapter represents the detailed discussion regarding the required level of information and quality of the information in BIM to be adapted in the service management system in the operational phase of the built asset. In chapter seven, discussions and recommendations are presented on how BIM adaption is beneficial in the operational phase of the built asset, the challenges, and how the potentiality of BIM is utilized in the operational phase more efficiently. The last chapter is the conclusion of the thesis work.

1.1 Background

BIM (Building Information Modelling) has significant potential for the life cycle management of the built asset. Many research and practice cases prove that BIM integration in the operational phase, such as facility management, asset management, and maintenance management, is beneficial. The built environment is attached to all aspects of human life such as healthcare facilities, education industry, and built asset management is a significant issue where adapting BIM in the built assets management is rapidly increasing as BIM has significant potential for necessary service management in the operational phase (Dave et al., 2018).

BIM can be considered a provider of the platform where all necessary details information available of a built asset both in graphic and non-graphic format, which information helps solve the problem occur the management in operational period (Hu et al. 2018). BIM is being adapted by the end-user authority and facility manager to provide support for services in the operational period (Zahid et al. 2021). Building information modelling is the best technology as the collector of required data in buildings' construction period, which can be used in different services in operation and maintenance of the built asset (Abdullah, 2014).

Co-working service place management is more complex compare to other built asset management. Nevertheless, all other standard building services are also required in co-working service place management, but some services are crucial in Co-working services such as space management, energy management, and user-oriented utility service. Enough studies have not been done especially to find out the potential of BIM for service management in co-working service places, but considerable studies have been done where different service of co-working service places was investigated from other perspectives. BIM adaption provides huge benefits in the operational phase of built asset management in different services such as space management, security and safety management and energy consumption efficiency improvement (Solla 2020). The strong functionality and great potential of BIM lead to the adaption of BIM in building space management systems (M A 2019).

Integration of BIM and IoT in the operational phase of a building could provide some excellent solutions for the thermal comfort of the workplaces, especially to monitor real-time observation of the thermal comfort situation of a built environment (Zahid et al.2021). Chang et al. 2018 proposed a framework where BIM and IoT integration generate a platform to monitor building performance data such as internal comfort monitoring and energy consumption monitoring for better decision-making for the facility management system (Chang et al 2018).

1.2 Research Objective

This study aims to discover the potential of BIM (Building Information Modelling) in service management in the operational phase of the built asset. Service management from a co-working service space perspective is the main focus of this thesis work. The thesis proceeds with some specific objectives to find out the expected findings with a proper investigation. The research objectives are followings:

- To identify the benefits of BIM in ultimate space utilization of built-asset.
- To find out the potential of BIM in indoor environment monitoring for user comfortability of co-working space.
- Prospective of BIM in automated utility services in co-working space, depending on user feedback.
- To identify the potential of BIM in energy-saving of working-space operation.
- To find out the advantages of BIM in marketing and promoting service of co-working spaces.
- To identify the advantages of BIM in the workplace management system.
- To identify the required level of information in BIM for service management from the co-working service perspective.

1.2 Methodology

A qualitative research approach has been applied in this thesis work. Intensive literature analysis has been done to investigate the thesis objectives. The academic journal, research article, industrial report and publication, conference proceeding, white papers, report of related institutions are the source of information to execute this thesis work.

This thesis work is divided into four phases; in the first phase, the scope of work was described afterwards, the thesis objectives were formulated, and lastly, how to reach the goal was described in the methodology section. In second phase of the thesis the current approaches and technologies in built asset management in operational phases are discussed. Moreover, the term 'co-working service space' identification has been done from this thesis study perspective in the second phase.

The third phase of the thesis work consists of investigating part of the thesis objective, finding the answer for the research objective by intensive analysis of literature and describing the relevant case study. Furthermore, investigate the level of information required in BIM to be adapted to the built asset's operational phase. In the final phase of the thesis work, important findings are summarized to recommend the opportunities and challenges of BIM adaption for service management in the operational phase of co-working service space. Finally, the thesis is ended up with a conclusion.

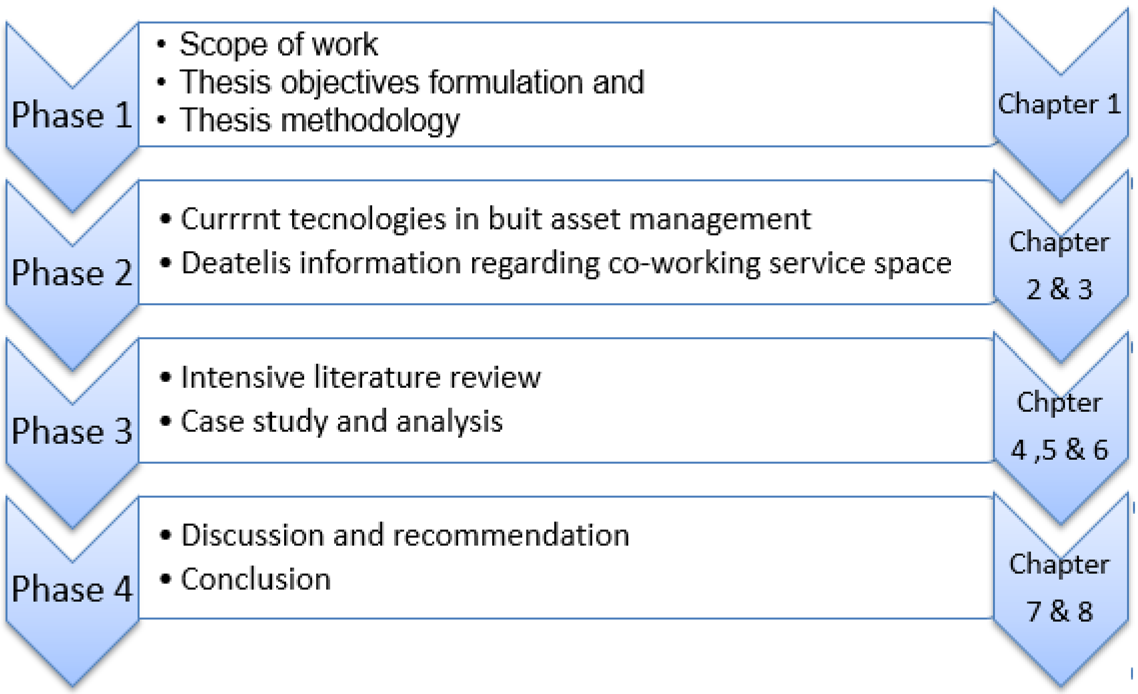


Figure 1: Methodology of thesis work.

1.3 Delimitation

This thesis is written to find out the potential of BIM for service management in the operation phase of built assets focusing on the co-working service space aspect. The thesis proceeds to investigate the possibility, benefits, opportunities, and challenges of adapting BIM for built asset operational service management. The deep discussion regarding technical details and programming details is avoided, but the necessary framework structure has been disused to understand the implemention ability of the different approaches of BIM adaption in the operational phase of the built asset.

Chapter 2

BIM in Operational Phase of Built Asset

2. BIM in Operational Phase of Built Asset

2.1 BIM

BIM is the latest digitalisation strategies in AEC industry. BIM can be called the technology and process in together where the technology part of BIM makes it possible to visualise what to be built for all stakeholders to find out any vital issue regarding design, construction and operation; the process part of the BIM empower strong collaboration and maximise the integration of all stakeholder in the project (Azhar et al. 2015). Building Information Modeling (BIM) aims to maximise the result in building and construction sector by connecting individuals/professionals, technology and the process (Building Information Modelling –(MagiCAD, 2021).

Building information modelling (BIM) represents a facility in digital format according it's physical and functional characteristics and BIM is a shared knowledge source of information as the basis of any decision making during the whole life-cycle of the facility from conception to demolition (National BIM Standard - United States, 2021). Building information modelling is a comprehensive process that can generate and manage the information of a built asset and BIM combined structured multi-disciplinary data to generate a digital representation of an asset for the total life-cycle from planning to operation (Building Information Modelling - Autodesk, 2021)

BIM is the latest technological advancement in the AEC industry that can make a difference in the whole lifecycle management of the built asset. Adaption of BIM in the design and construction phase is now common practice in different countries. Though the potential of BIM in the operational phase of the built asset also established, there is still some gap in the integration process framework. According to Patacas et al. 2020, facility management is facing challenges in information management due to lack of a structured framework that ensures a solution for the information related issues such as the delivery of asset information models, gathering distributed data from various sources, validating those models according to the requirements, and uses those data in facility management during the operational period of the built asset (Patacas et al. 2020). BIM is a process to make a digital representation of a facility or built asset along with the physical and functional properties, and BIM can be a reliable source of information to make any decision regarding built asset in the total lifecycle (Patacas et al. 2020).

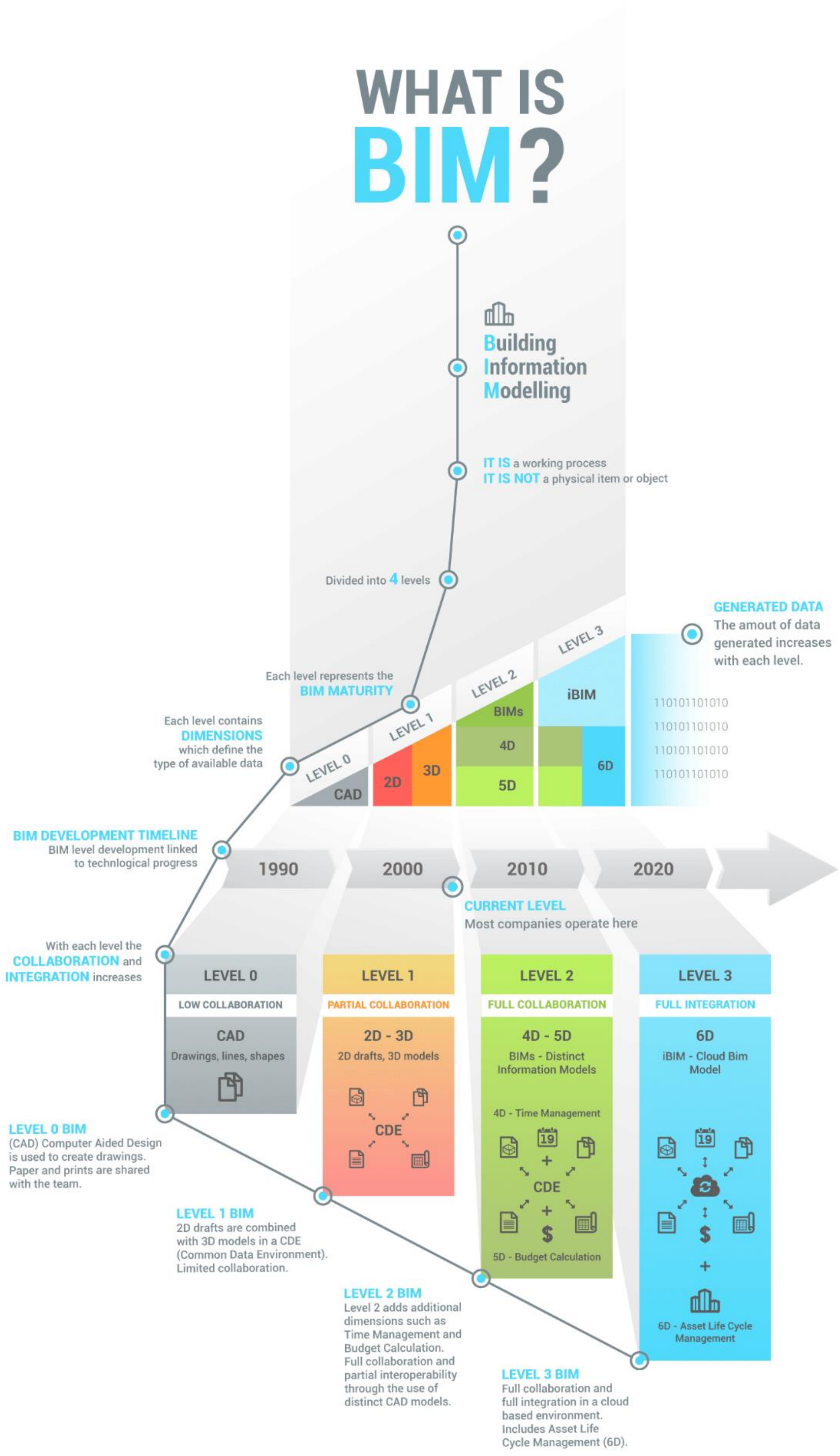


Figure 2: Development of BIM (BIM - The Future of Construction, 2021)

2.2 Built Asset Management

Build asset management is a combination of the different systemic processes such as operation, maintenance, modification, and expending of the physical asset throughout the life cycle (Akofio-Sowah et al. 2014). Asset management authority is responsible for maintaining all services enable with minimum cost by using effective build asset attribute and system. Asset management is more than the operation and maintenance of a building or built asset.

Al- kasabeh et al. 2021 stated Asset management in a combination of some objectives such flowing :

i) Assessment the current condition of built asset.
ii) After the assessment, prediction of future deterioration of the asset
iii) Prepare maintenance and repair strategies
iv) Make sure that condition has improved after corrective work is done.
v) Preparing asset priority list and fund allocation accordingly. (Al- kasabeh et al. 2021)

Adaption Building information modelling (BIM) has been increasing in the asset management process. Asset management system requires to validate detailed information of the asset to make required strategies for an effective operation through the life cycle. BIM is an enriched information model of the asset, which can be deriver force for asset management. However, the adaption of BIM in asset management faces some obstacles, such as the lack of technical difficulty in using the BIM data in asset management tools and data interoperability. According to Talebi, S. 2014 the number of available BIM tools that support the asset management is fewer than the tools available for the design, and the different technology alignment use in different tools also makes divination among the design phase and other phases.

2.3 BIM from Planning & Design Phase to Operational Phase of Built Asset

2.3.1 The trend of BIM adaption in different phases

Building information modelling (BIM) is a collaborative process that shares information between project stakeholders covering construction, planning, design, construction, and Facility management. The type of information in BIM are the 2-dimensional model, 3d-dimensional model, schedules, cost and building life cycle data, and materials related information. The benefits of BIM use make the adaption of BIM rapidly, especially in developed countries.

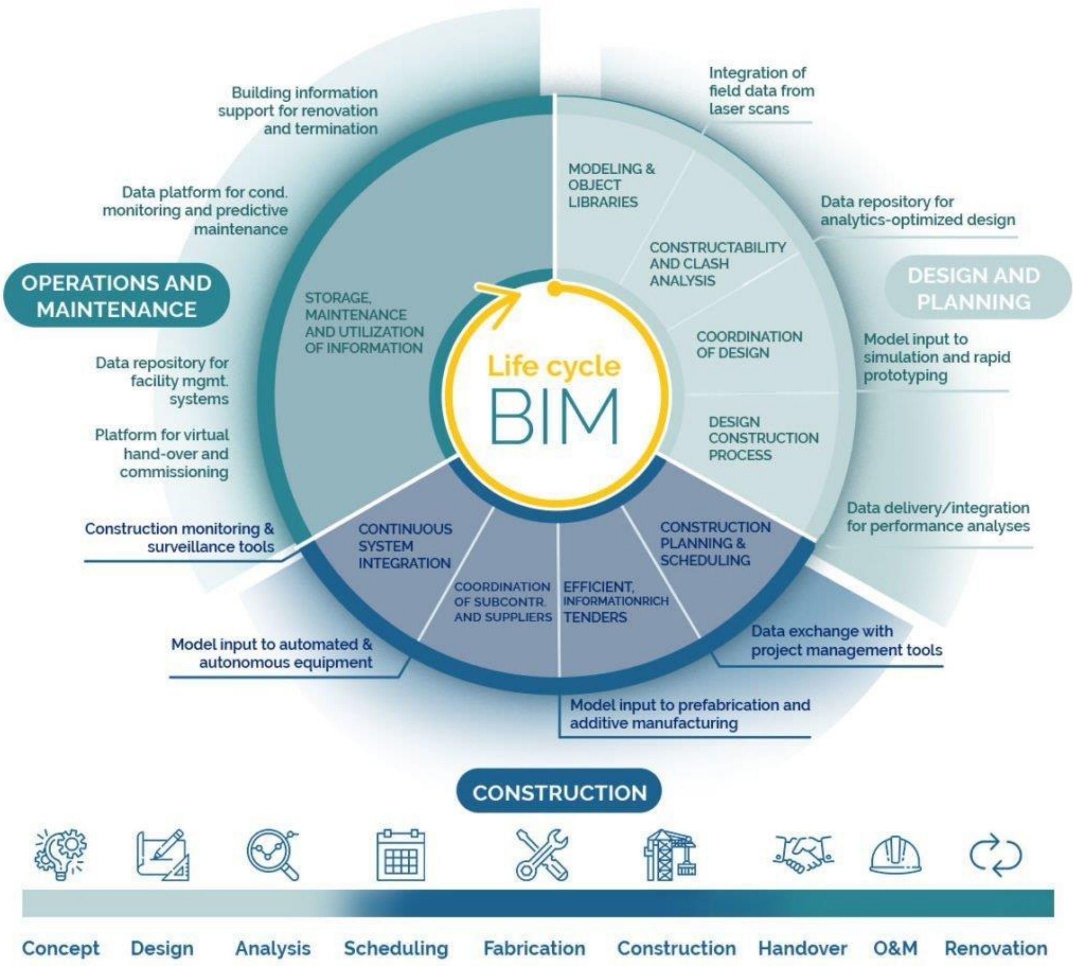


Figure 3: BIM in the different phases of the life cycle. (Cemex 2021)

According to the NBS BIM report 2016, 75% of design professionals of developed acknowledge that BIM is the most important in future. The United Kingdom BIM mandate has already recommended the BIM level 2 adaption in current practice since 2016, aiming to integrate BIM level 3 in the next few years. (Jang and Collinge, 2020).

According to the national BIM report 2020, 25% of BIM users still use BIM only for 3D modelling, where 37% of them adapted as BIM level 2.

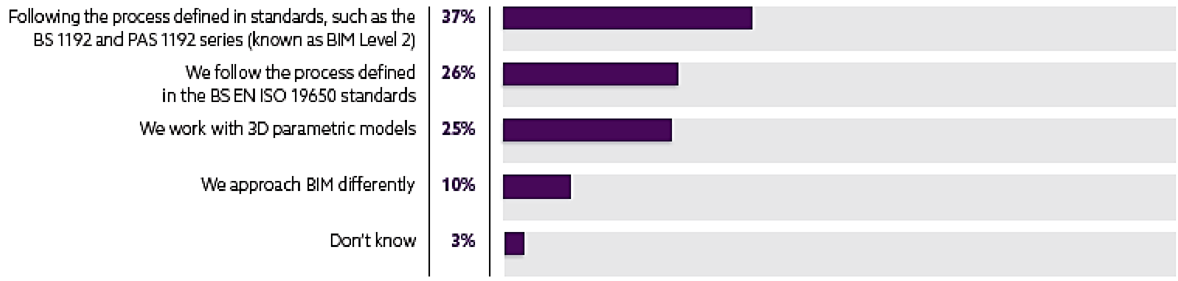
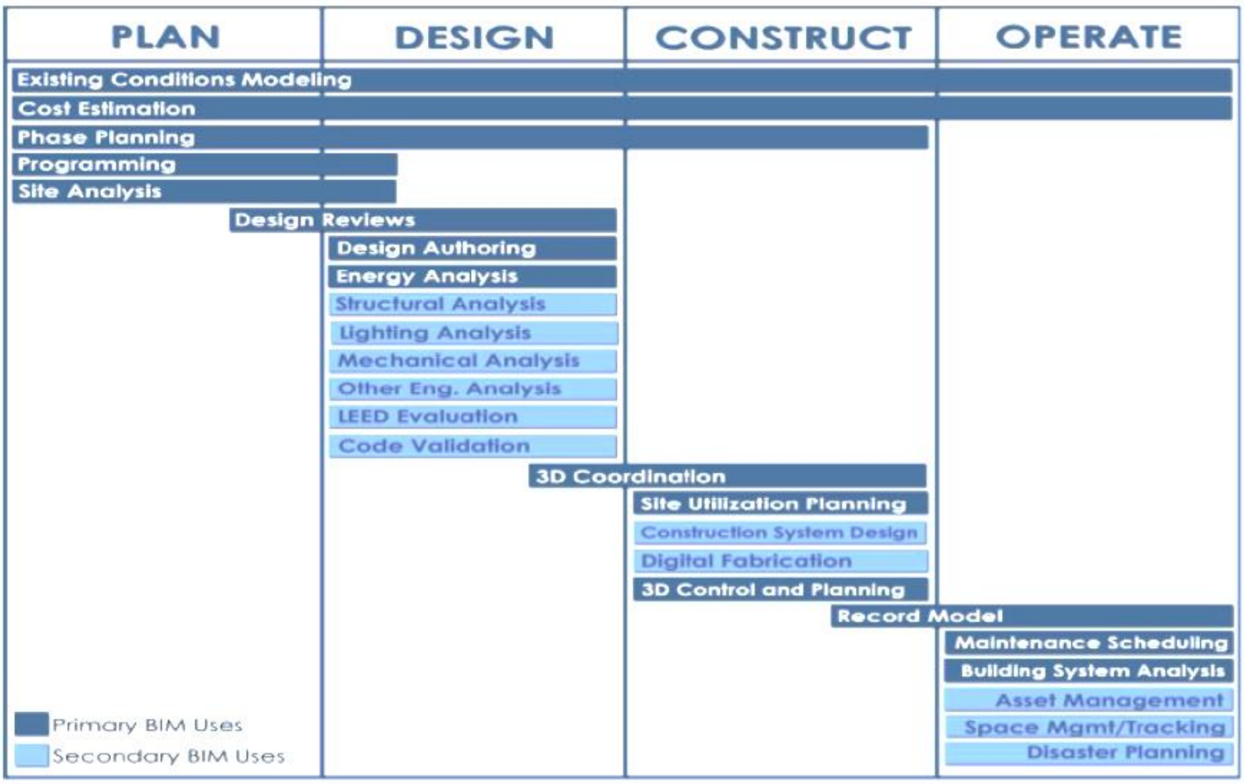


Figure 4: BIM level adapted by the user (National BIM Report 2020).

There is no need to prove the benefits of BIM in planning to execution phases of the construction projects. Though the adaption of BIM in the operational phase of the built asset is also well established, how far beneficial in terms of simplicity and financial perspective is still in discussion. A considerable number of research studies and some limited practical cases have already supported that BIM has excellent potential to be adapted for the operational phase and minimize the operational cost in the long run.

Table 1: BIM models in different phases of the project life cycle. (Jiang, 2016)



2.3.2 Prerequisite to adopt BIM in the operational phase

The benefits of BIM in facility management or asset management depend on some prerequisites. Only 3D BIM modelling for design and construction purposes cannot fulfil the requirements for operational service management. Some specific information available in design and construction BIMs is needed to be adapted in facility management or asset management directly or indirectly.

Availability of quality asset information on time is a concerning issue to apply asset management strategies in built asset management. As-built data and information are generated throughout the construction phase, but the condition assessment data can be collected after the operational phase. However, the design and construction face has a huge amount of data related to the built asset, which is crucial for the effective and efficient management of the building. The separate process of design-construction data and built asset data collection make an obstacle for built asset information modelling. The separate process aftermath causes a delay in the built asset management task and causes the additional cost to validate and verify all information to establish an asset management system. (Al- kasabeh et al. 2021)

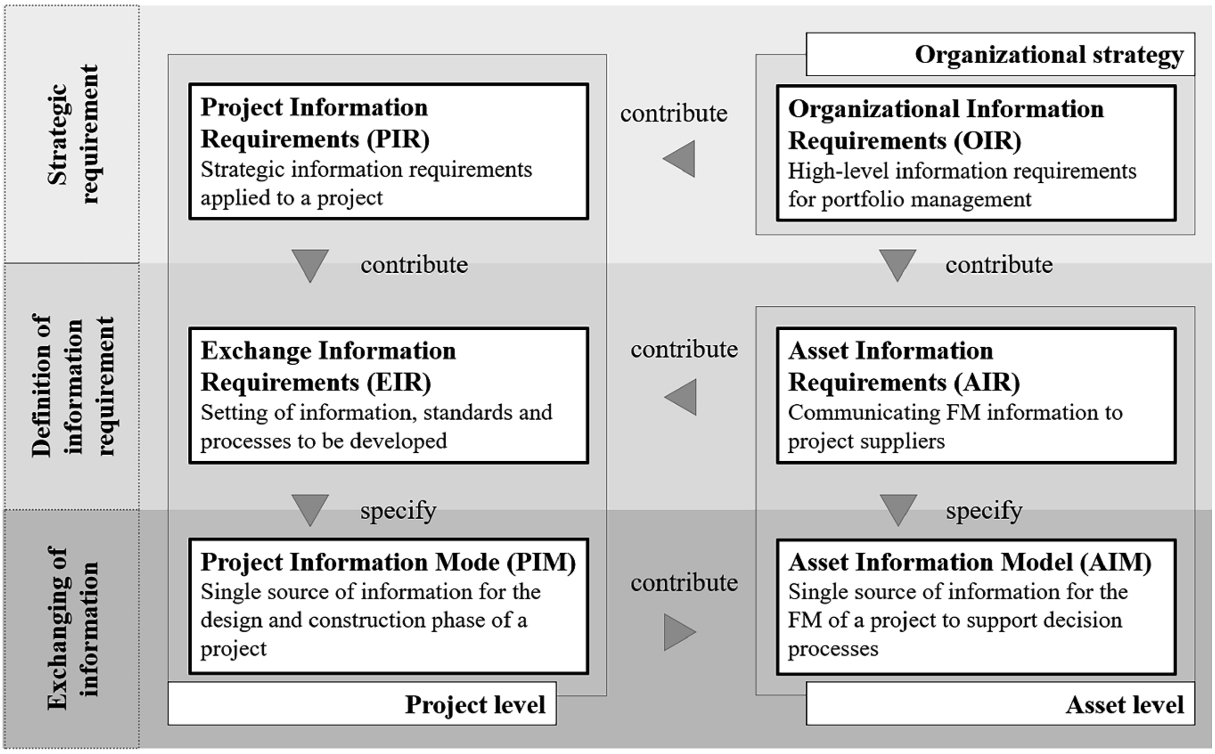


Figure 5: Information workflow for Asset Information Model (Daniotti et al. 2020)

According to figure 5 to get the necessary information for the Asset information Model the details requirement should be included in the very early phase of the project, eventually in the starting of the project during the design and construction phase. Moreover, the standard, format, classification and data interpretability requirements need to be identified during the project modelling stage. Otherwise, Asset Information Modelling can be a time-consuming and challenging task for the asset management authority.

2.4 Current technologies in FM and AM

The operational phase of the built asset is the service period of the building and infrastructure, in this phase, the built asset serves the purpose for what it is built. The operational phase of the built asset is longer than the planning and construction phase and is responsible for the maximum part of the cost of the whole life cycle of the built asset. In common practice, Facility Management (FM) is responsible for maintaining all facilities of the built asset according to need through day to day operational function, performing necessary maintenance and modification. Asset management is responsible for preparing all strategies related to the asset, such as improving the effective uses of the asset, improving the process, increasing the asset value, and confirming the ultimate utilization of the asset.

According to International Facility Management Association (IFAM), Facility Management (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' (IFAM 2021). ISO 41011:2017 stated facility management as an 'organizational function which integrates people, place and process within the built environment to improve the quality of life of people and the productivity of the core businesses' (ISO 41011:2017, Facility management 2017). Both definitions of facility management by the IFAM and ISO refer that the FM task is multi-disciplinary and ensures all facilities create a suitable environment for the occupants. Moreover, facility management is responsible for improving the productivity of the core business.

Paper based and excel based facility management is still in practice but the improvement of information technology has been rapidly changed the scenario of the facility management system. According to Cheng et al. 2020, spread sheet and the paper document is still used as an approach to information exchange in current facility management practice that make considerable delay to make the work order and other steps (Cheng et al. 2020).

CMMS (Computerized Maintenance Management System) and CAD (Computer-aided design) has been serving as facility management technology since long time latter CAFM (Computer-aided Facility Management) and other technology took part in market (Knudson and Janus, 2017). Currently common used technology in facility management are CMMS (Computerized Maintenance Management System), CAFM (Computer-aided Facility Management), EMS (Energy management system), BMS (Building Management system) and Building Automation System. BIM (Building information modelling).

2.4.1 Computerised Maintenance Management System (CMMS):

CMMS(Computerised Maintenance Management System) can be described as software consisting centralized maintenance information and process for maintenance operation, it help to maximize the utilization of physical asset such as infrastructure, machinery, vehicles and other equipment. Star of CMMS was first appear in 1960s and only used by large enterprise. In 1960s technician used punch card and IBM information for tracking the maintenance information. The use CMMS was started to popular in 1980s when computer reduced in size and became affordable. In 2000s CMMS was expended as the internet and web-based connectivity was introduced widely though in 1990s CMMS started to share information through local area networks. The current version of CMMS is mostly cloud base and facilitate huge functionality with rapid implementation, easy maintenance tracking and security option. (IBM 2021).

CMMS is an integrated software that store the information and help to maintain process that required in a maintenance facility such maintenance schedule, work order management. CMMS is a system of comprehensive software that able to manage the maintenance of huge range of equipment and asset (Mohanta 2016). CMMS is of most used computer-aided maintenance management system that contain information related to maintenance and help to manage maintenance activity of facility (Lopez et al. 2017). CMMMS normally have different module such as Asset registry, work order management, preventive maintenance.

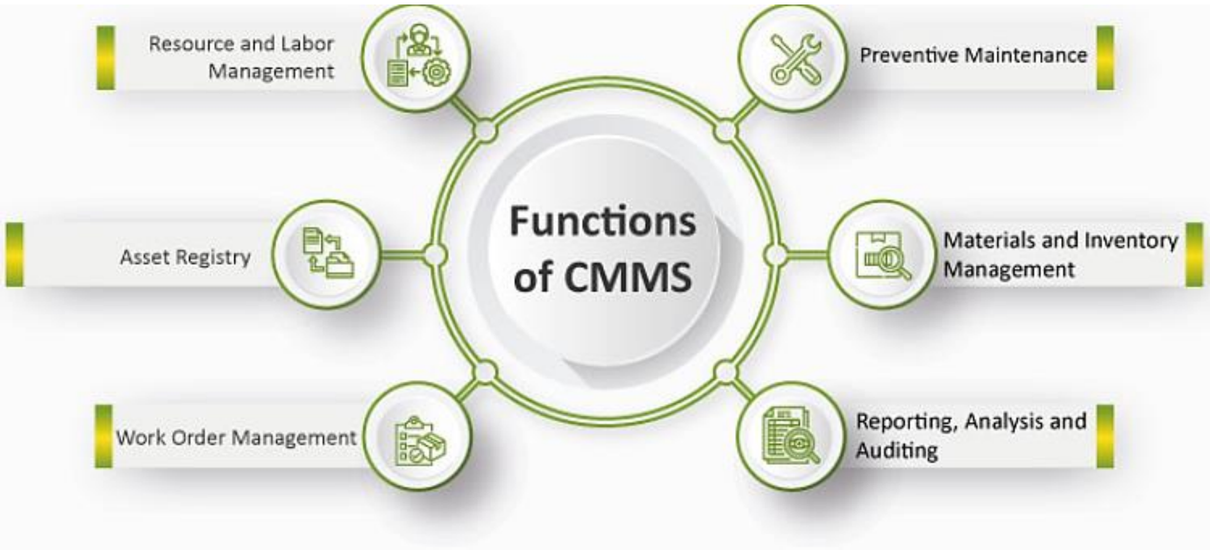


Figure 6: Different modules of CMMS. (Assetinfinity, 2021)

Resource and labour management: This CMMS module keeps record of available resources such as equipment and employee, schedules the shift, and assigns specific tasks to the crew.

Asset registry normally stores information related to an asset such as:

- Asset serial number, model, manufacturer.
- Asset location and position
- Asset related cost details
- Performance data
- Necessary manual and warranty details
- Availability of meters, sensors or other instruments

Work order management: Work order management is considered as one of the main functions of CMMS. Work order management consist following information:

- Work order number, description
- Type of order such as replace or repair
- Cause and remedy codes
- Details information regarding materials and the responsible person

Currently, CMMS system has some other capabilities regarding work order management as follows:

- Automated work order creation
- Reserved necessary materials and equipment against work order

- Schedule shifts for employees and crew and assign work to the personnel
- Review the performance statistic and downtime
- Planning actual cost and record cost-related data for further planning

Preventive maintenance: The preventive maintenance function prepares the schedule for the maintenance work as per requirement based on usage and time duration of usage of different equipment. It also initiates automatic work orders combined with work management functions. Materials and Inventory Management function of the CMMS keep tracing the materials required against maintenance work and make an inventory of the materials storage initiate supply order of materials as per requirement. Moreover, cost information recording for materials is also a part of this function. Reporting, analysis and auditing functions act as report and analysis aid for the CMMS for optimization of the continuous procedure of maintenance and support business decisions by providing a report for asset availability, material usage, the cost for the materials and labour and other reports. (IBM, 2021)

CMMS provides centralized maintenance management that increases asset visibility by gathering all asset information such as purchase information, warranty details, performance status, and efficiency rating in one system. Work visibility makes the maintenance process efficient by preparing the shift schedule and assigning the crew to the specific task. Automation of work order, preventing maintenance schedule, managing information for administrative use make easy them to procedure of maintenance management system and save working out a reduce error. (IBM 2021)

Along with a wide range of benefits, few challenges also involve the implantation Computerised Maintenance Management System. Winker et al. 2016, addressed six main challenges to implement CMMS in any organization as flowing:

i) Implement the CMMS in an organization that is not ready to establish a maintenance management strategy.
ii) Misunderstood the strategy of the CMMS process sometimes it is lead to the poor utilization of the system. In the worst scenario, the CMMS system only use as a work order management system
iii) Lack of adequate IT structure to get the ultimate portfolio implemented CMMS such as proper database server, uninterrupted internet connection.
iv) Failure to present the benefits and effective outputs of CMMS system to the top management is a challenging issue for getting required support.

v) Maintain change management strategies of CMMS system; if the proper tracking of change management cannot be implemented within the CMMS it makes other system functions.

vi) Lack of resources in CMMS system, enough information is prerequisite to implementing the system properly. (Winker et al 2016)

2.4.2 CAFM (Computer-Aided Facility Management)

Computer aided facility management is software system which help management support process of the organization with the enrich information database and graphical representation (Vyskocil,2007). Computer aided facility management was developed gradually science 1980s with the advancement of personal computer (Watson and Watson 2016). Plano software a service provider define CAFM as Computer Aided Facility management is software which allow facility manager to prepare plan, execute the plan and monitor all others activities related with space management or work place management such as maintenance management, utility service management, user service request space reservation management and asset movement (Planosoftware, 2021).

Accordingly to Marchionini et al. 2017 CAFM software some process such as following:

- Space management
- Occupancy management
- Reactive management
- Preventive management
- lease management
- Property management
- Asset management

Additionally CAFM software may has some other support process such as contract management, energy management, access control management of facility (Marchionini et al. 2017)

With CAFM facility manager can identified unnecessary expenditure, optimize the efficiency resource utilization, unprofitable use as facility easily and quickly afterwards finding the solution for problem occurred during operation of various services of facility also possible within minimum time frame and less labour for the facility management

(Vyskocil,2007). Moreover, CAFM helps energy consumption savings by keeping tracking the facility's energy consuming services (Watson and Watson, 2016).

There huge benefits of CAFM system in the operational phase o built asset where some significant benefits which make deference between CAFM and normal maintenance management system is that CAFM make transparency and enough knowledge of necessary spare parts for the relevant service and equipment. This huge transparent information and knowledge make the maintenance management seamless efficient and rapid by reducing repair time, enabling accurate early ordering of necessary spare parts and services. The most important feature of CAFM system that it enable to integrate other service or data base within the system with some standard data format. Through integration of built asset information as computer aided drawing and general information format make the CAFM system as combined system with enrich databased and various functionality. (Poor, 2014)

2.4.3 Integrated workplace management system (IWMS)

Integrated workplace management system is another approach for real estate management in the operational phase some vendors and research article argued that IWMS can perform all the service required for facility management and asset management in one platform. IWMS is IT based technology solution the can help any organization to keep record, measure the asset, and maintain inter-relationship between all type of assets such as built asset, fixed asset, mobile asset (Hanely and Brack, 2016). IWMS. IWMS provide more support process than the traditional computer aided facility management system and according its complexity it is recommended for those organization that required to manage large real estate facility (Maslesa and Jensen, 2019).

Table 2: IWMS and CAFM comparison (Plano, 2021)

IWMS	versus	CAFM
✓	Space Management	✓
✓	Facility Management	✓
✓	Maintenance Management	✓
✓	Real Estate and Lease Management	
✓	Project Management	
✓	Environmental Sustainability	

Real estate cost a huge part of operational cost for any organization normally it can be more than 20% of an organizational cost. IWMSs software can reduce the real estate and facility cost significantly and improve the business productivity at the same time. According to research and market states IWMS can minimize the real estate and facility management cost up to 14%, increase the facility usage efficiency up to 42%. (Plano, 2021)

Some other theology or approaches also used in operational phase of built asset management to manage the facility. Building management system (BMS), Energy management system (EMS) Building automation System. BIM also a technology that directly or indirectly being adapted in facility management system or in the operational management system

2.5 Impact of BIM in Operational Phase of Built Asset

PwC is an international service network that considerer the 2nd most extensive service network in the world. PwC has been involved with the Centre for Digital BUILT Britain and is responsible for creating an evaluation process to measure the economic value generated through BIM. PwC assessed two UK government projects to find out the benefits of BIM where they showed that BIM could save 3% of the total life cycle cost of built asset/project, 70% of that 3% is in the operational phase. However, in actual practice use of BIM in the operational phase is still overlooked in most cases (Ashar 2019).

According to Carbonari et al. 2018, though the creation of Building Model Information for the existing building is a challenging issue, the potential of BIM in the operational phase of building is considered significant. BIM is a unique source of information that information can be used for different kinds of service management during building operation such as:

- Spatial information of all building components
- Real-time data access facility of the built asset
- Creating a digital representation of the built asset
- Visualising facility for marketing purpose
- Maintainability checking
- Space facility management
- Emergency service management
- Studying, analysing and planning for noncapital construction.
- Energy consumption monitoring and controlling. (Carbonari et al. 2018)

Broadbent 2016, presented a BIM use case analysis on how can BIM save working hours in facility management. There is a considerable cost-benefit of adaption BIM in the operational phase of the building asset.

Table 3 : Pre BIM and Post BIM hour requirement for some FM tasks in a use case. (Broadbent 2016)

Pre-Post BIM Analysis

Example	Baseline Hours W/O BIM	Hours With BIM	Net Savings
1 : Plumbing leak	2.5 Hours	0.75 Hours	1.75 Hours
2: Shutdown Request	56 Hours	16 Hours	40 Hours
3: Structural and Fire Safety Analysis	3 Hours	0.5 Hours	2.5 Hours
4: Integrated Finish Schedule	160 Hours	32 Hours	128 Hours
5: Engineering Staff Training	200 Hours	22 Hours	178 Hours
6: Asset Information Entry and Update	1640 Hours	24 Hours	1616 Hours

Wills et al. 2018, represented a list of interfaces between BIM and FM-relevant BIM application and sustainable facility management. A scoring also made in this interface issues according to BIM application practicability accordance for facility management. GEFMA 160 standard was used as the base to make a list interface between BIM and FM-relevant BIM applications. (Wills et al.2018)

All interfaces between BIM and FM-relevant applications for sustainable facility management are rated with four categories: ‘Non-accordance’ refers to that inability to interact with sustainable facility management criteria and ‘Less accordance’ indicates very minimum capability to implement the BIM application in this issue of facility management. Furthermore, rest two criteria are ‘Average to moderate accordance, those items in which BIM applications implementation possible are rated in this categories, and the last one ‘High accordance’ rated for those issues where BIM application already used. (Wills et al.,2018)

Table 4: Visualization of interfaces between BIM applications and FM guideline GEFMA 160 (adopted from Wills et al., 2018)

		Data management process and information management process	3D control and planning	Calculation (5D)	Detailed planning	Scheduling (4D)	Building simulation	Visualization (3D)
Ecological quality	Energy management	•••	••	••	•	•	•••	•
	Water management	••		••			•	
	Waste management	••		•			•	•
	Emergency management	••	••				•	
Economical quality	User cost management	•••		•••		•		
Socio-cultural criteria	User satisfaction management	•					••	••
	Fault and complaint management	••			•	•	•	•
	Legal conformity	••					•	•
	Indoor air and drinking water quality management	••		•	•	•	•	••
	Building security management	•••	•	•	•	••	•	•
	Occupational safety management	•					•	•
Facility management organization	Operating strategy	•••	•	•		•	••	•
	Personnel	•		•		•		•
	Procedural organization	••			•	•	•	•
	Documentation and reporting	•••						
	Procurement	•••		••	•		•	•
Facility management service level agreements	Space management	•••	•••	•••	••	••	••	•••
	Operation acc. to DIN 32736	••	••	•	••	•	•	•
	Maintenance acc. to DIN 31051	••	•	•	••	•	•	•
	Projects (modernization/ restoration/conversion)	••	•	•	••	•	•	•
	Cleaning	•••	•	•	•	•	••	•
	Security	•				•		
	Catering	•		•	••	•	•	••
	Outside areas and facilities including winter services	••	•	•••	••	•	••	•

		•	••	•••
Definition	Non-accordance concerning the practicability of BIM applications for sustainable facility management.	Less accordance concerning the practicability of BIM applications for sustainable facility management.	Average to moderate accordance concerning the practicability of BIM applications for sustainable facility management.	High accordance concerning the practicability of BIM applications for sustainable facility management.

According to the result from criteria based categorise of FM-relevant BIM application for sustainable facility management based on 'GEFMA 160' objectives showed that 19.64% of issues in 'Average to Moderate accordance' and 7.74% issue comply with the ‘High accordance category’. Approximately 41.67% of issues show less accordance with FM-relevant BIM application, and 30.95% are considered ‘Non-accordance’ category. According to the category in 69.05% of sustainable facility management issues, FM-relevant BIM application is implementable, where in 27.38%, BIM application integration has a significant positive impact. (Wills et al.2018)

BIM is still mainly used for planning, design, 3D modelling and coordination; additionally, all respondents in the survey agreed that the considerable benefits of using BIM is limited within getting fewer RFIs (request for information), less changing order, better coordination, fewer errors, improvement in the planning, and identify the conflicts earlier. All respondents also agreed that BIM has excellent potential for asset management and facility management. According to the participant in the survey regarding the benefits of BIM, they already experienced the benefits of BIM in construction projects and are concerned about the benefits in the operational phase. The data required in the operational phase is currently added to the BIM execution plan. In some projects, BIM data export to the workplace management system, but other BIM applications for facility management are still in the early stage. (Brunet et al. 2018)

Table 5: BIM adaption scenario in Quebec, Canada (Brunet et al. 2018)

Main benefits of BIM for AM according to respondents	Capacity to re-use data in many systems Access to an inventory (register) of high quality for the equipment Improvement of the productivity as data are easier to find
Status of BIM in organization	All organizations have a BIM manager and a BIM execution plan; BIM is required for all new projects Not one organization has a method in place to calculate the return on investment on the use of BIM
BIM uses currently done for the projects	Planning The design reviews Production of BIM models 3D coordination
Current efficiency gains with BIM use	Fewer RFIs (requests for information), fewer change orders and fewer errors Better coordination in the sequencing of construction Improved project planning Decrease of rework Detection of pre-construction conflicts BIM helped react to changes during the design and construction
Steps taken to implement BIM	Investigate on the cost of adopting BIM Investigate on software that support BIM Evaluate the legal aspects of BIM practice
Most important factors for the success of BIM implementation	The involvement of senior management The attitude of employees towards changes
Most important barriers to BIM adoption	Ignorance of BIM benefits for the organization Lack of qualified staff Lack of BIM training Culture change towards work focused on collaboration Software immaturity in terms of data exchange and interoperability

The Nagpur Metro rail project owned by Maharashtra Metro Rail Corporation Ltd presented an estimated cost saving by adopting the BIM process for the operational phase. The estimation predicts that BIM adaption will reduce approximately 20% manpower cost in the operational phase of the project and 15% increase of information reliability and availability of information through the whole project lifecycle. (Bentley,. 2021)

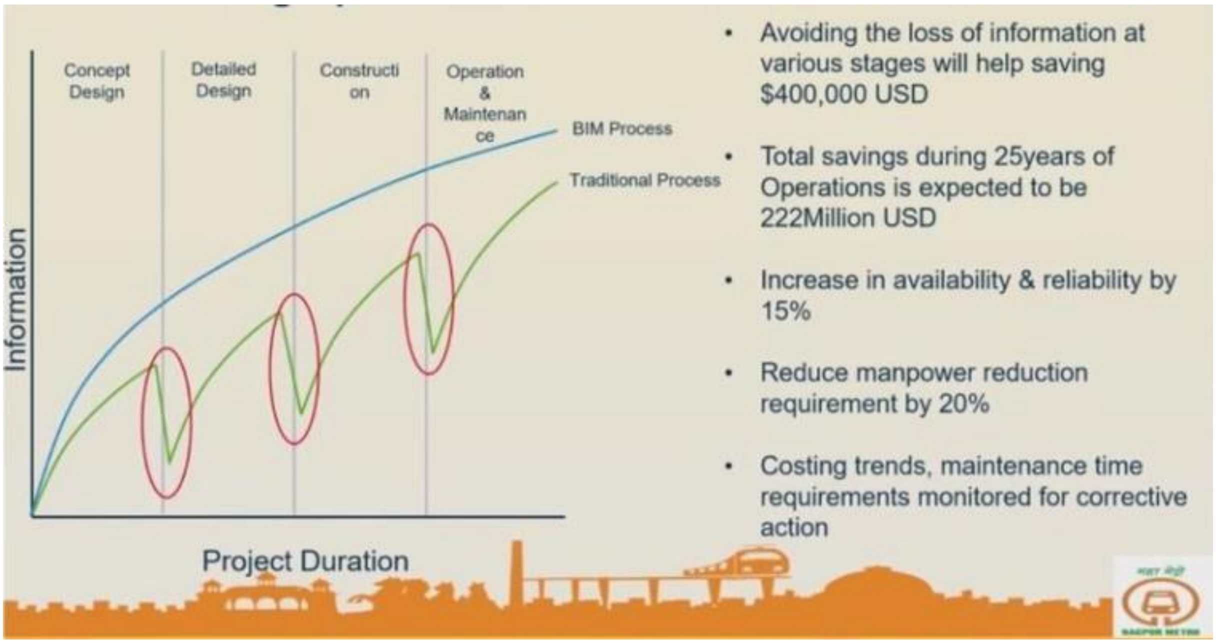


Figure 7: Cost saving projection in Nagpur metro rail project by BIM adoption for Asset Management (Bentley, 2021)

BIM has significant potential to be integrated into the operational phase of a built asset and improve the asset management system and facility management system. BIM integration also reduces the project operational lifecycle cost of the built asset. Zeiss 2019, found that BIM can save 5% operational cost of built assets annually after analysing the use case (Zeiss 2019). BIM is a source of information where all geometric and non-geometric information of built assets can be stored in an organized system used in operational phase real estate or infrastructure facility, but correct information and data interpretability are necessary. BIM adaption has a great positive impact in the operational phase, but the required level of data availability in the right format is a prerequisite.

Chapter 3

Co-working Service

3 Co-working Service

3.1 Co-working service facility

The co-working service facility refers to those organizations where more than one group works together in a built environment. A wide range of institutes implemented the co-working service strategy in their organization directly or indirectly. The co-working term is becoming popular in the business sector, government service sector, and educational institutes. Many business organizations are moving forward to the co-working service approach and accordingly changes their real estate facility to provide a co-working space facility. Many experts recommend that the co-working approach increases the productivity of the participant and help to share knowledge to each other, which positively impacts the problem-solving approach of the participant.

The educational institute is a good example where the co-working services approach is applied normally. In an educational institute, at least two major groups work together to achieve the goal; those two major groups are students and faculty members. The co-working approach is widely accepted as a great strategy for flexible working facilities and knowledge exchange (Orel and Bennis, 2020). In real practice, there are many more groups working together in an educational institutes such as different business and research institutes work closely with universities combining with the faculty and students. Different events such as conferences and career development programmes are held in university where various groups work together with co-working service approach indirectly.

Co-working service and co-working space facilities are described much more in the business organization than the educational organization. There is very limited systematic research done on how co-working space and other open collaborative workspace adoption effect. Some passive discussion happened how co-working approach impact in the office and the meeting space of educational institute in industry and academia where the expansion of co-working approach is mentioned as effective in the educational domain as a business domain. (Orel and Bennis, 2020)

3.2 Co-working office Space and its market growth.

A co-working space can be defined as a place where a group of individuals more or less from various backgrounds work in the same work environment (Jylhä et al, 2015). Though the co-working approach is practised in several sectors such as commercial co-working space, office places, government service sector, and the educational sector, only commercial co-working space is commonly discussed. There is a significant growth of commercial co-working space all over the world.

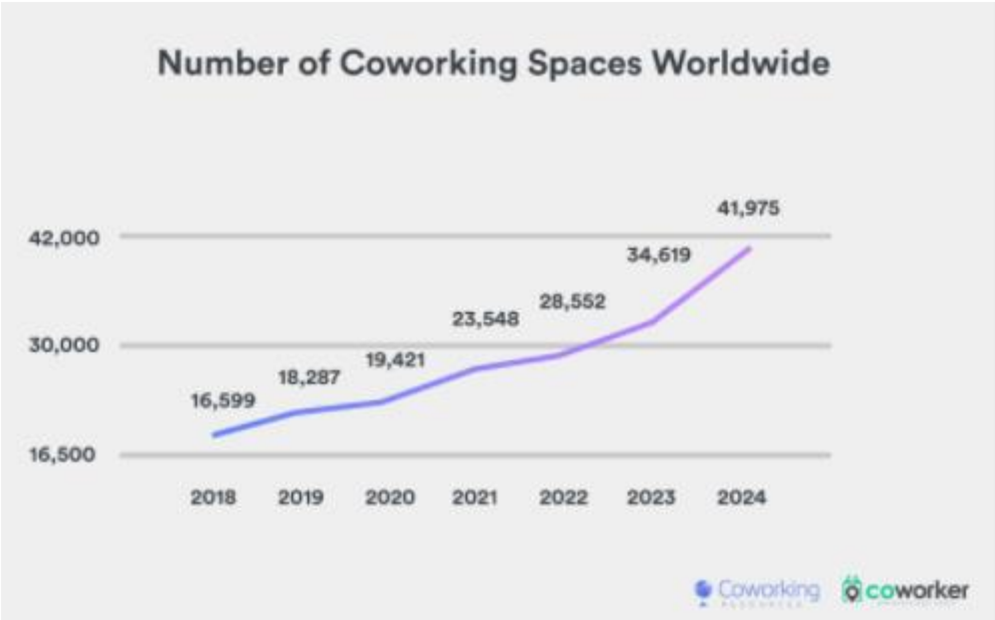


Figure 8: Estimated number of co-working spaces all over the world. (Risio, 2020)

A survey research on the co-working space market in 2020, conducted by 'Co-working Resources, predicted that there would be a rapid market growth of co-working space with an average 21.3% increase rate for the next few years. The projected number of co-working spaces will cross 40,000 by 2024. The market insight analysis of the survey represents that 32% of current co-working space operators want to open at least one new location within 2020 where 38% of operators plan to open 2-3 new locations within 2020. (Risio, 2020)

Figure 9: Future plan of current co-working space operators to expand their business.(Risio, 2020)

Corona pandemic makes bit slower the expected growth rate of co-working space. The demand also fall down at the end of 2019 and starting of the year 2020 but the recovery rate of the search result from google trend indicates that after the corona pandemic, the demand will recover rapidly.

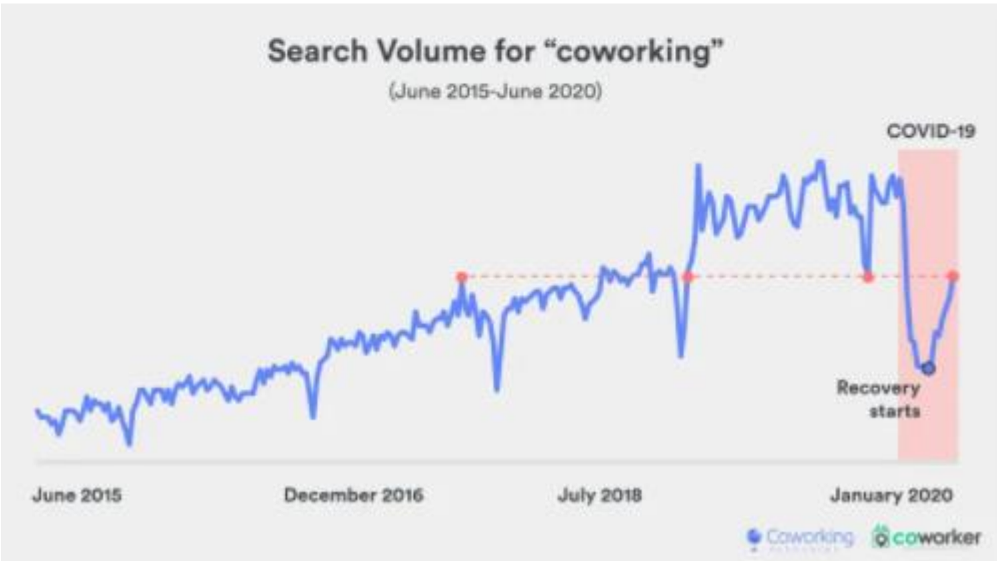


Figure 10: Online search volume of co-working space. (Risio, 2020)

According to the survey report by Coworking Resource, the United States is still in the top position by holding more than 3700 co-working places and holding 18.30% of the world market share. Where India in the second position, followed by the United kingdom, having 2197 and 1044 number of working space and 10,69% and 5,08% world market share accordingly. (Risio, 2020)

Table 6: Monthly desk price of Co-working space. (Risio, 2020)

Hot Desk Monthly Price by Region

Region	2018	2019	2020	Year/Year Change
Africa	$112	$116	$110	▼ -2%
Asia	$160	$149	$148	▼ -0.7%
Europe	$188	$206	$210	▲ +2%
Oceania	$347	$273	$262	▼ -4%
North America	$268	$243	$243	-
Central America	$163	$180	$176	▼ -2%
South America	$197	$141	$132	▼ -6%

Monthly desk prise in co-working space is changed compared to previous year all over the world except Europe zone. Both market growth and price reduction are happening simultaneously in the co-working space market, indicating that the approach co-working space is coming into the mainstream of the commercial office space market and taking part in the real estate business. (Risio, 2020)

3.3 Challenges of Co-working Service Management

Co-working services have a wide range of benefits in improving the working environment, reducing per person space cost for office management, great approach to exchange knowledge, and increasing participant productivity. However, service management in a co-working facility is challenging and complex whatever it is a commercial co-working place or government service or educational institute.

Commercial co-working space has some typical challenges that make the discomfort of the user such as distraction, lack of privacy, and inefficient equipment. A survey was conducted by a consulting firm on the co-working office space users group. The survey found 6 significant challenges in the co-working space (Herhold, 2020).

Top 6 Challenges of Coworking Spaces

1. Distractions and noise (48%)
2. Lack of privacy (48%)
3. Limited space (39%)
4. Insufficient equipment (31%)
5. Inability to personalize workspace (31%)
6. Security/safety issues (23%)

Figure 11: Challenges in co-working place user perspective (Herhold, 2020)

The challenges in co-working service management is referred to the facility management challenges. The co-working space approach is rapidly becoming one of the mainstream sectors of the real estate business. Therefore, service management challenges in co-working spaces are a critical issues for facility management personnel.

Co-working service facility have to ensure all facilities in their entity such as the good work environment, occupants comfort ensuring through proper utility service such HVAC system, air quality, good enough light system and cleanness and healthy environment. Additionally, some co-working spaces have more additional facility food & cafeteria service, day care service for child, sleeping pods and entertainment zone. The typical and additional service manager in a co-working facility is challenging compared to traditional office space or single company facility management as the occupant or user group are different and their expectation verity makes complexity. User have directly influenced the success of the co-working space business. After math, a service management strategy is an important issue, and challenging for the service management in a co-working service facility that ensures user satisfaction and service provider satisfaction. Facilitating all services required in a co-working entity with optimum maintenance and operation cost is a major concerning issue for the owner, operator, or responsible organization of the co-working facility entity. (STRACHAN and HIND, 2021; Kumar, 2021)

The co-working working space facility is already proven its acceptance now the responsibly on the FMs how this kind of facility with proper environment ensuring all services required for an appropriate workplace. FMs need to consider some factor to meet the ultimate satisfaction in those kinds of services such as occupational comfort, health safety, technology requirement, indoor environment, special needs of user, and ensure that work is productive and stimulating user creativity. In the co-working space approach, FMs/service management departments need to be more service-oriented and customer-centric. In this kind of service have to deal with directly customers Where FMs or service management departments mostly deal with top management in the conventional real estate or office management. (STRACHAN and HIND, 2021; Kumar, 2021)

3.4 BIM in Co-working Space Management

BIM is considered as a repository of built asset information having both geometric and non-geometric data. BIM adaption in the operational phase of built assets is already in practice. BIM integration in facility management is proven beneficial in the long term. Moreover, Integrated Workplace Management System required more efficient facility management strategies where co-working service demand is little more complex compere to traditional work space management. To develop an efficient facility management system for co-working place needs all information regarding asset and those data should be interpretable to require management system.

In a co-working service, user comfortability maintaining is one of the essential issues; energy consumption monitoring is also important. To create a healthy, comfortable working condition in the workplace, observing real-time data and immediate necessary action for required corrective or maintenance is crucial. The various studies already showed that BIM can be utilized in various ways in the operational phase of building.

BIM and IoT integration offer huge opportunities to provide the implementable framework that can be applied in the built asset management, such as real-time building performance monitoring, enabling customer-centric automated utility services, automatic notification for required services to the facility managers.

Chapter 4

BIM in Co-Working Service Management

4 BIM in Co-Working Service Management

4.1 BIM for Improving the Space Utilisation

Efficient use of space is a concerning issue for any organisation. Space management is considered as part and parcel of facility management by many expertise. Ultimate space utilisation can save many expenses for commercial space, office space, hospital space, and educational institutes. Efficient use of space minimises the required area and space-related costs such as space rent, operational cost, and maintenance cost (Cooper et al., 2017). Effective space utilisation optimises the physical use of space and related assets; moreover, effective space management positively impacts people who work in this space and increases productivity (Steiner 2006). Research conducted in Politecnico di Milano, Italy, found that space utilisation is considered the eighth important KPI among 33 key performance indicators for workplace management (Tagliaro 2018)

4.1.1 Challenges in space management

Ultimate space utilisation is a challenging task for any organisation. Several constraints need to be considered in space management lack of information for prediction the space types, usage frequency occupancy rate of activity (Abdul Rahman, 2012).

Frequency and occupancy rate are essential for space management, but occupancy rate is challenging work compared to calculating frequency rate for a specific space. Additionally, the space occupied time and occupancy size are also essential issues for a good working environment. Collecting all information such as the number of occupant, time duration, and frequency is difficult for the space management personals to optimise. Fulfil demands for all kinds of occupants also make space management complex as different people satisfy with different layouts and interiors. Lack of enough study on space management is also a constraint to make good space planning in working place as the previous study help as a guideline for the space planning. (Saaid et al. 2018)

4.1.2 BIM in Space management

BIM consist of all information of the built asset, such as graphical information and non-graphical information that makes BIM the primary source of information for the operational phase of the asset. The non-graphical information and the graphic model (3D model) provide the facility mangers/ asset managers with an intensive understanding of the built asset details with clear visualisation, including necessary information (Hu et al. 2018).

Diakité and Zlatanova (2017) showed how the BIM model can be used in space management. Diakité and Zlatanova used BIM to prepare the Flexible Space Subdivision framework (FSS). Diakite and Zlatanova described how navigable space can be determined from an accurate 3d model considering the moving object and the fixed object, including furniture and other objects such as light Air-conditioned unit. The accurate open space calculation and navigation path designing provide opportunities to the facility managers to make possible the ultimate usage of space. BIM model is used as the main platform to perform the analysis of the flexible space and navigation path findings (Dialkite and Zlatanova 2017)

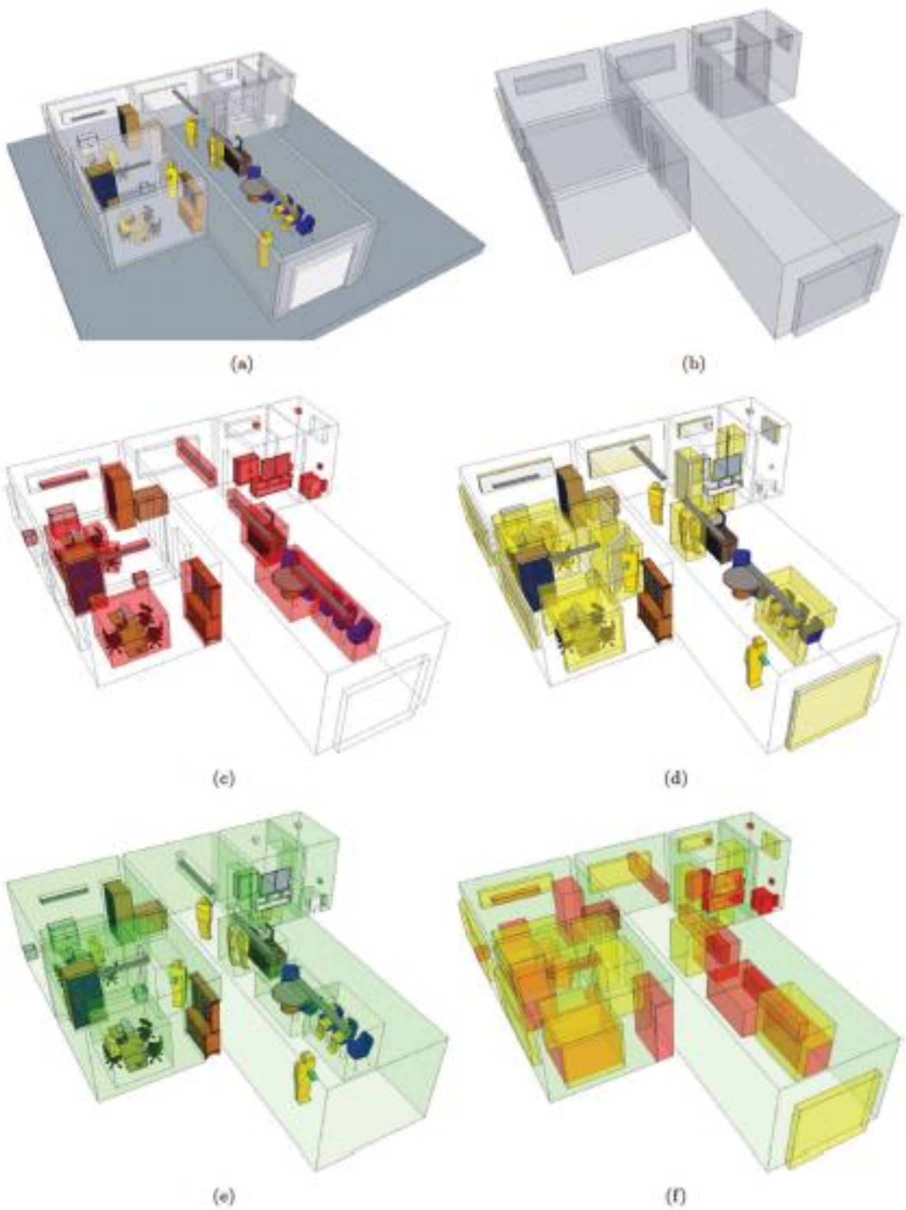


Figure 12: BIM Model used in Flexible Space Subdivision framework (Diakité and Zlatanova 2017)

Grani (2015) mentioned in his article how BIM can help the facility managers in space management in a simple way. Space management is an important task for the facility managers; space needs and space usage are usually dynamic and being changed according to the organisational requirements. All data relating to the space such as location, area and aggregation are essential for trend analysis, portfolio reporting, contract management, energy efficiency process and other services. BIM has both 3d views of the model and the 2d floor plan with filter options including all information required in space management. Moreover, BIM supported space management system combined the geometric and spatial information of models to the asset register information, tenant register and other performance data that help to improve space utilisation.(Grani 2015)

Grani (2015) provides two simple examples of using BIM in space management. Generation and representing the space type from BIM:

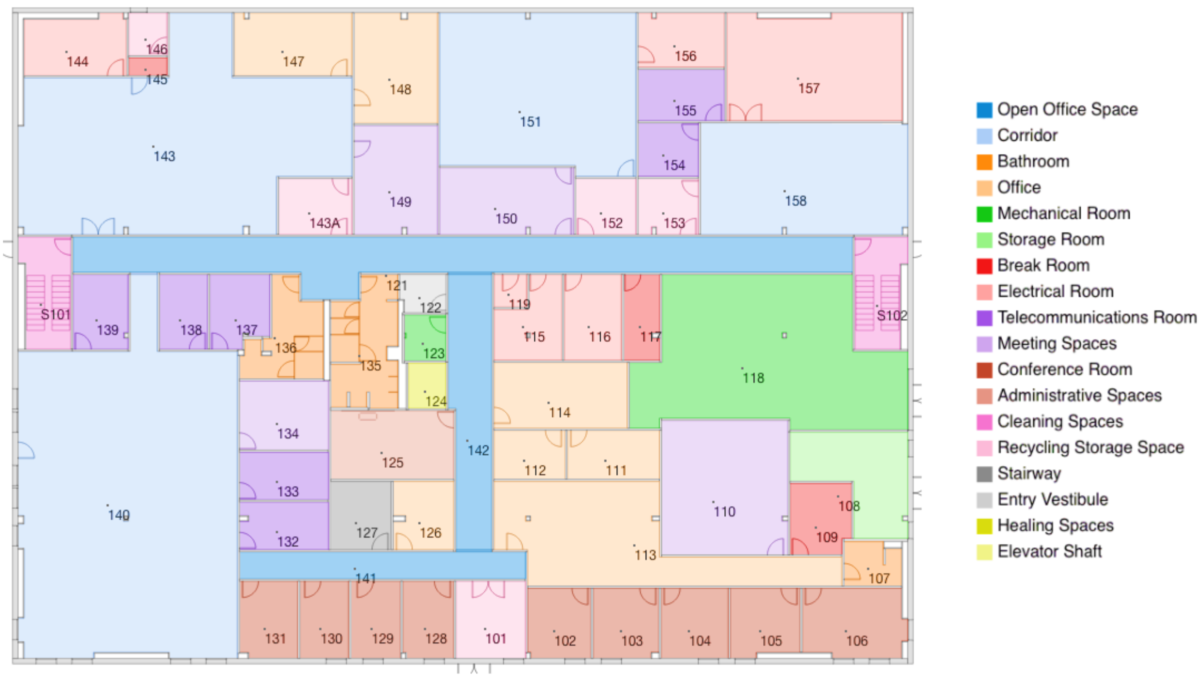


Figure 13: marking of floor space according to types in BIm. (Grani 2017)

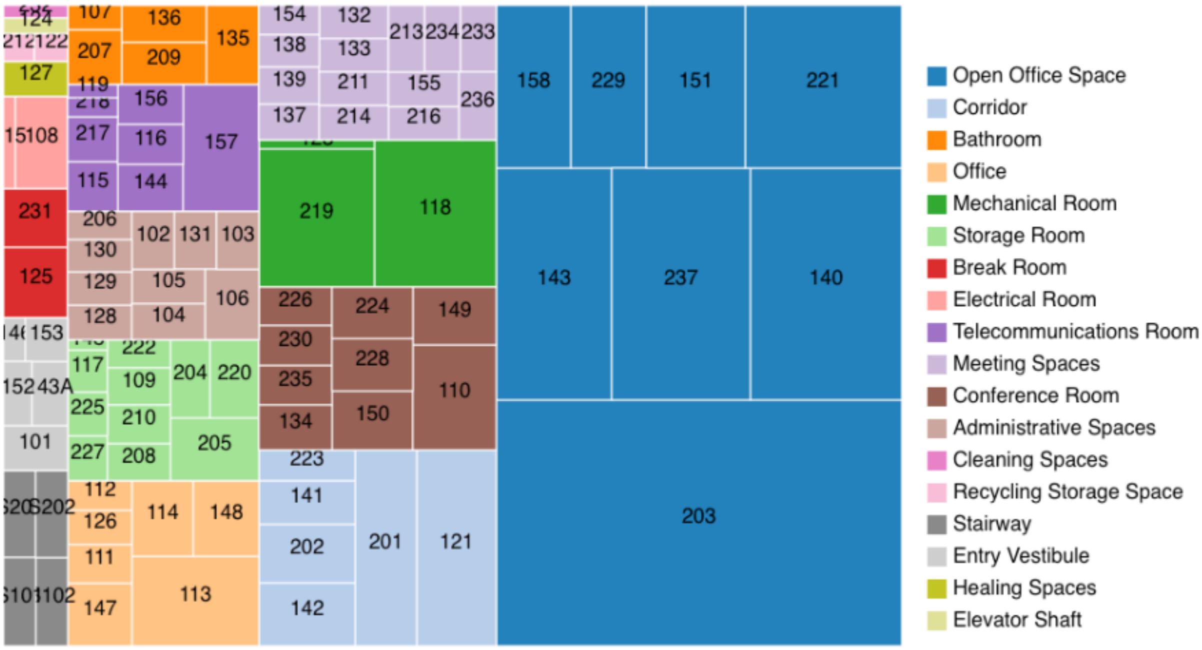


Figure 14: Representing total building space according to types as treemap by BIM (Grani 2015).

MA et al. (2019) developed a BIM-based space management system that can prove advantages over traditional space management tools. Detailed information on the indoor environment was provide by the visualisation operation in BIM. BIM and Space Usage Analysis method was combined to check the current building usage and plan user demands within available space. A BIM-based automatic indoor grid map generation system also helps space management. An advanced development was performed for more relevant data extraction that helps BIM-based space allocation and visual management of indoor navigation. (MA et al. 2019)

4.2 BIM in indoor environment monitoring of Co-Working Space

User comfort is an important issue for all built environments, such as residential building commercial entities or office space. In the workplace, user comfort level directly affects the productivity of the occupant. The productivity of occupants depends on the indoor environment, where indoor thermal comfort is a critical fact; occupants perception and performance normally increase to the ultimate level if the place is thermally comfortable(Kükrer and Eskin 2021).

4.2.1 Importance of indoor comfort in working place

A survey study on 34,000 occupants in 215 office buildings of United States of America, Canada and Finland showed that only 11 % of building archived recommended 80% occupants satisfaction regarding indoor thermal comfort and 26% of building able to managed 80% or above occupants satisfaction in indoor air quality section (Huizenga et al. 2016). Several attributes considerably impact the thermal comfort sensation in an indoor environment, such as temperature, air humidity, mean radiant temperature, air circulation, and occupants' activity (Yu et al. 2009). In addition, the ventilation system of space aims to confirm the required air circulation to all occupied areas to avoid contamination (Kabrein et al., 2017).

The sound level and noise have a significant impact on occupant working potentiality, behaviour, performance, so the autistic comfort of the office is also an essential issue for a good working environment (Chen et al. 2019). The Comfort level of the workplace depends on the combination of some factors such as daylighting, indoor electric lighting, temperature, accosting condition, and indoor environmental quality (Paradis 2016). A research study at Harvard University titled 'Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments 'found that CO_2 level affects significantly the occupant cognitive function such that cognitive function decrease 30-40% when CO2 level increase 500 ppm to 1000 ppm and cognitive function decrease almost up to 60% decrease when the CO2 level reach close to 1500 ppm (Allen 2015).

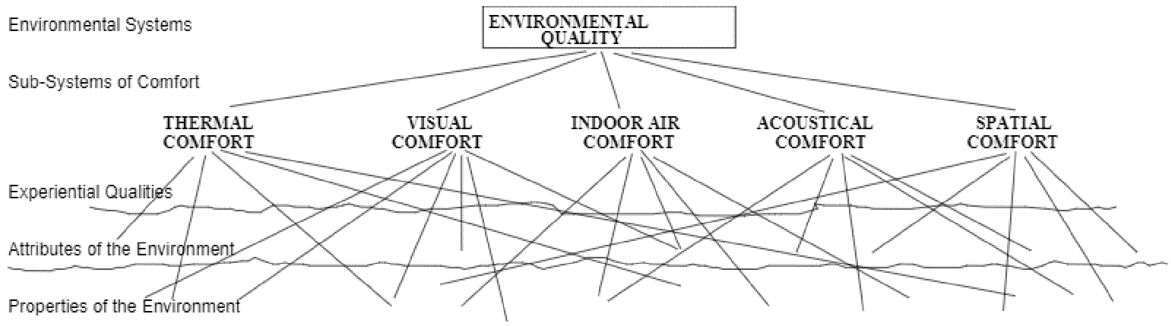


Figure 15: A semi-graphical representation of the relationship of the different parameters in indoor comfort. (Elzeyadi 2002)

User comfort is a prerequisite for any workplace. In a co-working space, it is more challenging to maintain a stimulus condition for the occupant's high level of cognitive function because of the huge variety of occupants, individual or group. Different kind of expectations from the user may makes complex the facility manager jobs in a co-working place. Achieving user satisfaction with good service is an important issue a challenging part of the co-working service. Nowadays the vast improvement of information technology makes possible and essay to real-time building performance evaluation and take necessary step for required service with the help of IoT (Internet of things) and AI(Artificial intelligence) in building operation system (Kumar 2019).

4.2.2 BIM Integration in User comfort monitoring of working space

BIM (Building information modelling) has great potential to be platform to monitor the building performance with others having built asset information and the geometric model. The innovative built environment technology includes built spaces with the smart object like sensors, meters in a building management system to improve the building efficiency, building security improvement, monitoring occupants comfort where BIM is being used as a platform with other necessary software with the help of API (Application Programming Interface) (Zhang et al. 2015).

Several studies have shown how BIM and IoT integration can be applied in the operational phase of built environment performance monitoring and providing real-time services. Zahid et al. 2021 showed a BIM and IoT integrated approach for indoor thermal comfort optimisation in their study titled 'Dynamic Predicted Mean Vote: An IoT-BIM integrated approach for indoor thermal comfort optimisation'. Desogus et al. made 'a study titled 'BIM and IoT Sensors Integration: A Framework for Consumption and Indoor Conditions Data Monitoring of Existing Buildings' where researcher represents and integration of low-cost IoT sensor and BIM model (Revit model) by Dynamo script to monitoring the indoor environment of build asset such as temperature, humidity, air quality. 'Development of an IoT and BIM-based automated alert system for thermal comfort monitoring in buildings' a study conducted by Valinejadshoubi et al. 2021 represented an instigated process to monitor the indoor environment condition of build asset moreover an automatic alarming system depends on indoor conditions through the wireless connected device to the system.Kazado et al, 2019 proposed a framework where BIM (revit models) and sensor integration provide indoor temperature and CO2 concentration within BIM model (Kazado et al., 2019).

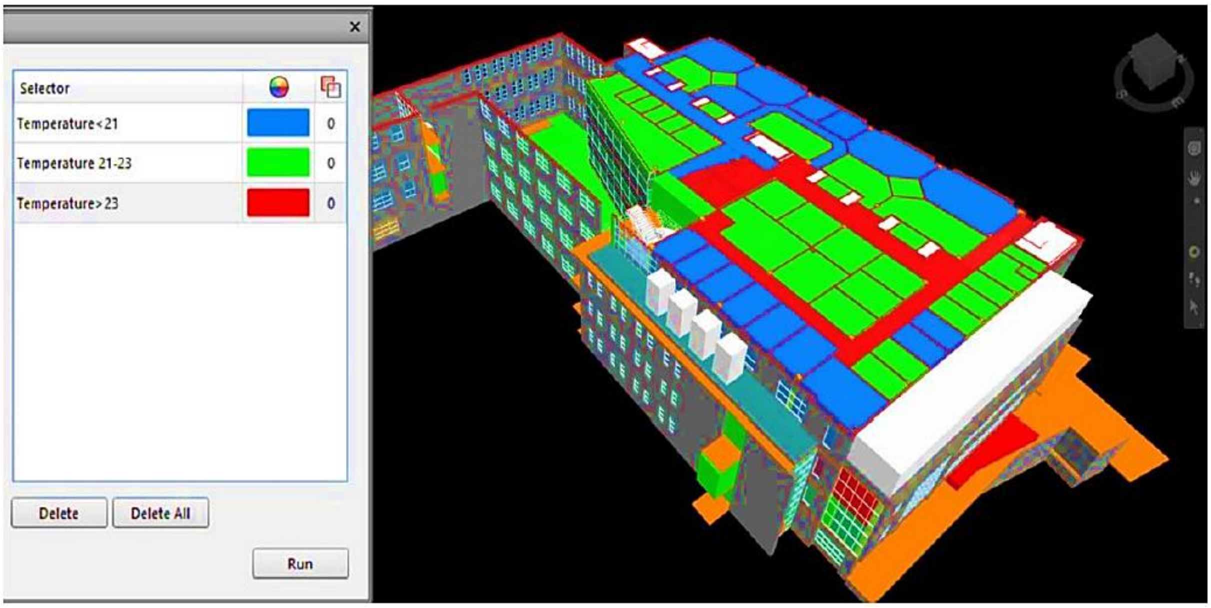


Figure 16: Temperature data visualization in BIM model with colour code (Kazado et al., 2019)

4.3 Automated Utility Service and BIM

Automated utility services such as heating or cooling adjustment, light intensity or visual comfort in a co-working place can be an effective solution for occupants comfort. As in co-working service places participants, verity is more than any traditional office, and the demand may be different from different occupants where service according to the occupant's requirement is complex. Automated service according to the occupants pre-suggestion or depend on real-time feedback can rocket up the customer satisfaction a co-working service place.

4.3.1 Capacity of BIM in utility service automation in the built environment

Dave et al. 2018 represent an IoT and BIM integration framework where built environment monitoring and space booking services are shown as implemented services with a suggestion that different kinds of other services can be integrated in this service with developing APIs for integration. Two functions are controlling of HVAC system option was integrated within the space booking app. Occupants can control the booked space's temperature with three different options such as Colder, Auto, Warmer. Occupants also control the ventilation system with two different options, such as Auto or Boost. As the occupants can control the HVAC system to get their desired environment, this integration provides lots of benefits such as ultimate user satisfaction, saving any additional person to the requirement of occupants, instant service avoiding all complexity. So this automated utility service option reduces cost, improves user comfort, and speeds up the service delivery time. (Dave et al. 2018).

4.4 Potential of BIM for Improving the Energy Consumption of Working Space

Energy consumption cost is a huge proportion of building operational cost. Energy consumption is directly impacting the sustainably of the building and as well as to nature. Building operation is responsible for consuming the one-third of total energy consumption of the world (Pan and Garmston, 2012). Energy costs can be up to 40% of the total building operational cost (Farrimond, 2021). According to L. Chena and W. Pana 2015, the balding sector is responsible for 40% of energy consumption, so it is a great area of concern to reduce the energy consumption in this sector.

4.4.1 BIM integration in operational phase for energy consumption improvement

BIM has the potential to improve the energy consumption in the built asset. As the different agent occupies the workplace, it is difficult to manage or minimise the energy consumption. BIM can be integrated into energy consumption monitoring with the help of an IoT platform for optimal use of energy. BIM informative model can help the automation of the building system that can reduce the energy consumption with real-time controlling the energy management system through controlling the HVAC system, and lighting system of the built environment. Moreover, BIM already proved its potential in facility management where BIM help to take necessary preventive maintenance according to schedule that prevents the extra losses of energy due to late maintenance or faulty operation of the energy system. Additionally, BIM can significantly impact any energy-related renovation by simulating different implementable scenarios in the working space.

Desogus et al. 2021, proposed a framework with the case study that real-time and historical energy consumption monitoring is possible within BIM model through integration of BIM and IoT sensors. All other indoor condition parameters such as temperature, humidity, light intensity monitoring are also possible in the same framework. The case study showed that corresponding historical data analysis of different indoor parameters and energy consumption of a certain area/room can identify the improper activities or problems of the respective system such as HVAC or the lighting system. Such as if there is no energy consumption against the room lighting system for a few days, it indicates that the room was unoccupied, but energy consumption against the HVAC system happened for the same room during absence of the occupant, which is the waste of energy. In another scenario, light intensity remained almost the same whenever the lighting system consumed energy or not, and the light intensity was not fulfilled the requirement event when the lighting system was switched on and consuming energy that indicated the lighting system of this room was not working properly required maintenance. (Desogus et al. 2021)

Table 7: Framework for monitoring indoor parameters and energy consumption in BIM (Desogus et al., 2021)

Sensors	
Sensors➔Internal format	Level 1
API: Internal format➔IoT platform	Level 2
IoT Platform [Storage and Display]	Level 3
API: IoT Platform➔Dynamo	Level 4
Dynamo	
Revit BIM	

4.4.2 Potential of BIM to improve energy used through simulation process of existing building

Montiel-Santiago et al. 2020 showed with the case study of a hospital building how BIM can play a significant role in making decisions for further steps for reducing energy consumption by simulating different implementable scenarios. Though building sustainability and energy efficiency evaluation in planning and design phase by the use of BIM tools, it is still interesting and less practised field how BIM tools and processes make great potential to improve the energy consumption of the existing buildings. The world's building sector causes 33% energy-related CO2 production and consumes 40% of the energy. BIM can be used to evaluate the building's lighting procedure to improve energy efficiency. Other factors are also examined, such as lighting equipment consumption, occupancy comfort control, daylighting, building orientation, the efficiency of the HVAC system, and the glazed area on the wall. But all factors affecting the energy consumption of the building cannot be modified for an existing building. (Montiel-Santiago et al. 2020)

Revit software was used to create the Architectural model for the building and the Building energy model also developed in Revit software. Finally, simulation and analysis was performed within Revit by the INSIGHT add-on. At first, all possible cases was analgised to get the maximum, minimum, and average building consumption. As the case study building as existing building a final energy consumption building was determined with conceding all current characteristics of the building. After that different scenario with propose modification was analysed with separate factor consideration to count the energy savings respective to the factors. (Montiel-Santiago et al. 2020)

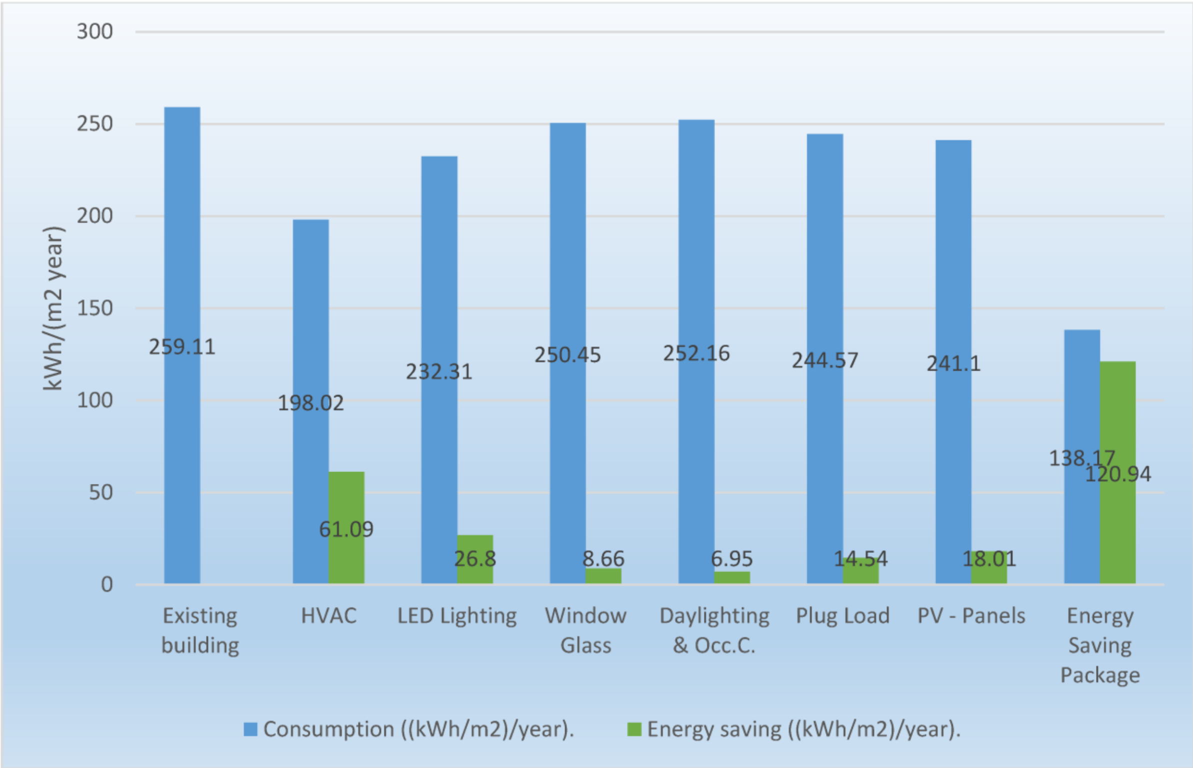


Figure 17: An existing building's energy consumption and energy saving analysis (Montiel-Santiago et al. 2020).

The chart shows that energy consumption can make close to half of current uses if all the considered factors are taken into account. But in an existing building, all modifications may not be possible but considerable energy consumption can be reduced only by modification of HVAC and LED lighting system. Therefore, in this study potential of BIM has been reflected in reducing energy consumption through simulation and analysis. Thus, the capabilities of BIM tools can help reduce the working place energy consumption with necessary modification.

4.5 Interrogation of BIM in Workplace Management System

4.5.1 Workplace management system

Workplace management system or integrated workplace management system is more than computer-aided facility management where space management, energy management, occupants comfort observation, lease management, asset management, and project management are also included with facility management (Sheynkman 2021). Almost all integrated workplace management system services required the use of build asset data in both geometric format and detailed information of asset.

According to the iOFFICE,(a service provider) Integrated Workplace management service provider IWMS have five core components as following:

i) Space management facilities
ii) Maintenance management
iii) Real estate management
iv) Sustainability and energy management
v) Capital project management (iOFFICE, 2021)

Figure 18: Integrated workplace management System. (What is IWSM, 2018)

4.5.2 BIM in workplace management System

The integrated workplace management system is mainly dependent on a computer-aided design system. More specifically, in the space magnet service required, the building model is necessary. So the information from CAD/BIM model can make the process of IWMS service easy by providing geometric information of the spaces such as area, volume, and specs criteria. Through synchronising the database of the integrated workplace management system to the BIM model, graphical visualisation space mapping and other services can be possible. Building Information Modelling (BIM) has also been achieving more attention in this sector as it is a geometric model and a source of information on built assets. BIM potentiality is already proven to reduce the information exchange gap between the construction phase and the operational phase of the building. Some Integrated workplace management systems already support information exchange between BIM and IWSM (What is IWSM, 2018).

Solla et al. 2020 showed how BIM could be integrated into space management in 'ARCHIBUS' (facility management and workplace management service provider). Space management is a core service of the integrated workplace management system. A university campus building was the pilot case in this study. The cases building is the civil and environmental faculty consisting of 11 floors, 840 rooms, and 30755 square meters. Integrating BIM with ARCHIBUS different services related to space management service such as inventory, space performance, occupancy rate analysis, and movement management activation was possible with the help of smart client extension. Furthermore, making the report for the space category with the 2d and 3D presentation was enabled with the system (Solla et al. 2020).

4.6 Advantages of BIM for Marketing and Promoting of Co-Working Space

4.6.1 Potential of BIM to be integrated with the marketing of real estate

Building information modelling is a great resource of any built asset when the BIM model is created to maintain standard procedure. BIM enrich with both geometric and no-geometric information of the asset. The geometric representation can be used for the last end-user for marketing purposes. BIM is the virtual representation of a built asset through which all stakeholders can see the built asset even in the design phase. Pre-occupants building performance evaluation of the built asset can provide a huge advantage for large-scale real estate marketing even in the design phase of the building.

In the end, user-centric real estate marketing can benefit from BIM using the BIM model for marketing purposes. Creating animation from the BIM model and representation for visualisation purposes is a very basic use of BIM for marketing. There are lots more technology or options available in the real estate marketing sector where BIM can be the main resource such as web base portal where users can see the actual model of the asset in details with necessary information and with a different perspective view. Various tools can be integrated with the user interface to evaluate their desire space/ office, shop, apartment with necessary indicators such as measurement options and estimated energy consumption. Realistic visualisation is the most prior issue to satisfy the client. Details information regarding the materials and equipment will add advantages to the marketing strategies.

4.6.2 BIM model integration in the web portal for marketing purpose

Different BIM consultant firms offer a web platform for the real estate owner to represent their built asset through web service. Team CAD is BIM consultant who represents a web base app named 'BIM Real Estate App'. In BIM Real Estate App the BIM model and external data based were integrated or create a web platform where end-users such who buy the property or rent the property/flat can see the model with a different perspective view and some basic information about the built asset. Moreover, there is some extensive option for the user such measuring the tools to get measurement of any object of the model. (BIM Real Estate, 2020)

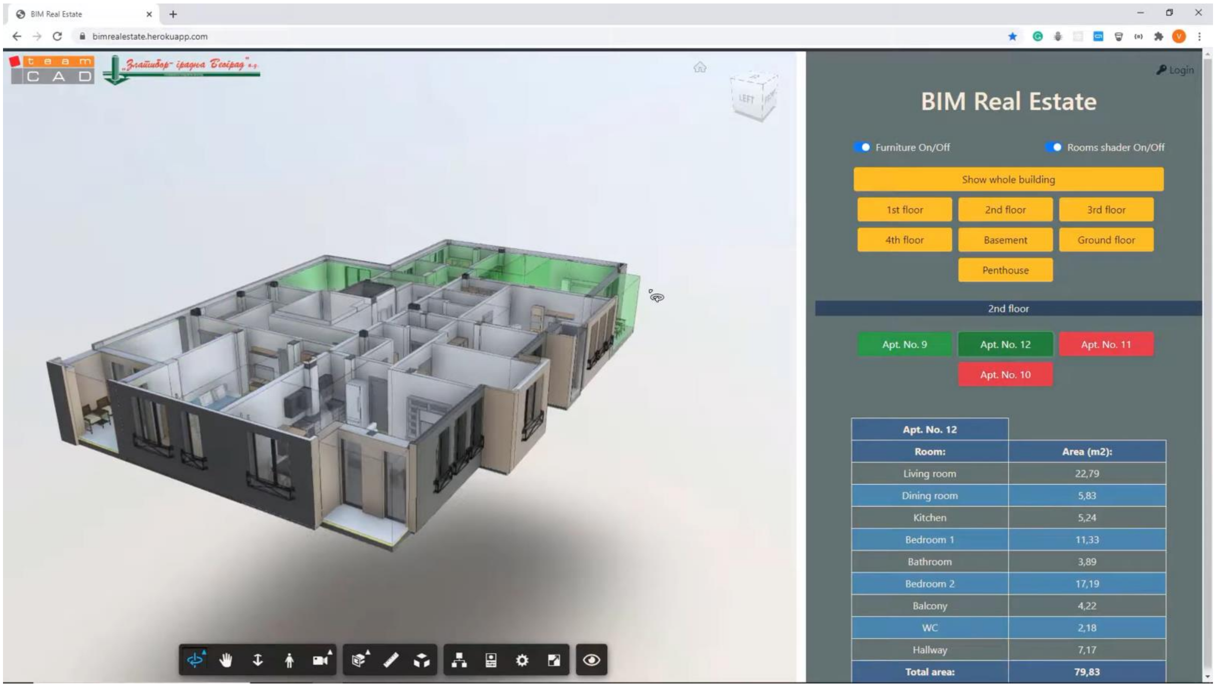


Figure 19: Beam Real Estate App (BIM Real Estate, 2020)

Users can select a floor of the model, then only this floor model will be presented where available, and no available flat for sale or rent will be shown with different light colours. Then available apartments can be selected to see the necessary information. There is a measurement tool available with this tool user can get the dimension of any object in the model, such as room dimension, furniture dimension, or any free spaces. Moreover, a panoramic view option is also available in this web app; with those options, users can see the realistic panoramic view of the selected room. The owner of the property can change the availably of the property status through login in the web browser easily. (BIM Real Estate, 2020)

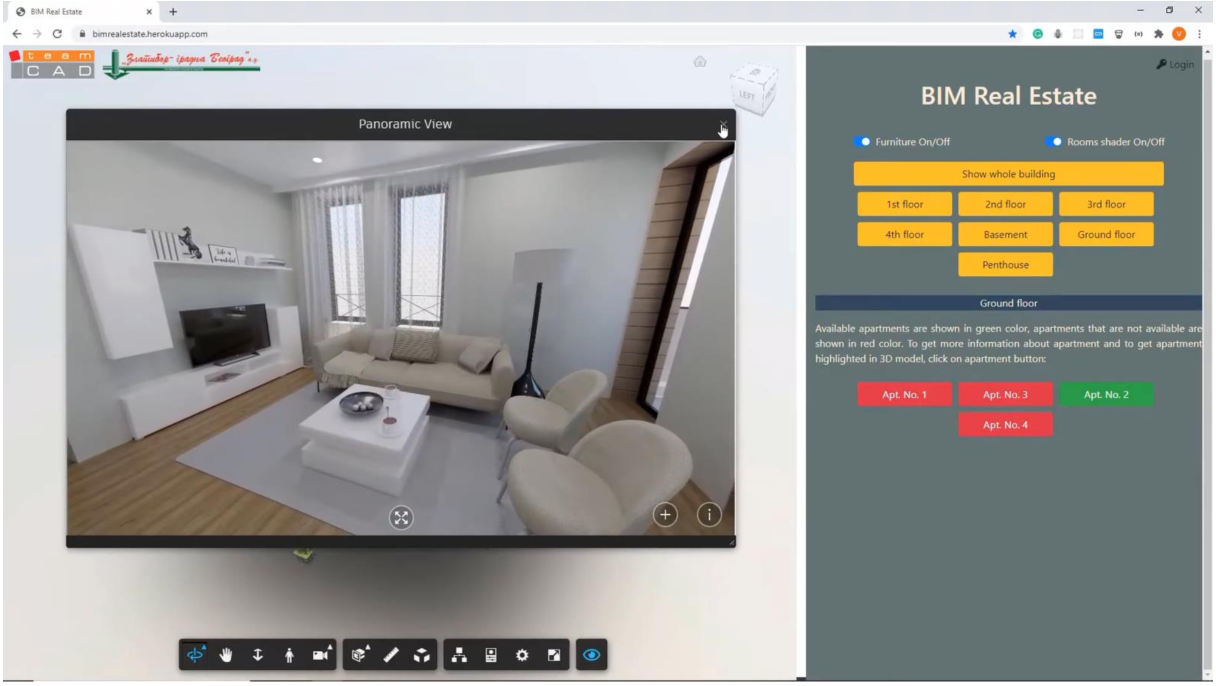


Figure 20: Panoramic view in Real Estate App (BIM Real Estate, 2020).

The BIM model can be used as the main resource for preparing the digital brochure for office space or co-working space marketing. In addition, the BIM model can transform into a realistic virtual representation platform through web applications such as Real Estate App presented by Team CAD.

Chapter 5

Case Study

5 Case Study

5.1 Case Study 1

This case study was adopted from a research paper titled ‘A framework for integrating BIM and IoT through open standards’ conducted by Dave et al. 2018 published in a journal named 'Automation in construction' Volume – 95. In this case, the study represents a platform that integrated Building Information Models and IoT sensors to provide real-time information of a built environment, such as occupancy comfort and energy usage of a university campus building. A space booking system also designed in this study by this programme user can book their space through their smartphone with mentioning their expected indoor environment. (Dave et al., 2018)

Case study university campus has almost all criteria of co-working service as university campus used by a huge community such as student, teacher, researcher, expertise and other community. Furthermore, maintaining all facility management services in the university campus is a challenging task as the occupancy rate is not fixed for every day and all over the time for a total period such as a year. The meeting room, group study room, the conference room is not used with a fixed schedule. Facilitate all services as per requirement in co-working service can be found in university campus management. (Dave et al., 2018)

BIM is a valuable and important technology in terms of integration IoT in the built environment. the built asset has close integration with almost all the human activities both in micro-level such as things, space and building and macro-level such as campuses, cities and urban areas. However, the built environment sector faces a considerable obstacle to handling a vast amount of information due to a lack of standardisation. BIM is a source of huge information of the built environment and IoT developments need context and spatial data to be integrated into the built environment. The integration of BIM and IoT domain within Open standards can be a way of IoT development in built environment. (Dave et al., 2018)

Real-time visualisation of 3D model is becoming more popular and necessary in the AEC industry and built asset management. The 3D representation of any built asset provides a realistic visualisation of the asset, which is useful for both the design & construction phase and operational phase. However, the 3D model or the BIM model has several complex data sets that are challenging issues for real-time rendering of the 3D model. As the commonly used software tools in BIM for 3d model representation is required, higher-performance enable hardwire resource and take time to render raw BIM model usually fail to real-time rendering process that needs for in any front end-user interface. A simplified BIM model can be used for the real-time rendering purpose of the build asset model. (Dave et al., 2018)

The primary aim of the proposed system was to connect spaces/built assets and the data generated from those buildings/spaces through IoT sensors/devices during the operational phase of those assets. Campuses, universities or any other institution is a good place to test this study as an implementation of practical use case because of the dynamic environment of those institutes that facilitate rapid development of innovative solution opportunities with interactive participants, students, and researchers. Moreover, people are enough intellectually intelligent to interpret the visual and spatial information in the form of 2d or 3d representation according to the spatial position factor that can be useful during data analysis, such as the data from a temperature sensor close to a window can be ignored during data analysis because of the position of the sensor. (Dave et al., 2018)

A secondary aim of this proposed system is to categorise or standardise the data according to their sources spatial position in the built environment as the plain data in a database cannot make the source location information like from which sensor or form where the data come from. (Dave et al., 2018)

Three challenges were focused on in case study 1, which are flowing.

a) The integration of built environment data and IoT sensor, makes possible to monitor the indoor environment and circumstances of the built asset on a real-time basis. The collected data can be an indicator for the necessary step for any required service.
b) Ensure that open standards are used for integration and development for the IoT and BIM so that further development can be possible in a wide range and faces a minor obstacle.

c) Develop an implementable application that can represent the potential of this integration in the practical field. (Dave et al., 2018)

The Otaniemi3D is the name of the framework that was actually implemented in this study. Otaniemi3D is an open platform implemented in a university campus to integrate the Building information using IFC with wireless sensor nodes through Open APIs. The total system architecture can be divided into three main elements:
IoT Devices: Those devices are installed in a built environment to sense and read the environment differently. (Dave et al., 2018)
Backend Server: In this server, several coupled services can be integrated to communicate among them maintain the service-oriented design style. In this study, IoT and BIM services are included in back end services. Some other services are shown in figure:21 as a suggestion for future integration. The functionality and data of each element of this backend server are represented in several frontends such as web-app, application and mobile application through a standardised interface. (Dave et al. 2018)
Front ends: The main functionality of these front ends is to make communication possible for the user with the system through an interactive interface. Usually, front end can be a computer application, web application, smartphone application. The front end mainly gets data from the backend server and represents this information to the user through a user-friendly form. But it is also possible to receive information from the user and send it to the backend server.(Dave et al., 2018)

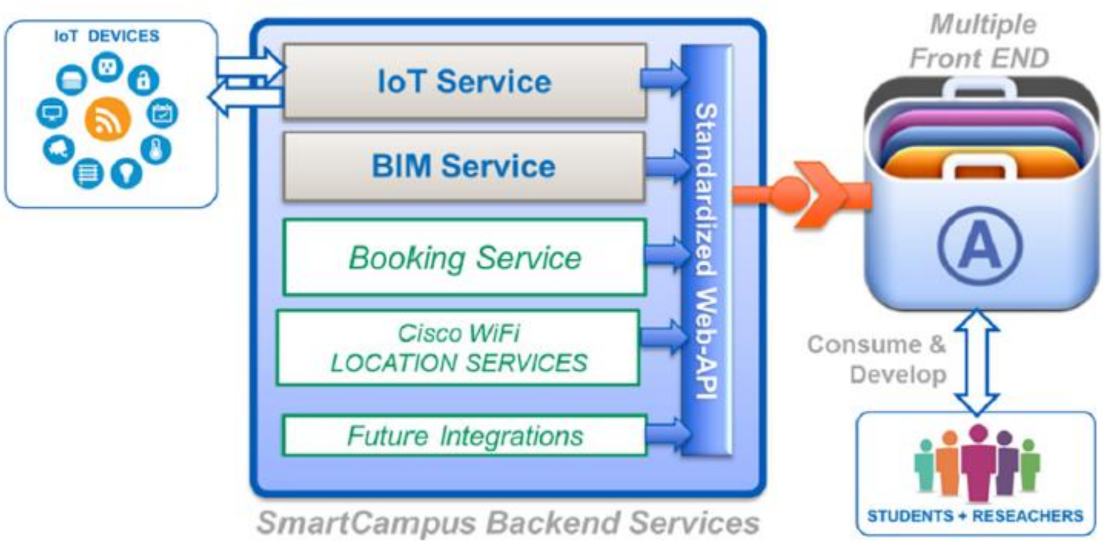


Figure 21: System Architecture of proposed system (Dave et al., 2018)

How BIM services work with front ends is an essential aspect of the potential and functionalities of BIM integration. The main function of the BIM service is to maintain the relationship between the spaces/built asset (as IFC format) and Internet of things IoT data. Translating the static IFC files into interactive web documents required some necessary consideration during the BIM modelling or modification later. In some cases, the model translation in IFC formats such as IFCsensor Type and IFCSpace causes the loss of some model features. To expose an interactive 2d/3D model in the front ends such as the browser, maintaining the model's original features is necessary. So BIM Modelling required consideration to be integrated in this type of system, and some additional manual programming can be required for the proper translation of the model to the front ends. (Dave et al., 2018).

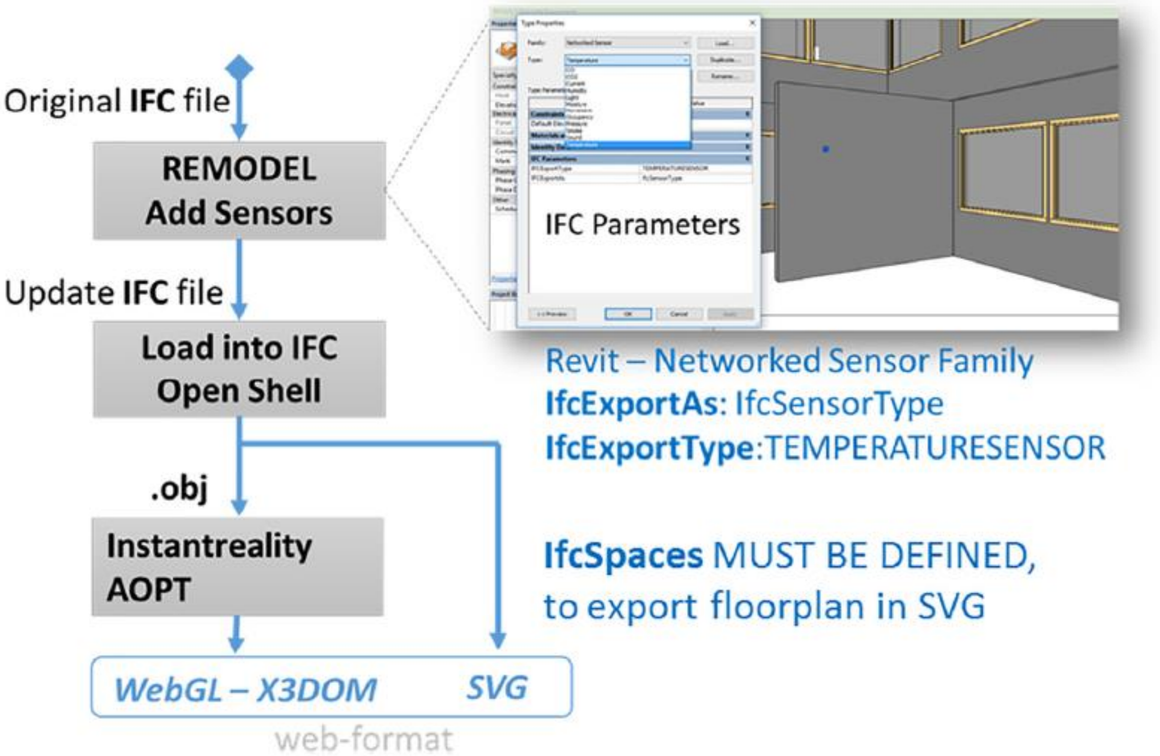


Figure 22: Original IFC file to web format conversion process (Dave et al., 2018).

The above-described system has been implemented in a campus of Alto University, where three dimensions of data representation of the built environment are shown.

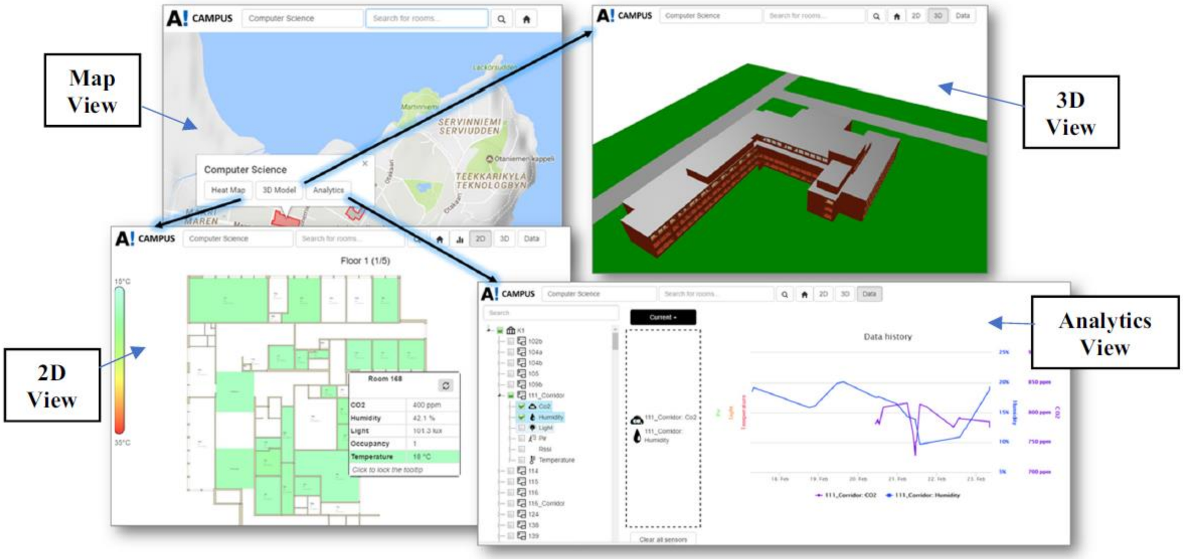


Figure 23: The user interface of the proposed system(Dave et al., 2018).

Those dimensioned are:

1D view:

1D view normally represent the data collected through the sensor in graphical representation through the front end. Both historical data and real-time data will be available for the user. Users can get the data according to the space, such as for different room corridors separately. There are several data regarding indoor environment will available such as room temperature, humidity CO2 concentration. Modified period selection is possible to observe the trend of the perimeter, for example, for the last one month's data or last week. Overall flexible spatial data for real-time and for a certain past period of indoor environment perimeter can be observed through this 1D view. All data is collected through sensors and processed in the backend server. (Dave et al., 2018).

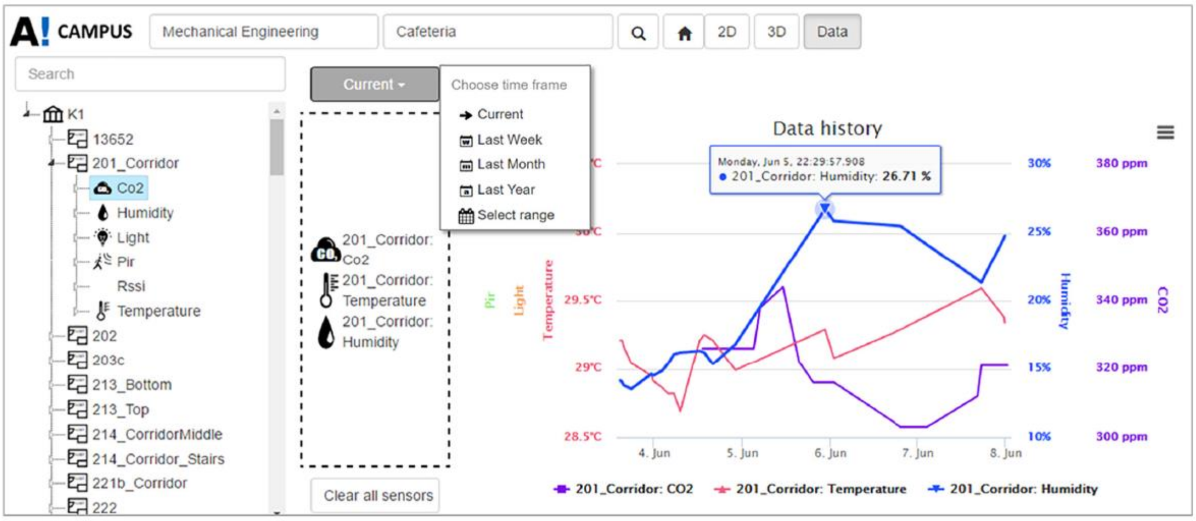


Figure 24: Graphical representation of Data as 1D view (Dave et al., 2018)

2D view:

2D view also represents the same data as 1D view but not as single data or traditional graphical representation of the particular location. For example, in 2D view, a heat map will be generated for the whole floor for a building for a certain period average data that heat map overlaid on a floor plan and represent the data with the variation of the colour for a particular parameter of the indoor environment such temperature. The difference between the 1d view and 2d view is that the user can see the whole floor information but is location-specific. Especially this 2D view is beneficial for the facility manager where he can clear the scene of the total build of floor condition and identify the problem related to this system. For example, if any specific location shows very deviation with the other places like too hot or too cool for a certain period, it indicates there might be some issue in the heating or cooling system in this specific area. The floor plan will be represented from the BIM Model through the standardised API. (Dave et al., 2018).

Figure 25: Heat map of a floor as 2D view (Dave et al., 2018).

3D view:

In 3D view, two types of presentations are provided: the sensor's location in the 3D model, and panoramic images of the spaces with sensor location in images. The panoramic images are interactive, and users can get data for and specific sensor by click on it from panoramic images. There is a search bar in the 3D model interface; after selecting/writing the location name or room number in this search bar a custom viewpoint is created in the middle of the room. By clicking on the custom viewpoint, the interactive panoramic image opens where sensor location is marked. Users can spot on marked sensor location and get data from the sensor by clicking on the sensor. (Dave et al., 2018).

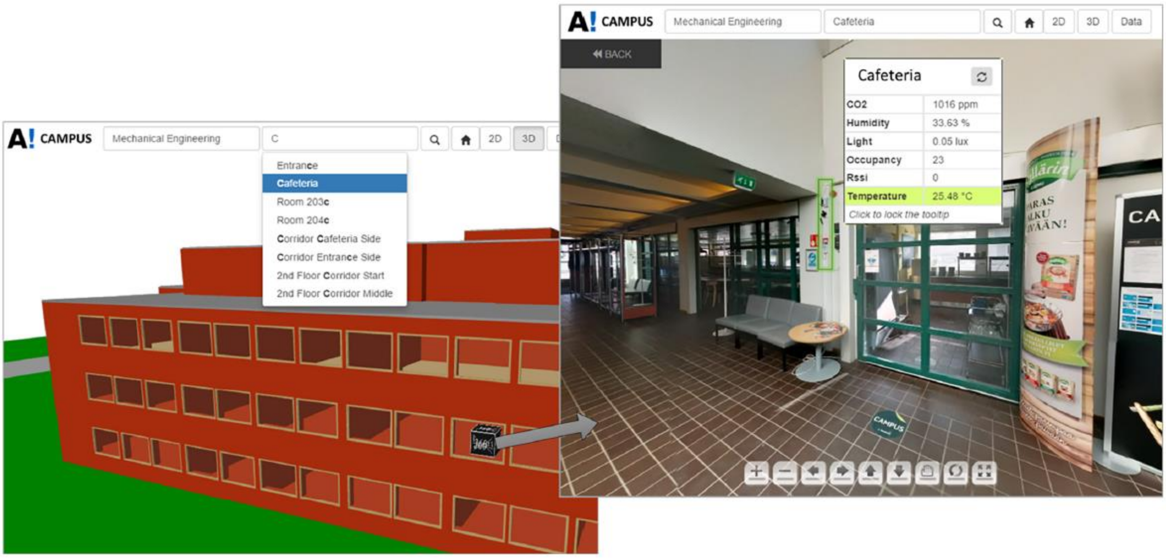


Figure 26: 3D Model view and the panoramic image indicating sensor location (Dave et al., 2018).

According to the system architecture, multiple services can be integrated with this system later using open APIs. Another service space/room booking service has been added to this system as a use case to demonstrate that system is implementable accordingly as proposed. The HVAC service control is also included in the modified space booking service while integrated with the Otaneami3D system. This use case is also an example of the integration of a building control system with IoT sensors and space booking services. (Dave et al., 2018).

A mobile application has been developed for the space/room booking service in Alto university campuses by which students can book the group work facilities and meeting room, the user also can navigate some other facilities that were not available in the previous booking system. During the development of the Alto space app (space booking app) developer observe an opportunity to integrate the Air conditioning and ventilation system with the space booking system using open standards development. Furthermore, an additional option was introduced for the communication department of Aalto University by allowing them to send a message through the app in case of any emergency situation in campus. (Dave et al., 2018).

There are six buildings of Aalto university campus are available in the Aalto space booking app where a user of the app first select the building and the floor of the than all information of this floor will be available in the app, such as how many places are available places in this floor, how many of them are free what is the seating capacity. After selecting a room picture of this room will be visible to the room's seating capacity are shown in the app. Booking time length option is also shown in the app after confirming the room, such as booking for 30, 60 or 90 minutes. (Dave et al., 2018).

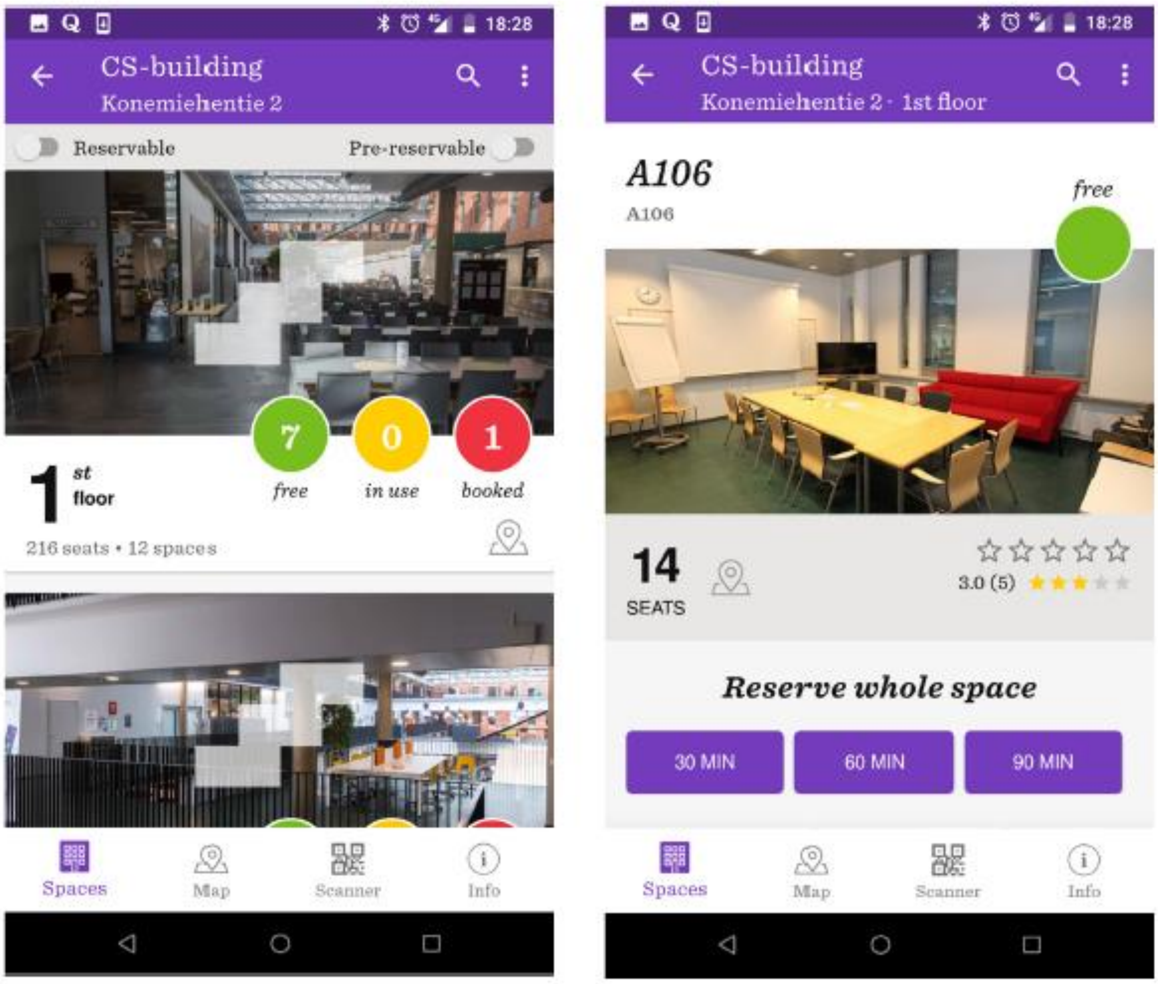


Figure 27: Aalto space app interface during room booking. (Dave et al., 2018).

A new feature controlling the air condition and ventilation system added with the space booking app allows the user to control the air conditioning system and the ventilation system of the booked room. Users can set the thermal environment while using the time of the booked place through three options: colder, warmer or auto and they can also mention the ventilation system with tow available option such as auto or bust according to their needs. The air conditioning and ventilation system access make possible the user control in the HVAC system. (Dave et al., 2018).

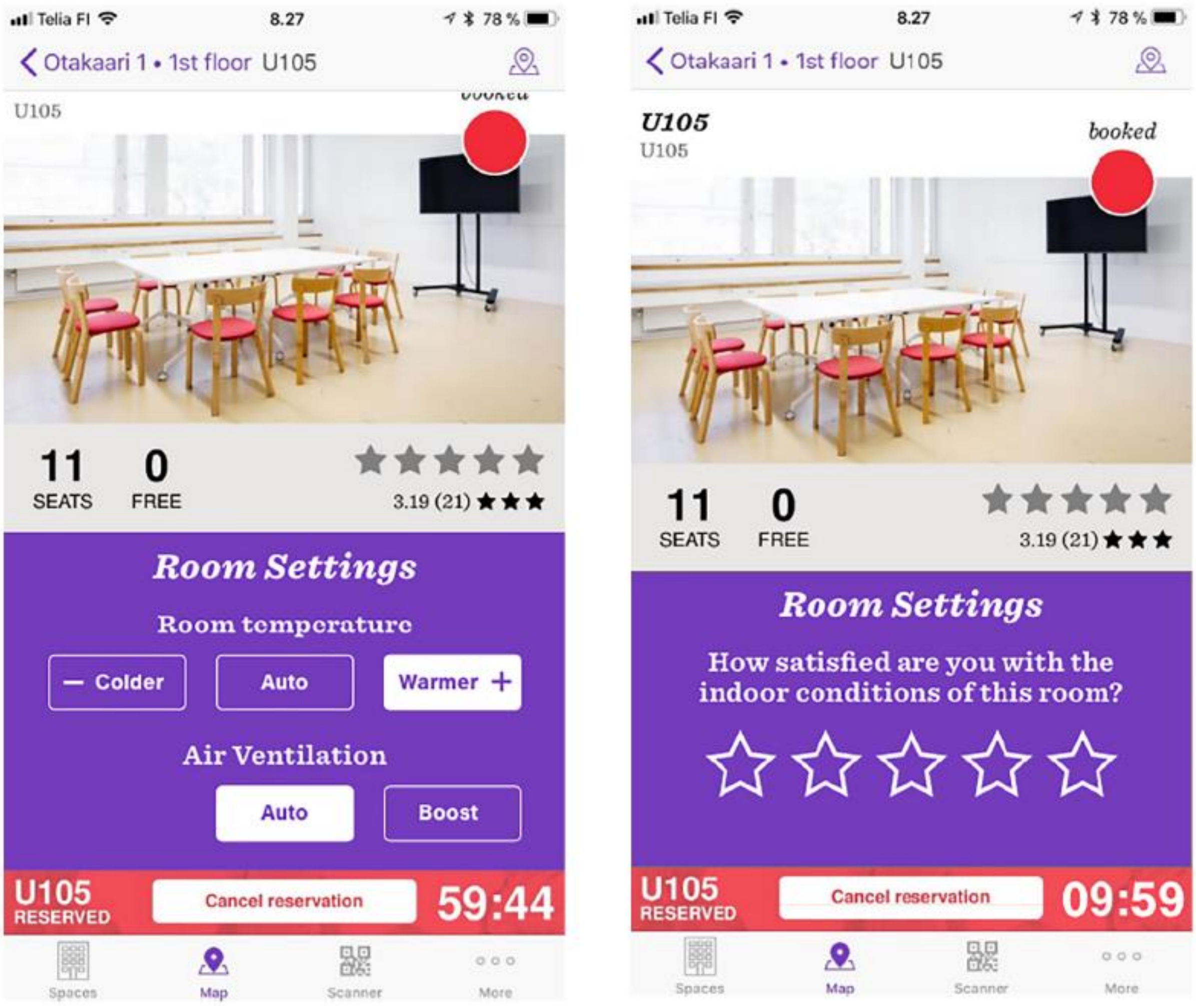


Figure 28: Space booking app showing temperature and ventilation settings(Dave et al., 2018).

In the next level of development, real-time temperature reading and the CO2 level also will be shown in the booking app. Moreover, there is a feedback option for the user about their experience with indoor room conditions, which can help the authority make decisions for any kind of maintenance or improvement in the future. (Dave et al., 2018).

With sensors installed, integrated with spatial information and providing live data in a real-life setting through an open framework, researchers and students can use this to analyse to support research projects, for example identifying user comfort patterns or energy usage patterns with changing sensor data, outside temperature and variety of other factors. Alongside the Aalto Space app, other similar initiatives are in progress, where the data available through the Otaniemi3D platform is being utilised in projects funded by Tekes (Finnish Innovation funding body) in collaboration with Aalto's Electrical Engineering, Civil Engineering and Computer Science department. The results from this will be disseminated in future publications. (Dave et al., 2018).

Energy usage monitoring, user comfort monitoring, space utilisation reducing carbon footprint are more concerning issues in any largescale working place, especially for campuses management. RealGo project is a project of Alto university that tries to integrate the IoT sensor with Building Information to achieve better facility management of campuses and provide a better service to the campus user. RealGo was a partner of this study, and integrating the air conditioning and ventilation control system with space booking service will cut down expenses of HVEC system and improve the customer experience. Furthermore, it was suggested that Integrating sensor, real-time data and spatial information of built environment will provide the opportunity for future development of other services, such as user comfort pattern analysis and energy usage analysis with manipulation of sensor data. (Dave et al., 2018).

Case Study 1 Analysis:

University campus is a large scale built asset both in terms of user numbers and total space under one umbrella. Different kinds of activities happen in any university campus, such as normally teaching procedures and research, academic conferences, commercial events, a public event such as vaccination some extend collaborating office work with other private or public organisations. Considering all use purpose of the university campuses is a large scale Co-working service place. Moreover, in a university campus, various kinds of service need to be managed for the facility managers and asset management department, such as classroom management, office room management, the group working facility management, laboratory management, and library management parking management. Any implementable service management system in a university campus can be implemented in any other co-working service management with necessary modification in facility management and asset management context.

There are three services covered in Otaneami 3D platform (case study 1) monitoring the indoor environment quality of the built environment, room/space booking system and control of the air conditioning and ventilation system through the room booking system. The indoor environment monitoring system is mainly used by the facility management or asset management authority as it only monitors the situation, but users can also use this service. This service is essential as maintaining the occupancy comfort situation of any workplace is one of the top priorities, whether it is a university campus or any other traditional office space or co-working service. Moreover, in a co-working service monitoring, occupancy comfort is more critical than in a traditional workplace as the occupants are from various companies or organisations. Without an automated monitoring system, manual reporting and maintenance system in indoor environment controlling system is clumsy, time-consuming, laborious and expensive. User satisfaction also will be more through the rapid solution of any issue with an indoor environment of any built asset.

BIM (Building information modelling) is one of the main components of the system architecture of the developed system as shown in figure 21. BIM model is used to present the 2D view (figure 25) and 3D view (figure 26) of the indoor environment. The primary objective of the proposed system of the case study is to integrate BIM (Building information modelling) with the IoT (Internet of things). Though there are only a few services implemented through proposed services and BIM is used directly only in one service monitoring indoor environment quality, BIM is used as the model of the built asset which will be needed in any further services. For example, after getting any issue in the indoor air conditioning or the ventilation system needs to take the necessary step where BIM is required. In the near future, suggesting required maintenance service depend on the problem that happened in any system such HVAC system can be added in the proposed platform where BIM data is required as the BIM model have all the information about the asset and the details of component installed in the system within the built asset.

In the room/space booking service, BIM was not mentioned in the service process, but the room booking service is also part of the whole platform where BIM is a back end component. BIM can be used in further development. Mostly the facility management authority can use a 2d plan from BIM model with the indication of booked and free rooms to check the booking and free services for a specific period day, week or month for the regular services and maintenance service schedule. Users can also use the same 2D plan to check them all booked and available room for booking, including the comprehensive information such as seat capacity of the room, the maximum light intensity of room, availability of big screen. BIM also has the potentiality to be used as front ends and for the space/room booking services both for the user and for the campus authority.

Integrated air conditioning and ventilation service with room/space booking service is a good implemented example of automated utility service per occupant requirements. Through this service, users get access to the utility service control that is good for the user and the facility service department. As the facility department does not provide facility service as per user requirements, users do not need to depend on the facility management department.

There are possible opportunities for future integration with open standards APIs with a proposed platform where BIM can be a great source of information. BIM also use frond ends to represent the information to the user. Moreover, BIM can interpret the data from IoT devices to necessary processes for analysis with spatial information. This case showed a successful integration of BIM and IoT sensor to manage facility service in university campuses, indicating that BIM has enough potential in co-working service management with combining with other systems.

5. 2 Case Study 2

Case study 2 was adopted from a journal titled 'BIM and IoT Sensors Integration: A Framework for Consumption and Indoor Conditions Data Monitoring of Existing Buildings' from the journal titled Sustainability volume: 13 published on 17 April 2021. In this case study, a framework for monitoring energy consumption and indoor condition monitoring of built environment through BIM and IoT sensor integration. The proposed framework for indoor condition monitoring and energy consumption monitoring system through informative/BIM model was implemented in a university building in Italy. (Desogus et al., 2021)

Lack of enough specific data during building operation regarding building performance is an obstacle to proper energy consumption and other services. For example, the Energy Performance Certificate (EPC) states that only 10% of building in Europe achieved an energy performance equivalent to the first two classes of EPC systems according to the data collected by the Building performance Institute Europe(BPIE) from sixteen members country. Thus, European buildings are still far away regarding energy efficiency to flow the pathway to achieve the objective set by the European Commission 2050 roadmap. (Desogus et al., 2021)

IoT (Internet of things) devices and sensors offer a great opportunity for energy consumption and indoor quality monitoring of buildings during the preoperational period. The building information modelling process and tools can provide all information of built asset to the management department such as spatial information, dimension data, space information, properties of the components of the buildings, and maintenance information. The BIM model and information are crucial for any proposing any necessary alteration in building operation and retrofits design. Integrating IoT and BIM can make a great platform for building performance monitoring in terms of energy consumption and indoor environment conditions. Moreover, this integration lead to make decision for necessary step for improving of building performance. (Desogus et al., 2021)

IoT sensors need to be installed inside the building to measure the indoor environment, energy consumption, and other factors in this case study. Placing the sensor in the existing building can sometimes be an area of concern if this building is a constrain from an architectural point of view; otherwise, installing IoT sensors is comparatively easy. IoT device is not an expensive component and widely available in the market. Different technologies are available in the market for the sensing network, but the wireless product is very much suitable for installation and a good option to avoiding the wired networking problem. More specifically 'Z- Wave' radio standard is a widespread acceptable option in this sensing system. The Z-Wave standards allow the necessary modification and expansion in the system later, consume significantly less electricity for operation, and are powered by standard batteries makes essay the operation. (Desogus et al., 2021)

In this case study, two types of power supply options are used, power supply from socket points and powered by the non-rechargeable battery. In the first simulation, power was supplied from main socket without any modification of the electrical system. Though this does not look like a crucial issue to implement the system, it is a constraint to placing the sensor in the right position. The second option of the power supply provides the solution to install the sensor anywhere. A technology was developed to implement the system activities with mixed power supply options (wired and wireless) that allows the installed sensor as per system requirement. (Desogus et al., 2021)

As per the proposed system protocol, a mesh network was generated by installing the necessary sensing device for Z-Wave communication protocol where each device can set up a mutual communication environment where the sensor can exchange data to the other device. All sensors in the system can communicate the main hub that is a controller or gateway, directly or through another node; the controller is the system's main component, which is responsible for collecting all data and transmitting it to the user interface end such cloud platform. The collected data are stored in a cloud-based platform and will be accessible for the user through the interface from the computer, smartphone or tablets. (Desogus et al., 2021)

The system developed for the case study covered a 100-meter range which can be expanded easily as far requirement and low-cost device availability is a positive influence to expand the system later. After comparing some factors mainly the economic point of view, the Z-wave devices of WiDom products were selected for the case study project. A z-plus certified sensor device was installed for data collection of several parameters of indoor condition that device integrated the temperature, humidity and brightness and noise level sensor in the same box. Moreover, an energy driven Z-wave sensor installed can be used as a relay switch with an integrated power meter and as an energy meter placed at the input of the electrical system or any portion of the electrical system. (Desogus et al., 2021)

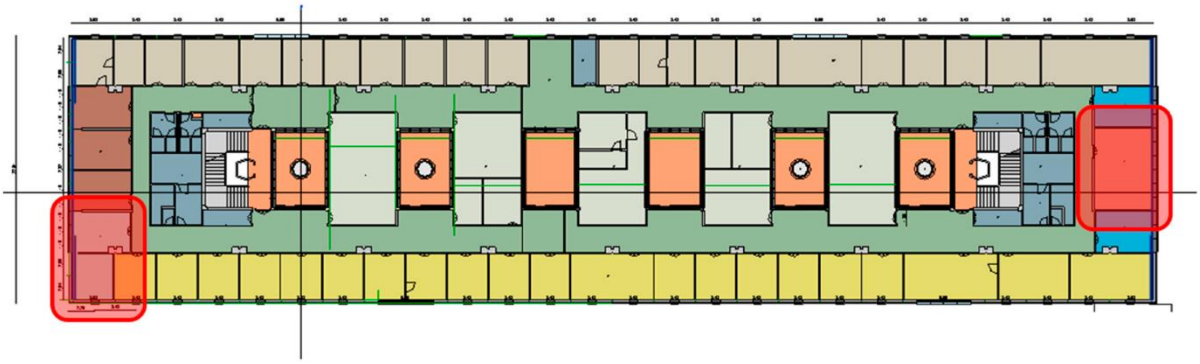


Figure 29: The selected room where IoT sensors were installed(Desogus et al., 2021).

Two rooms are selected from the case study building for the pilot project purpose shown in figure 29 where described network system was developed with installing the mentioned sensor device. Those sensors are connected with the main hubs/gateway, which collects all data from the sensor and transfers it to the IoT platform on a real-time basis. Data have been recorded for every five-minute interval for energy consumption, and the temperature, humidity, illuminance, and noise level of the room are also recorded as the same time and time interval. (Desogus et al., 2021)

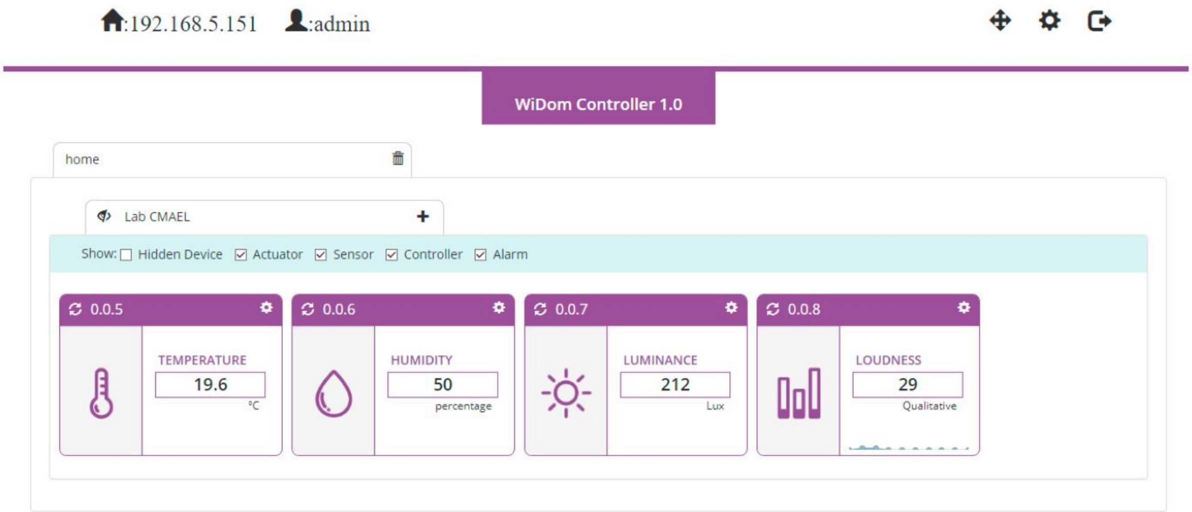


Figure 30: Valu of different parameters value in the manufacture web portal(Desogus et al., 2021).

The sensor data is available in the sensor manufacturer web portal. Typically it is possible to integrate the data in any other IoT platform and others interface systems. ThingsBoard is an open-source IoT platform that was selected as an IoT platform for this study. 'ThingsBord connects the device through Industry-standard IoT protocol and is responsible for collecting, processing and visualising the data. Data loss rarely happens in ThingsBoard as it combines fault tolerance, scalability, and performance during data transition. This platform also allows monitoring data through a built-in interface and custom widgets, and a flexible dashboard. It also offers a secure protocol to monitor controlling the data by using other advanced server integrated APIs. Historical data is also available in this platform through graphical reorientation. The mentioned IoT platformed was installed in a server at the university. (Desogus et al., 2021)

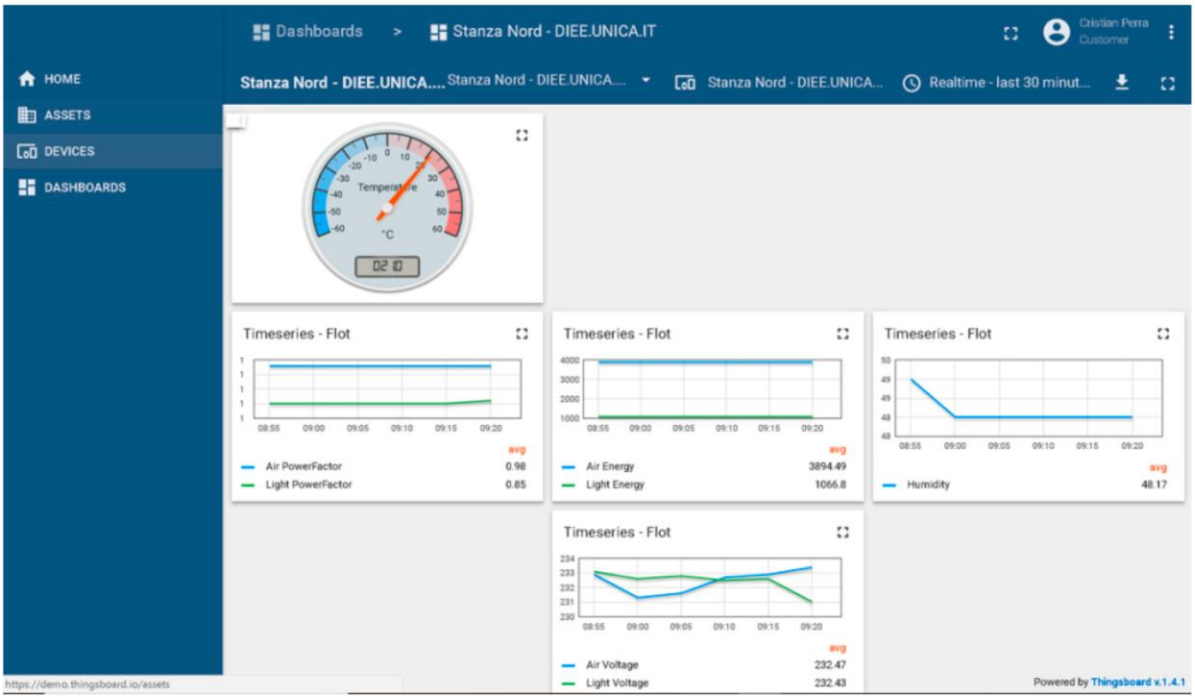


Figure 31: User interface representing the data(Desogus et al., 2021).

A primary objective of this study is to create an implementable framework for energy audit procedures for the existing building integrated with an informative model of the building. The informative model is a reliable source of information and representation platform that helps make any intervention plan for the building basis on shared knowledge.. The case building is old and did not have a BIM model before an informative model (BIM model) was created using Revit Autodesk. During the creation model process tried to respect all details of the building with accurate information regarding shape, thickness and dimensions, avoiding simplicity strategies to get an informative model as much as possible. (Desogus et al., 2021)

A detailed, informative model is necessary for planning any restoration or functionalities modification planning of the built asset. Besides the geometric information, other virtual information such as material properties, functionality details, operational information of necessary equipment, maintenance producer for required services also needs to integrate into them informative model for planning any modification during the operational period of the Built asset even for regular maintenance. Right code standard is a significant issue for virtual representation of the object, and the interoperability among all sections of the building process also depends on the code standard. In this case study, UNI 8290 standard was maintained. (Desogus et al., 2021)

As improving the audit process of the building through BIM/BIM model is the primary objective of this study, getting continuous information of the indoor parameters, including energy consumption within the BIM model, was the goal of this study. Therefore, the location of sensor identifying in the model was not considered a necessary step in this study. 'Local' is a Revit object that provides an option to associate the data and information. The shared perimeter was created to in the 'local' object of the Revit, so that the monitoring data can be present within the model. (Desogus et al., 2021)

The Revit software was chosen for the seamless dynamic automated data exchange between the sensor and BIM model. Dynamo visual programming is an integrated visual programming platform in Revit software. The most important feature of the Dynamo is that no code list typing is required to create any algorithm logic on it; it provides a great opportunity for the main user of the Revit software to use visual programming options in a simplified approach avoiding code writing difficulties. Nodes are used in Dynamo to make a flow chart of the algorithm where input and output are the connecting of the option are the connecting channel of node to each other. (Desogus et al., 2021)

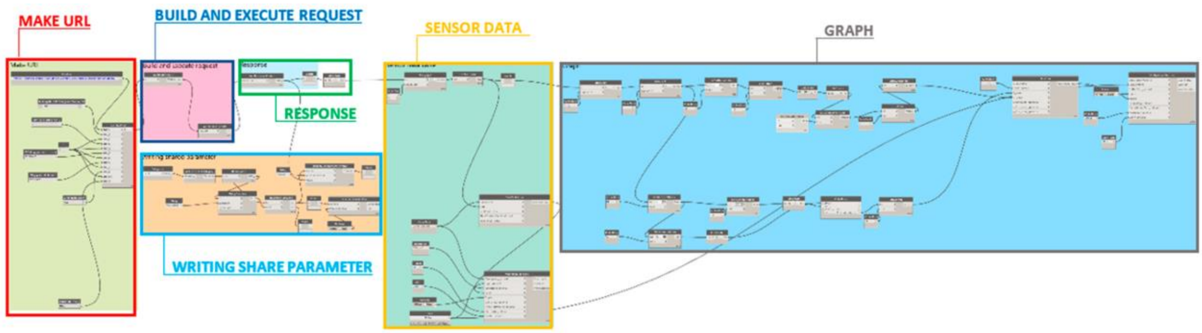


Figure 32: Dynamo script for prposed system (Desogus et al., 2021).

Nodes are the main element of the Dynamo, with the help of the programming tool, an operational algorithm process was created in this case study. The process script enables automated workflow to take input data from the auto side of the model history, such as from any excel file or any online platform or server. Dynamo is available in the Revit software, and it is capable of taking sensor data from the IoT platform through APIs, including the time series of the positioned sensor in the selected room for this case study. The total workflow from data collection to the data transfer to the IoT platform and data representation with Revit software is completed automated. Through this process, monitoring the indoor building condition with the real-time observation of selected perimeter (temperature, humidity, CO2 concentration.), including energy consumption monitoring, is possible within BIM Model. (Desogus et al., 2021)

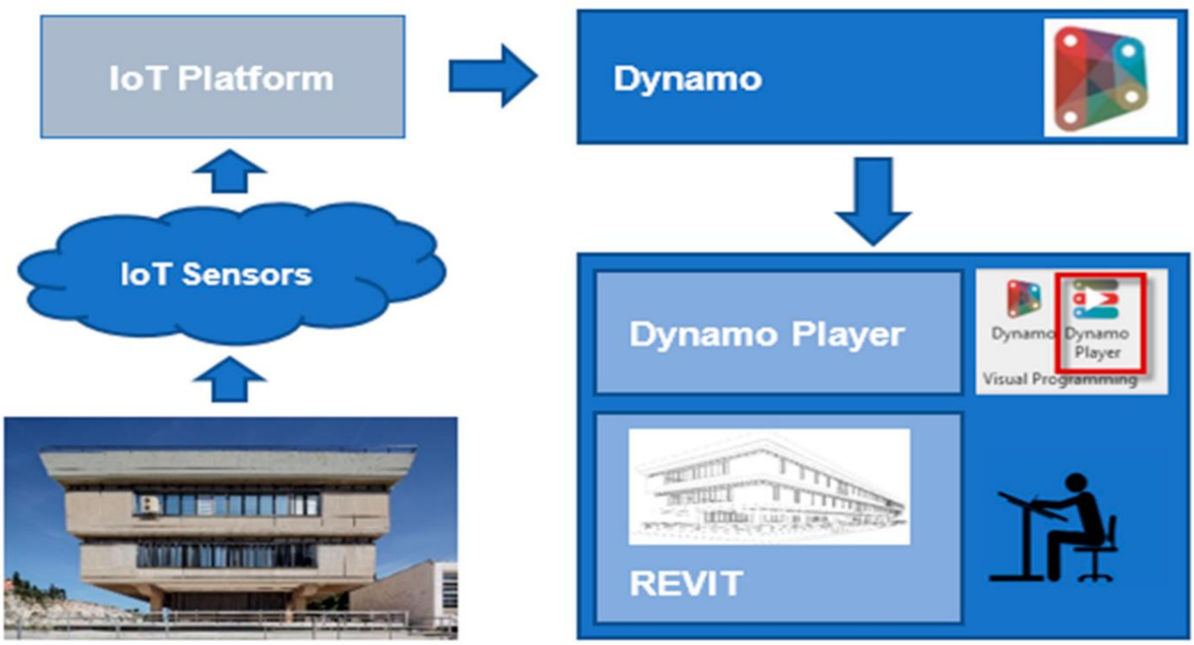


Figure 33: Data flow from built environment to BIM model (Desogus et al., 2021).

The proposed framework makes a channel to exchange data between the IoT platform and the informative model (BIM model) of the built asset. The suggested dynamo script can be run in the Revit interface with Dynamo player, where users can get the measured parameters monitoring data. The user/operator can select the perimeter, room, sensor, and time duration to monitor the data.

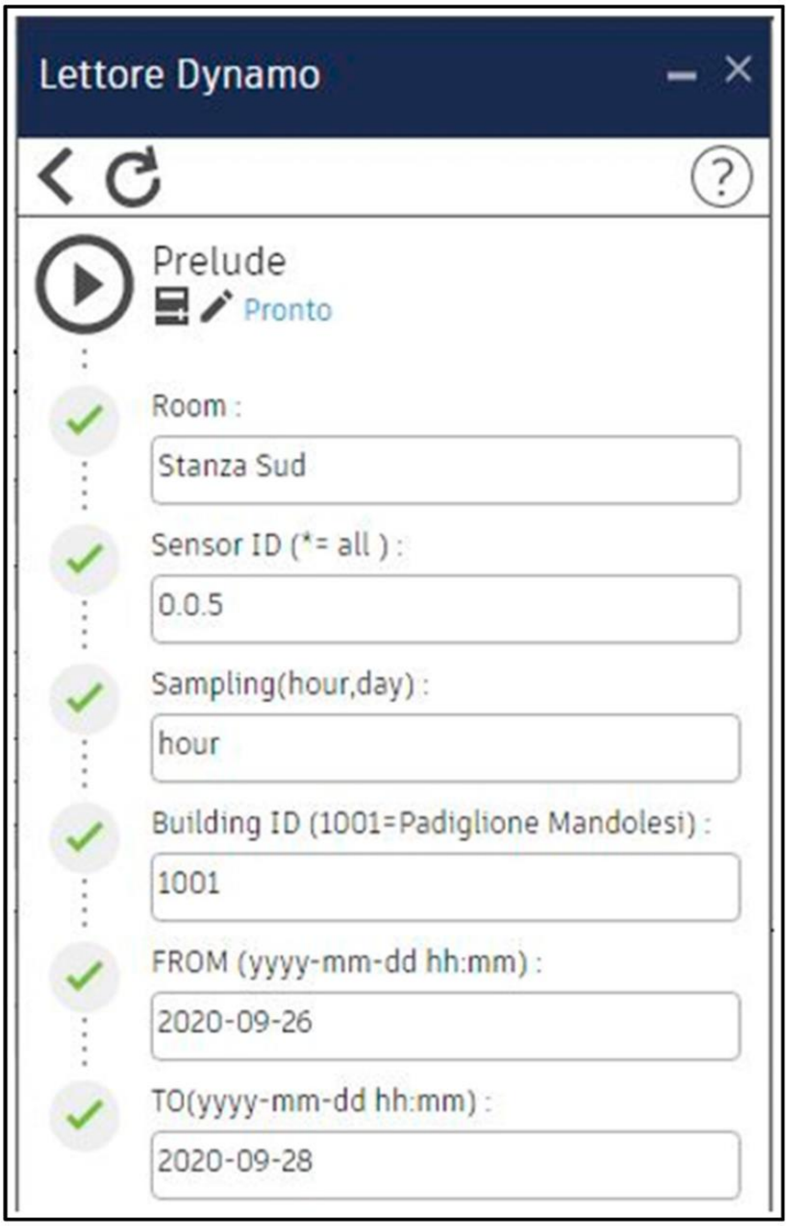


Figure 34: Dtat requirement input window details in Dynamo player (Desogus et al., 2021).

Data representation within the Revit software interface as shown as in figure 34 as per operator selection.

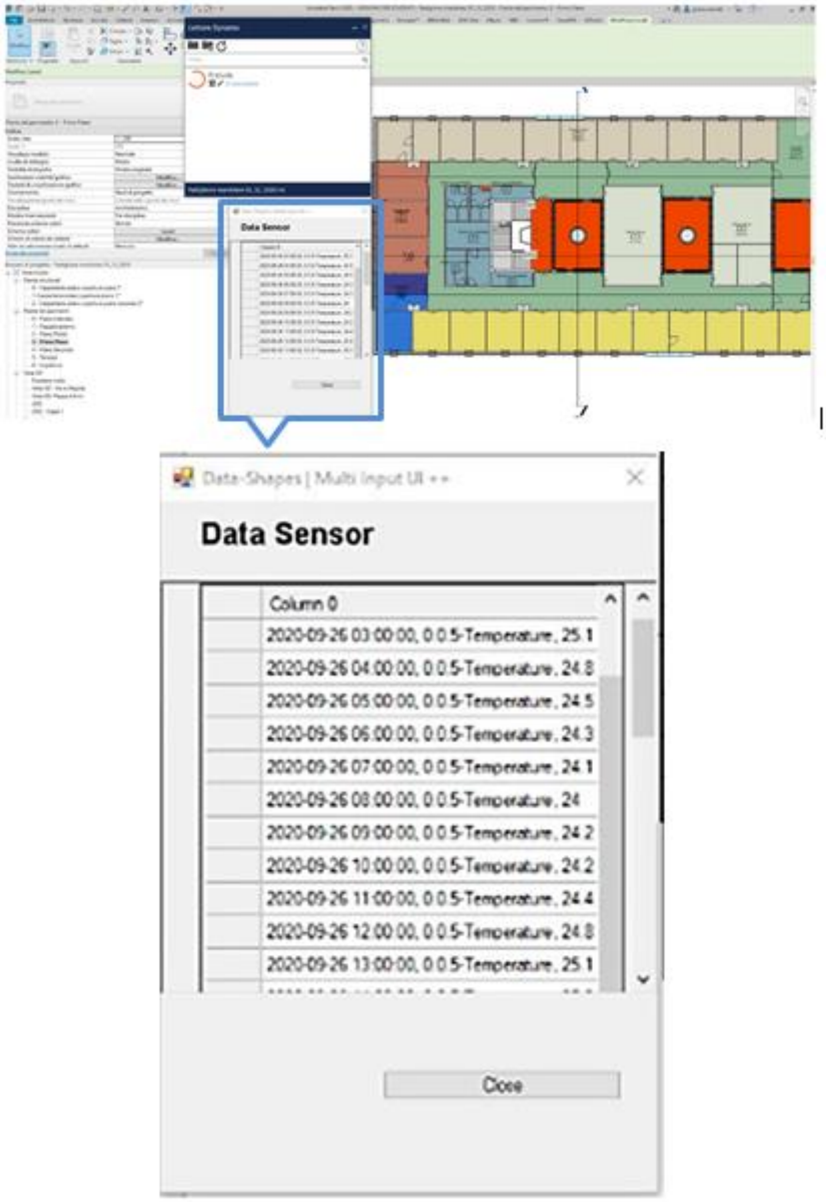


Figure 35: Indoor environment monitoring data showing in BIM model (Desogus et al., 2021).

Graphical representation of the parameters for a certain period (week, month, day) is also possible in the same interface. Through the graphical representation of the indoor condition parameters comfort condition of the indoor environment can be measured, which is essential for any kind of built environment. (Desogus et al., 2021)

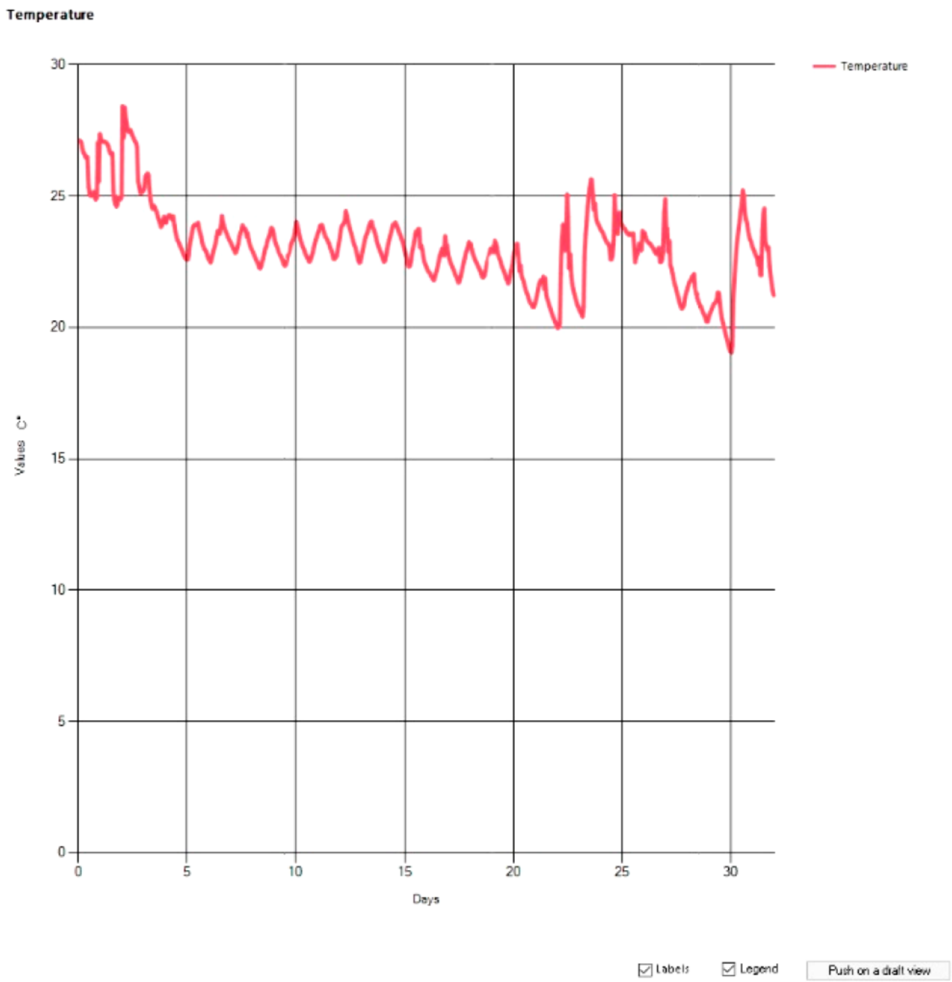


Figure 36: Temprature data of August 2019 (Desogus et al., 2021)

In Figure 37 the temperature data of August 2019 is shown where the temperature range is between the 27 to 19°C but most of the time, it was in 23 to 24°C. The fluctuation of temperature in the last 3rd part of the month refers to the intensive use of the air conditioning system.

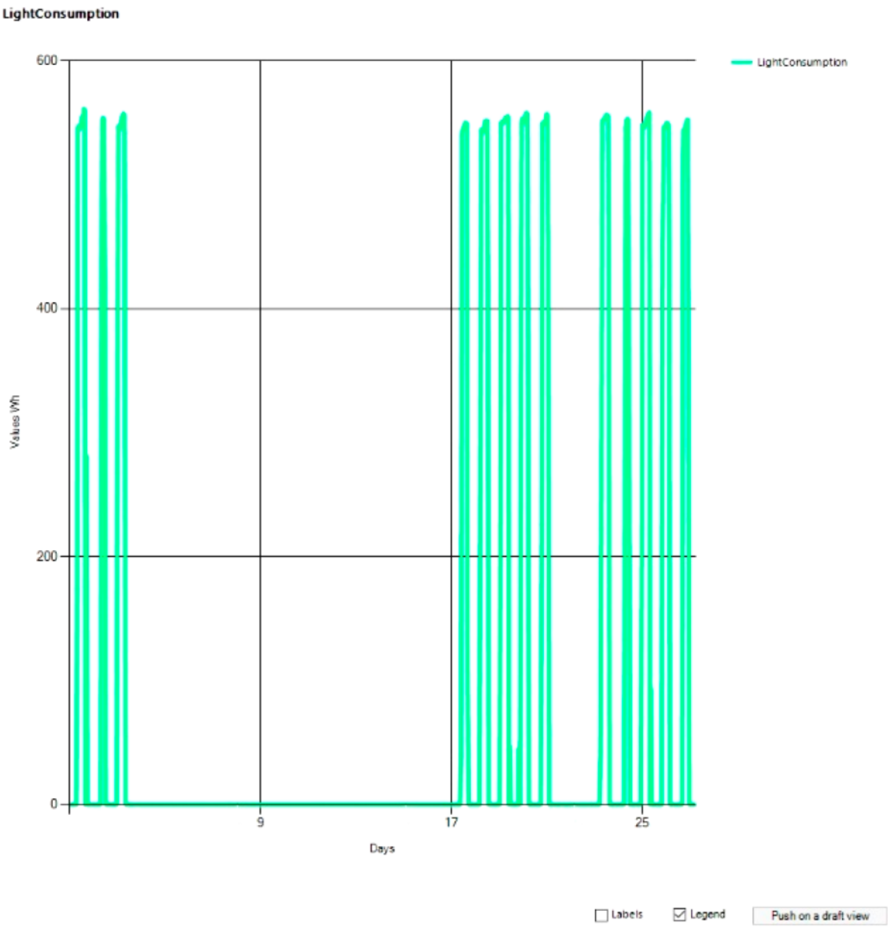


Figure 37: Energy consumption for the lighting of August 2019(Desogus et al., 2021).

In the above figure 38 electrical consumption for lighting purposes shows that electrical consumption is null from the 3rd to 17th day of the month. This is because the consumption data in the graph refer that room was unoccupied.

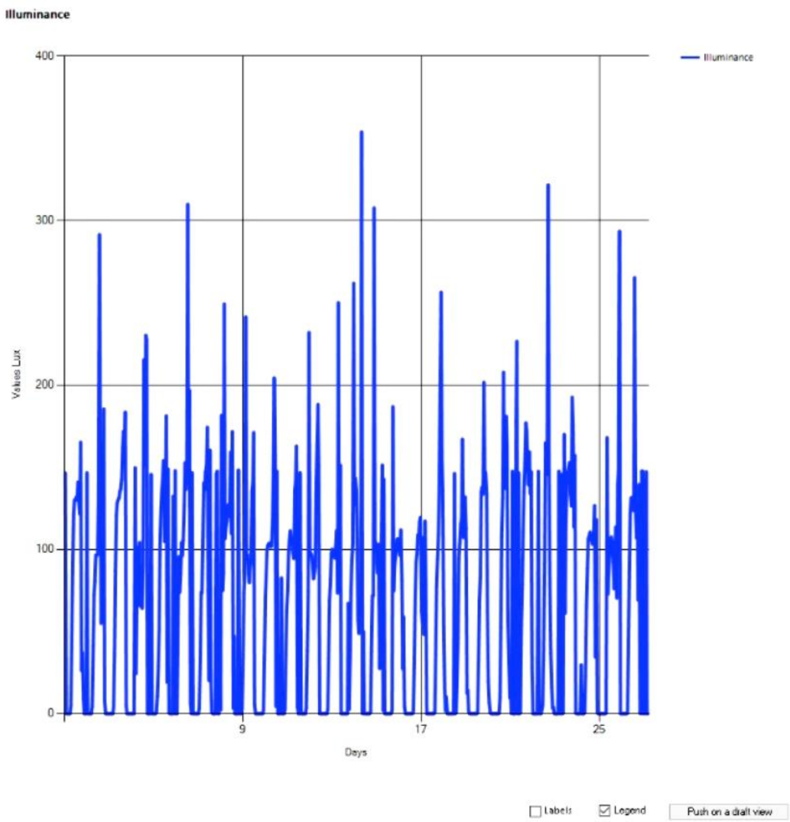


Figure 38: Light intensity report of August 2019 (Desogus et al., 2021).

Figure 39 graph representing the light intensity and figure 38 represents the enrgy consumption of the same room for the same month. There was no considerable fluctuation of light intensity when no energy consumption for lighting and energy consumption happened that indicate that there might be some problem in the lighting system of this room. (Desogus et al., 2021)

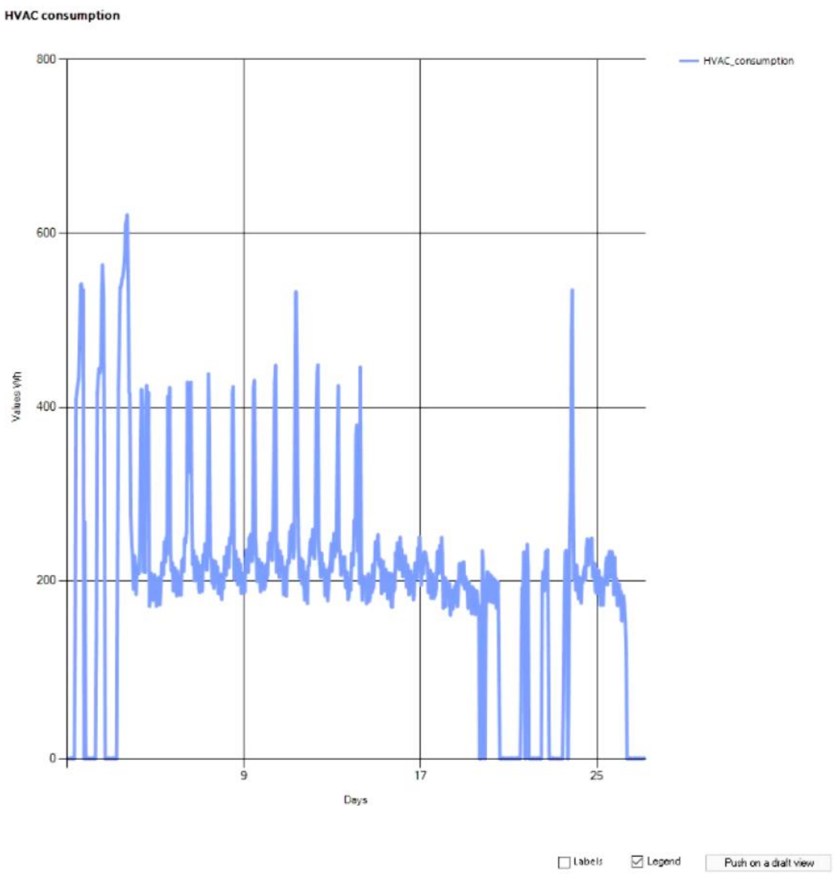


Figure 39: Energy consumption for air condition of August 2019. (Desogus et al., 2021).

The energy consumption for the air conditioning system for the case room for the month of August 2019 is showing in the above graph in figure 40. From the energy consumption graph in figure 38 for the lighting system, the room was not unoccupied from the 3rd to 17th day of the month. However, the above graph shows that the air-conditions system consumes energy for the whole month eventually air-conditions system was not switched off for someday in after office hour. As the case study, an office building air-conditions system is not required after office hours. So aftermath there is considerable energy lost identified in the air conditioning system of this mentioned room. (Desogus et al., 2021)

Historical data for the different parameters of indoor and energy conditions can help the operation of the building and identify any required maintenance or modification in the system. Moreover, find out the critical fact to make any strategies for reducing energy consumption during operation can be identified by analysing the historical data of the Built environment indoor condition. Monitoring all parameters for indoor parameters through the BIM/informative model makes it easy for the facility /Asset management authority. (Desogus et al., 2021)

Analysis of the Case Study 2

One of the primary objectives of case study 2 is to monitor the energy consumption data and the built environment data within the BIM model. Both real time Data and historical data can be monitored in this approach framework. Total three options of data monitoring has discussed in this model the basic one is data monitor through IoT sensor manufacture default web portal and the data monitoring through another IoT sensor data monitoring platform named ‘ ThingsBoard’ and the third one is the data monitoring through BIM model.

A remarkable option in this systems is that data monitoring is possible through BIM model and other online platform. Building performance data monitoring within the BIM model offer easy built environment monitoring and energy consumption monitoring system. This approach offer facility to implement the building performance monitoring system in small scale. Additionally, the integration of another web-based data monitoring platform is offering easy interface for the building user and other authority who are not directly responsible for building operation.

Energy consumption data monitoring and the other services data monitoring that consume energy make easy to identify the energy loss through services in this approach framework. In case study an example for energy consumption for lighting system showed that there is no user in a room for couple of weeks but the same time air-conditioning system was on and consume energy for the whole unoccupied period which is directly loss of energy. Similar to the previous example energy consumption for lighting system and the light intensity data showed that lighting system was not working properly. The system provides facility to identify the poor building performance fact relatively in easy process. And data monitoring through BIM model provide and in hand option for facility management/building operation authority as they will got the data and spatial information from source.

There is no automatic indication option for poor performance or energy loss integrated in approach framework. It can be a significate tool building operation and prevent energy loss if there is any indication system introduce in the system in real/time basis. It is very much possible with cross checking the real time indoor parameters such as temperature, light intensity with energy consumption monitoring.

Further development of proposed framework can be a base for the automated utility services. Analysis of the monitored data in proposed framework energy loss can be identified easily, real time analysis of the different perimeters inside the building can be used as a driver force for making decision for automated utility services. For example if the light using data indicate there is no user in a certain room for a specific time the air-conditioning system will be switched of automatically that can save energy consumption. Automated utility system able to save cost in multiple way such as it save energy con consumption and it save operating personal cost. Moreover, automated utility service improve the built environment performance and help to improve the user satisfaction.

The approach framework in case study 2 is a framework that enable to monitoring building indoor environment parameters data and energy consumption data with the integration of IoT sensor and BIM model. The inclusion of energy consumption monitoring and other indoor environment perimeters monitoring that directly or indirectly responsible for energy consumption makes an great platform for improving indoor environment and energy saving approach of built environment. There are a huge probability of further development of approach framework which can lead to automated utility services as per requirement with more efficient energy saving facility.

5.3 Case study 3

The case study 3 adopted from a conference paper titled ‘Integration of BIM and Archibus for Facility Management (FM) in FKAAS, UTHM Building’ published in IOP Conference Series: Earth and Environmental Science in 2019. In this case study integration of BIM within a space management platform has discussed in details to discover the benefits and challenges. In this case study the an university campus BIM model was integrated within ‘Archibus’ space management platform. (Solla et al., 2020)

Space management is most important facility management service for both government and non-government organization. BIM can be great resource for the facility management especially the space related service such as occupancy management, space allocation and utilization, and other required services from the occupants regarding space issues. BIM consist all information of space including the measurement and visualization facility, equipment inventory in any certain area that make space management process very easy, convenient, reliable and less time consuming. Having all information of built asset BIM provides an organized information of the property to the facility manager that will be utilized in other service management during operation and maintenance including space management service.(Solla et al., 2020)

ARCHIBUS is platform that integrate workplace management for real estate, built asset management, and facility management for defining multiple functions of an organization. Archibus is web base application that enable space management service through web browsing and mobile application. Archibus has all information regarding the space of the facility with necessary zones, divisions and department according to the organization requirements. Archibus has option to keep data about the occupant capacity, occupant rate and frequency which make possible for the user to generate report regarding space utilization, efficient space allocation, and survey report for further improvement in space management. Archibus enable to link with the BIM tools such as Revit and Microsoft office that make possible the geometric view with information and graphical information presentation of the facility. The facility manager able to access to the facility information and geometric view within same platform in Archibus that make possible to improve the space management facility. (Solla et al., 2020)

The case study building is a university campus with two towers with six and nine floors consisting of 30,755 square meter area in 840 spaces. During the construction of this building BIM approach was not applied so the drawing was available in .dwg format and readable with AutoCAD. Revit BIM tools have been used to prepare the BIM models. As it is an old building preparing BIM model for the facility management was a challenging step. Previous space code system integrated within the Archibus system with BIM model. In the last step of modelling necessary checking for information availability and interpretability was checked before integrate with the archibus platform that can be said as model validation step. (Solla et al., 2020)

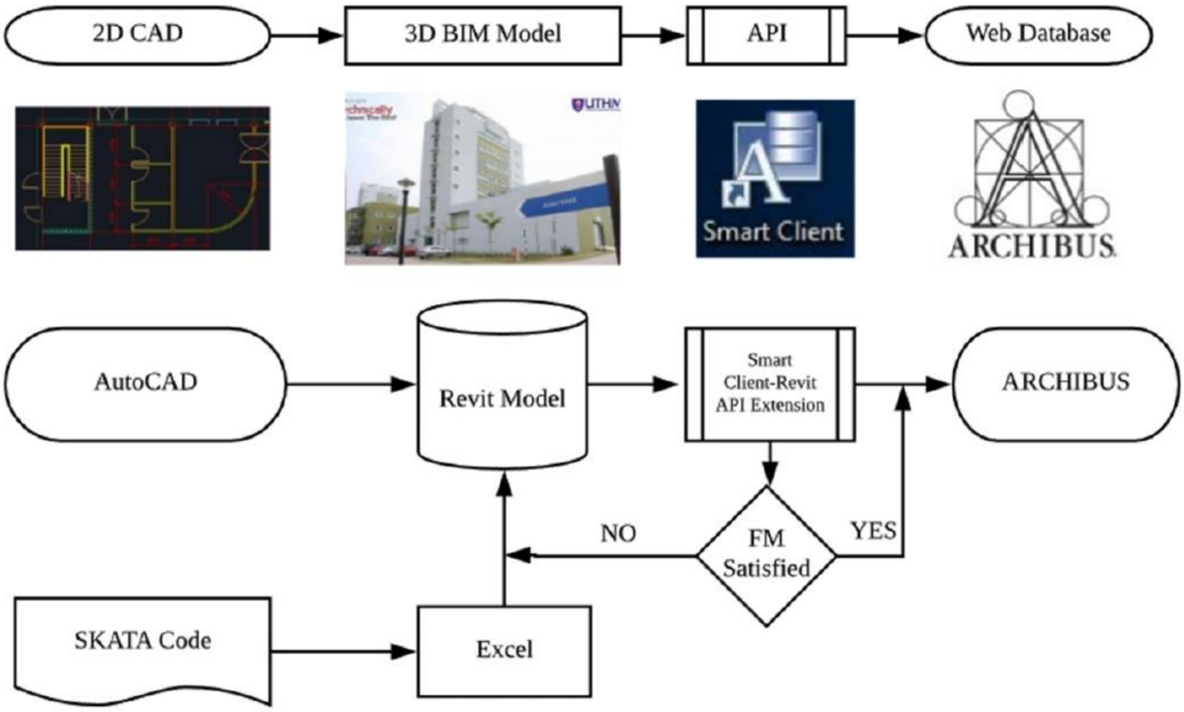


Figure 40: BIM integration process in ARCHiBUS for space management(Solla et al., 2020).

To integrate the BIM model to the Archibus platform Smart Client API (Application Programming Interface) was used. The code system was used to categorize the space, and it uses purpose for facility management. After linking the BIM in the Archibus platform able to presenting the whole BIM model with accurate information such as the right floor area in the BIM model and the room number. The Smart client extension was able to transfer any required data from Revit Model on a real-time basis to any application of Archibus. That makes it possible to prepare reports for space management at any time that consist of necessary data such as:

a) space inventory report

b) space performance report

c) Occupancy report: occupancy rate, tracking vacancies

d) Movement management etc. (Solla et al., 2020)

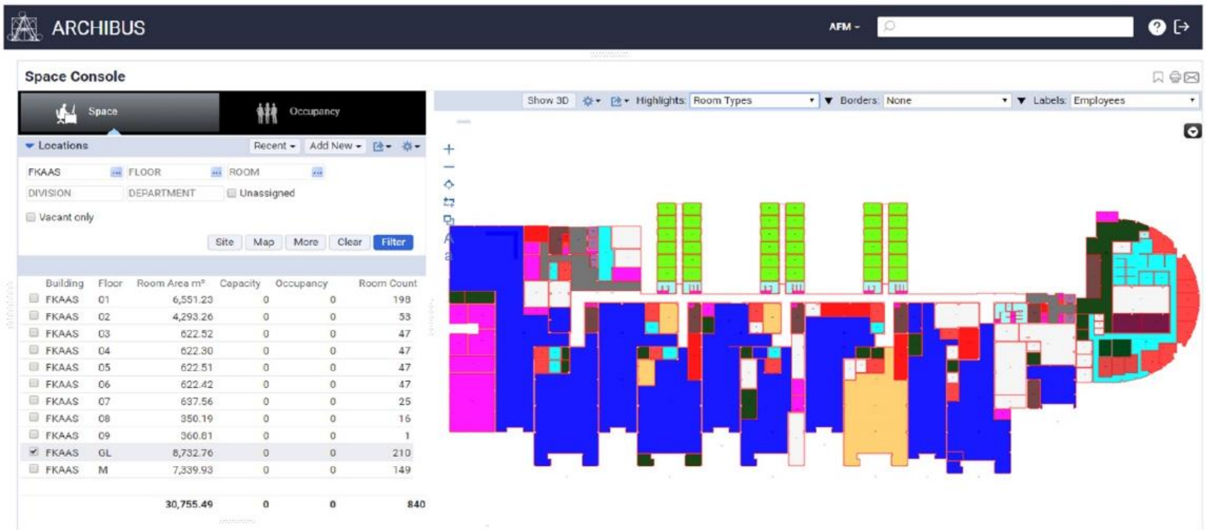


Figure 41: 2D view of spaces in Archibus(Solla et al., 2020).

Both 2d and 3D view of the model view is available in the Archibus platform additionally the space category can be identified with different colours that holistic vie of the space both in 2d view and in 3d view. Moreover, the 3D navigation facility makes easy to preview the building from different angles, which helps the facility management plan with space management and other services. (Solla et al., 2020)

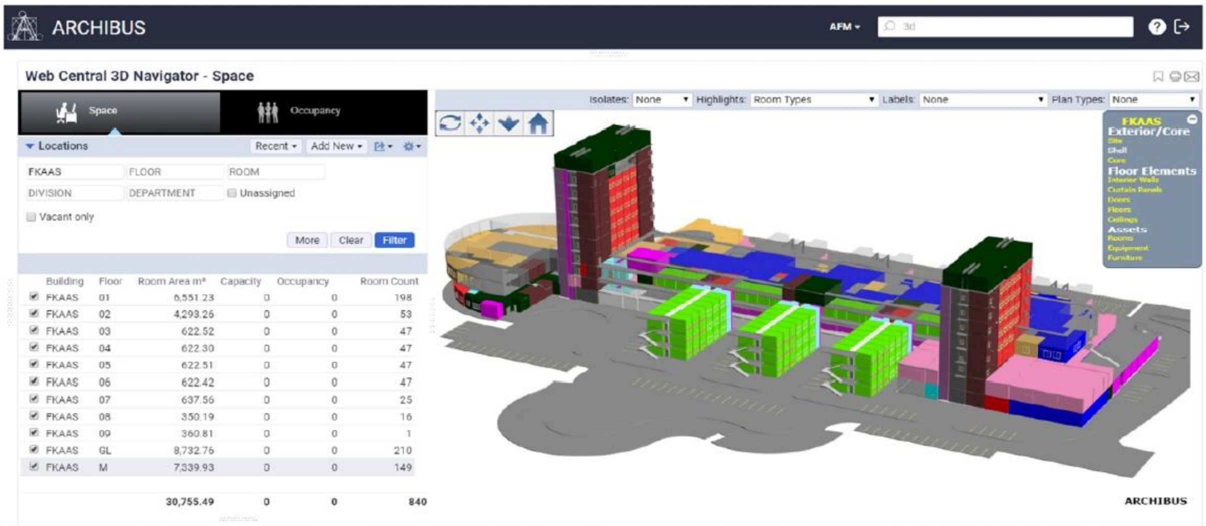


Figure 42: 3D view of the case building with space in Archibus(Solla et al., 2020).

BIM integration with Archibus makes space management part of facility management reliable and easy for the facility management. BIM is working as the main geometric representation of the facility in the Archibus platform; additionally, BIM can be used as a non-geometric information resource for other facility management services. (Solla et al., 2020)

Case Analysis

Case study 3 showed that BIM can be adapted for space management services. Space management service is one of most necessary services in co-working service place. This case is a use case example, and BIM has integrated within a space management service provider platform (Archibus). As BIM is already integrated into a service provider platform, no further development is required for this integration process. The integration of BIM enables the 2D and 3D representation option, including navigation facility. And all the space can be categorized according to times, both in 2D and 3D view. All this option makes facility management task easy in a space management context. The real-time space inventory report generation feature saves much workload for the facility management department. Moreover, the report generating facility increase the efficiency of further space planning.

There is no information mention about the space booking service facility for the occupants or the user. Furthermore, detailed information about the occupancy track is also not described in the case. Some other services also can be introduced in this service with further deployment. Such a holisting view of occupied and free space for a specific time or day can be introduced with a 2D visualization facility of the BIM model.

Chapter 6

Required Level of Information in BIM for Service Management

6 Required Level of Information in BIM for Service Management

Building information modelling has enough potential to be utilised throughout the whole life cycle of a built asset, but the amount of information, structure of information, and the quality of the information is a prerequisite to help in the operational phase of the built asset. Service management refers to those services that need to be provided in a built asset operational period. Service management in the operational period of a built asset can be explained as the summation of the facility services and the asset management services. However, the most common service between facility management and asset management is common, and the ultimate goal for both facility management and asset management is the same.

BIM adaption only for the design and construction phase is considerably more frequent than the BIM adaption for facility management concerns or the operational phase of the built asset. Most BIM tool practitioners in the design phase of the building are concerned about the only design perspective, such as clash detection and often ignore the data accessibility for the operational phase (Liu and Issa 2014). Eadie et al., showed in their study, only 10% of the projects are concerned about the benefits of facility management during the adaption of BIM; the rest consider the cost-benefit of adopting BIM for the design phase. According to Becerik et al., 80% of the working hours of Facility management personnel are spent in seeking the correct information in terms of messing information from the design phase. As the maximum life of a built asset is the operational phase and the more significant portion of cost also need to spend in the operational phase, the facility management or asset management service is significant. BIM can make great deference if the facility management service is considered from the design phase of the building.

6.1 Information level in BIM for the operational phase

Facility management service is mainly responsible for managing services in the built asset operational period combining with asset management. Facility management is an integrated organisational management process responsible for ensuring that the building and infrastructure are maintained correctly and used properly with continued corrective measures (Matarneh et al. 2019). Facility management needs to perform various kinds of services to maintain a good built environment for the building occupants and improve building performance.

Facility management service faces challenges to have the correct data on time within a comprehensive package to execute their work daily and for long term schedules. Useful and accurate data is a prerequisite for an effective facility management service and asset management service to make any decision. Various technology is now used for facility management services such as Computerised Maintenance management System (CMMS) and Computer-Aided Facility management system. Whatever the facility management system or technology CAFM/CMMS, data are required for the services; those data must be inputted manually or need to transferee from other data domains with the data exchange protocol. Manual data collection and input to the facility management system are time-consuming, error-prone, laborious (Matarneh et al. 2019).

Implementation of Building Information Modelling in the operational phase of the built asset through the integration of BIM in facility management provides a solution for getting ready information from the design phase (Matarneh et al. 2019). Availability of accurate, relevant, and update information in the Facility management system make the operational and maintenance system more efficient and cost-saving. The ultimate benefits of BIM integration in facility management depend on the availability of the required information for the operational BIM. It is a common statement by the facility management authority that the involvement of the FM personal in the design phase of the building is necessary to ensure the maintaining information quality in BIM from the early stage of the project/built asset. In the handover stage, it must ensure that the required information is also handed over within the handover package (Bozorgi et al. 2018 and Fraghaly et al. 2018).

Data format or standardisation is also an issue to ensure the data exchange between the BIM and the facility management or asset management platform. Construction Operations Building information exchange (COBie) standard is mostly suggested standard for non-geometric information exchange. Construction Operations Building information is a spread sheet format in which non-geometric data of construction projects can be organised in structured form and essay to use by the owners or the facility managers in the operational phase (Thabet et al. 2016). There are several tools and method already available now to exchange information to the asset management or facility management platform, but identifying the required information and information exchange from the design phase to the operational phase (input into facility management or asset management system) is a challenging issue in built asset management (Matarneh et al. 2019).

Matarneh et al. 2019 has represented a list of 45 items of information required for the facility management or asset management, which are discussed in the various previous related research work. All information required in BIM for facility management or asset management can be divided into five different categories such as following:

i) Facility related general information
ii) Energy-related information
iii) Maintenance management information
iv) Space management information
v) Information for asset management. (Matarneh et al. 2019).

Table 8 : List of required information in BIM are discussed in related research (Adopted from Matarneh et al. 2019)

No.	Information	**Frequency** (Number research study discus this information requirement)
1	Design criteria	4
2	Handover documentation	7
3	Spare part information	9
4	Manufacturer/vendor info	17
5	Serial number	10
6	Asset location	18
7	Warranty info	21
8	Replacement cost	9
9	Installation guide	3
10	System/equipment performance	4
11	Expected life	8
12	Sequence of operations	3
13	Maintenance history	6
14	Preventive maintenance schedules	12
15	Inspection reports	5
16	Key plans	4
17	Asset name	10
18	Systems and their associated systems	8

19	Equipment lists	3
20	Asset description	13
21	Identification number	14
22	Spatial information	11
23	Legal regulations and compliance	6
24	Make and/or model	7
25	Installation date	5
26	Asset specification	11
27	Purchase information	5
28	28 Bar code information	9
29	Performance code	4
30	O and M manuals	8
31	Classification	11
32	Asset Condition	4
33	Life cycle cost	4
34	Room tag	4
35	Accessibility performance	4
36	Certificates	3
37	Sustainability performance	6
38	Facility general information	6
39	Contracts	2
40	Occupancy ratio	4
41	Capacity	4
42	Ownership	2
43	GIS coordinates	5
44	Risk assessments	5
45	Locations of control panels/valves	2

Farghaly et al 2018, prepare a taxonomy for BIM and Asset management interoperability where the authors showed that 60 different kinds of information are required in an Asset Model for the energy consuming item. The framework was named as ACE-IM (asset consume energy information management). All the required information is divided into six types: space/location, classification, asset capex, specification, warranty information, and maintenance information. (Farghaly et al 2018)

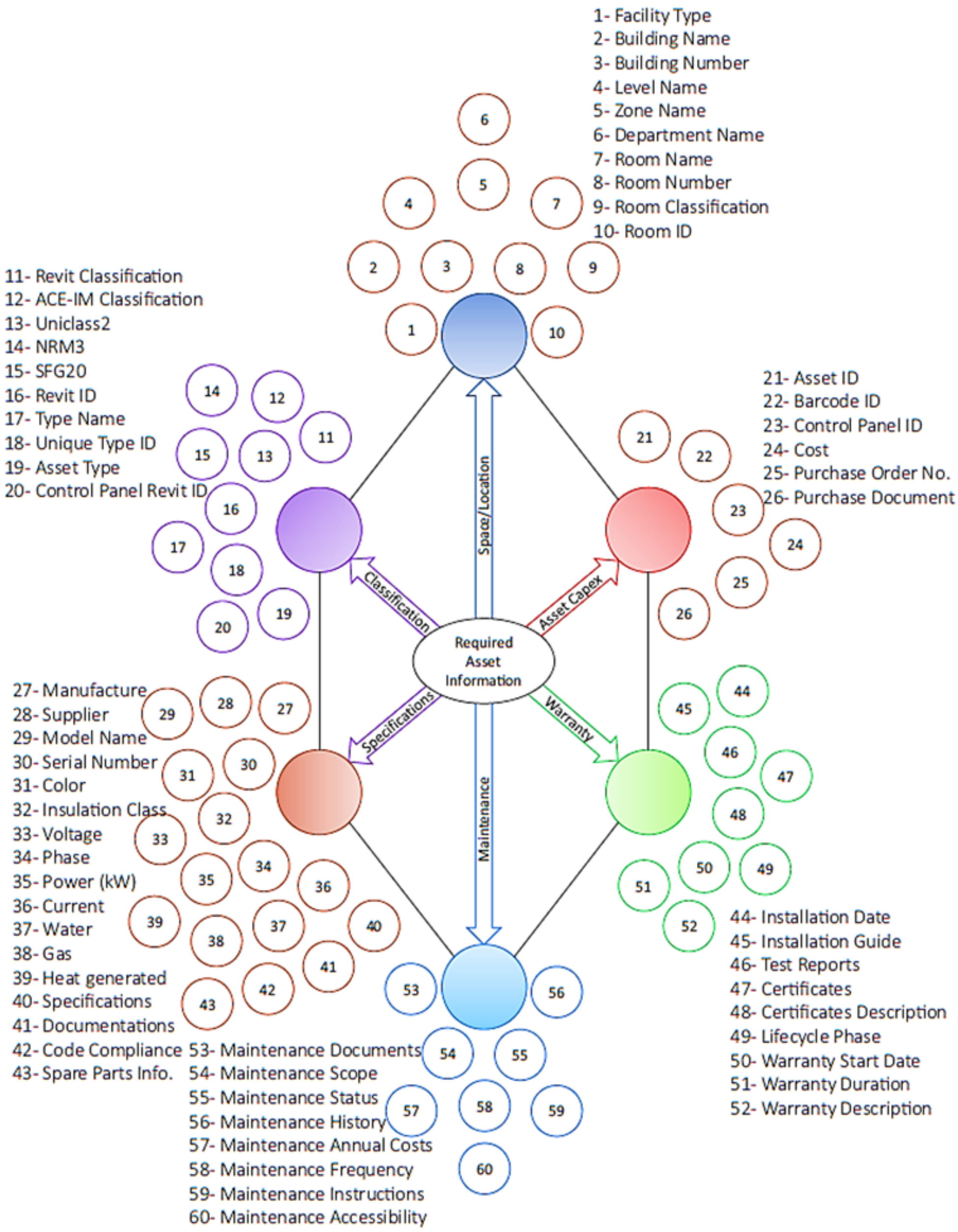


Figure 43: list of 60 kinds of information of energy consumption items required in asset information management (Farghaly et al 2018).

Both figure number 44 and 45 showing that how much information is required in a asset model for all energy-consuming items in a building beyond the only geometric model of the asset. The high level of information (LOI) availability is required to develop an asset management system and facility management, which mainly comes from the design and construction period.

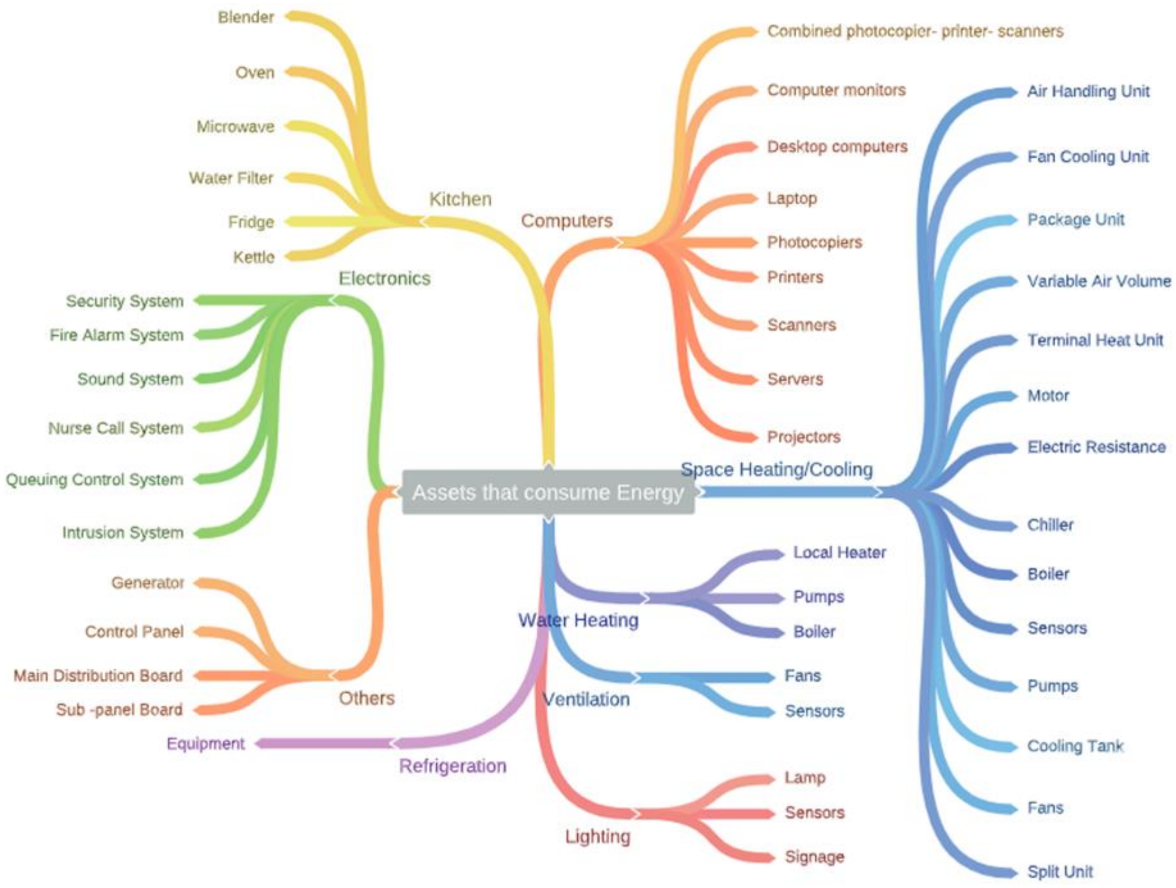


Figure 44: list of commonly available energy-consuming items in a building. (Farghaly et al 2018).

6.2 Level of Asset Information Model

Kristian Grani, 2016 proposed an Asset Information Model maturity level approach that can indicate information required level in the Asset information model. As the design phases of the built asset have been changing from paper to CAD and Cad to BIM, the facility management also moves forward in the same direction. Therefore, asset information model can be described as integrating geometric and no-geometric data of the built asset in a structured format. The AIM contains the as-built documentation, design and construction information, data generated through operation and maintenance of assets and data within the AIM continuously being updated and supplemented by the new data throughout the life cycle (Kristian Grani 2016).

The AIM level as Kristian Grani, 2016 proposed are following:

Asset Information Model (AIM) Level 0:

In AIM level 0, geometric data of the model is stored on paper or in the electronic plot files. Other data and documentation are kept as physical paper-based storing processes or in PDF format mostly. Some of the structure data may be stored in a simple database such as a spreadsheet. Some classification and pointers may be available among the different parts of facility management, but there is no connectivity or navigation possibility within those parts. Moreover, there is significantly less option to edit any handed over documents.

Asset Information Model (AIM) Level 1:

AIM Level 1, refers to the Computer-Aided Facility Management (CAFM) where the 2d floor plans are linked within CAFM system. In this level, intelligent floor plans are kept up-to-date, and space are stored as polygons, other component and equipment are stored as blocks. This level AIM enables space management and asset management through linked data and documents where some data are stored in a database and editable. But most of the documents are stored in pdf format.

Asset Information Model (AIM) Level 2:

Asset information Model Level 2 indicate the integration BIM in the Asset management system or CAFM system. In this level the data and documents in the CAFM system linked with the BIM model object and BIM viewer functionality are integrated within CAFM system. All the space attributes and other equipment of built asset are presented in 3D environment with more intellectual data. Data import from COBie in CAFM domain is possible in the AIM level 2 but some properties in the model can be accessible only through the BIM viewer function. Data exchange between CAFM domain and BIM depends on the format support to the CAFM domain and depends on the BIM tools data format.

Asset Information Model (AIM) Level 3:

In level 3 of Asset Information Model, the FM/Asset management system can import all data from the as-built BIM model with the necessary information intact. All the geometric information and non-geometric data are interlinked in this level of the AIM model. Data required to prepare a regular maintenance schedule and corrective measures for the long term asset management strategies should be available in this Asset Information model. Moreover, all information is available in this level of Aim that is required to implement the asset management strategies, including regular maintenance and long term corrective action. (Kristian Grani 2016).

Above Asset Information Model levelling system clearly indicates what kind of data and data standardisation is required for an enriched Asset management system. Of course, only data availability can not the asset management process, but the data interoperability between BIM model and asset management domain is necessary for an enriched asset man agent system in terms of BIM integrated asset management system.

6.3 Validate FM system information requirement process

Necessary and accurate information input in the BIM in all project stages from the design phase is vital to get an informative BIM model for the operational phase of the built asset. COBie is a commonly used format for the non-geometric information of the BIM model, but if unnecessary and inaccurate information input in various stages of construction in BIM can make COBie unmanageable and make huge obstacles in the operational phase building (Fraghhaly et al., 2018).

Maintaining the Construction Operations Building Information Exchange (COBie) specification from the project planning stage makes it easy for facility managers and owners to identify the required information for the FM system. Early integration of COBie in the project help also to maintain quality checking for the required information in every stage of the project phase, and this checking facility makes it easy to get a rich database of the built asset in the handover phase. As COBie is an open data format, it makes easy and seamless data exchange within the BIM and FM system. (Matarneh et al. 2019).

Matarneh et al. 2019 proposed a process to gain a validated informative COBie compliant BIM for the facility management system with few steps as below:

- The facility management team and the owner will confirm the required information for the operational phase then they will provide the final list of the required information to the design team through a COBie compliant excel file.
- The design team will make ensure that all required information is available in their design BIM model. Next, FM team, owner, and the design team collaboratively check the information required in the design model and make necessary modifications as per retirement if necessary. Then the design team will hand

over the BIM-design model, including the COBie spreadsheet to the construction team with maintaining the necessary specification.

- In the construction phase, the construction team is responsible for developing a COBIe compliant As-build BIM model and ensuring that all pre-identified FM system information requirements availability in the model. After the construction phase of the project construction team will hand over the as-built BIM model and COBei spreadsheet to the facility management team.
- After taking over the as-build BIM model and COBie spread sheet and their pre-defined required information, the FM team will enrich the same COBie sheet with the necessary information to create preventive maintenance strategies.
- In the final stage facility management team create link between COBie parameters and facility management parameters to maintain the FM system using open standard COBie. (Matarneh et al. 2019).

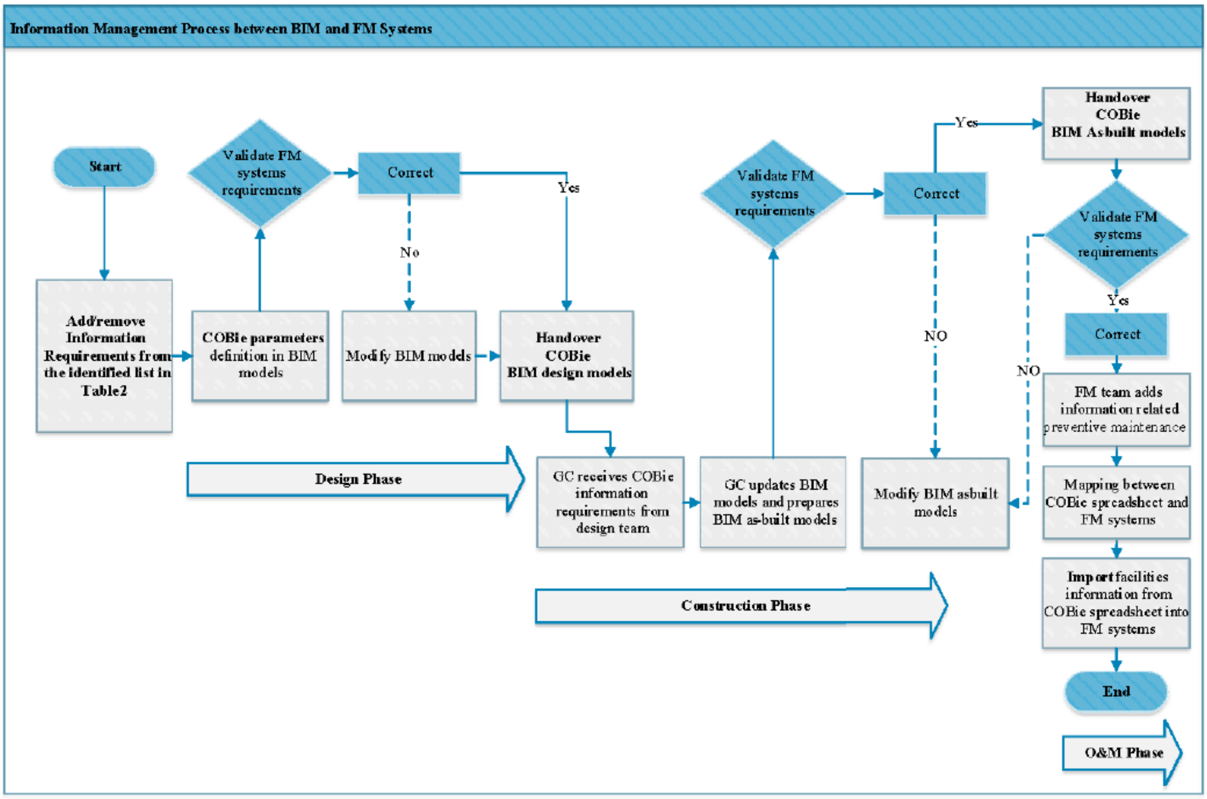


Figure 45: Process diagram for information management for FM system throughout the project phase (Matarneh et al. 2019).

Chapter 7

Discussion

7 Discussions

In the last few decades, technology has been changing rapidly due to the rapid development of information technology data becoming a more valuable asset day by day. All sectors such as the manufacturing industry, service sectors have been improving their efficiency with the help of modern technology. Building Information Modelling (BIM) is the most revolutionary technology to change the Architecture, Engineering & Construction (AEC) industry. Though BIM has considered the most successful modern technology in the AEC industry, it has been showing its potential beyond the construction industry. BIM is already in practice in the operational phase of the built asset, but it is still a topic of discussion and needs more development.

7.1 Benefits of BIM

Integration of BIM in any service management system for operational facility management of built assets can fulfil the information required regarding the built asset if the design BIMs and construction BIMs are prepared to maintain the standard to be used for the whole life cycle of the buildings. BIM can be used as the initial database for any services in the operational phase of those built assets, where BIM was implemented in the design and construction phase. BIM adaption for the operational phase is also possible for the existing buildings where BIM was not applied in the design or construction phase.

Operational service management is comparatively complex in large scale built assets such as educational institutes, university campuses, commercial co-working office space, and other spaces where co-working service is a matter of concern. Some particular services are more crucial and challenging to manage in co-working service provider built assets, for example, space management, indoor environment monitoring for maintaining user comfortability, efficient energy management & energy consumption monitoring, immediate response to the customer/user requirement, automated utility services according to user need.

Space management is one of the most prior services in co-working services places, whether a university campus or commercial co-working office. In section 4.1 and in case study 3, it has been found that BIM can improve space management as a standalone tool or with integration in other space management applications. The most necessary features in space management are space inventory, occupancy frequency rate monitoring, and efficient use of available spaces. BIM integration makes the space management task easy, efficient, and less time-consuming by providing geometric and non-geometric information of the built assets with 3D and 2D visualization options. Additionally, the BIMs model can be used to check occupancy capacity, find the most suitable layout of co-working space, and offer various layout options visualization for large spaces.

A good indoor environment is essential for any workplace, and an indoor work environment monitoring system is a prerequisite to maintain a suitable environment for the occupant. The BIM and IoT integrated framework was proposed to monitor the indoor environment monitoring system in case studies 1 and 2. BIM was adapted as a backend resource for multiple services, including indoor environment monitoring, where BIM facilitates the 2D plan view of any floor indicating thermal condition. In case study 2, the indoor environment data can be monitored within BIM model (Revit). There are few more examples in section 4.2, showed that BIM has enough potential for indoor environment monitoring. Indoor comfort is more crucial for the commercial co-working space as the customer/user is not from the same organization and can leave the place any time due to discomfort.

Efficient energy management is another challenging facility management service in the operational phase of any large scale built asset that provides workplace facility or co-working service facility such as university campuses, office space. A real-time energy monitoring system helps to reduce energy consumption. An energy monitoring approach is also included in the proposed framework of BIM and IoT integration in case study 2. There are few examples of how the energy consumption monitoring information and indoor environment monitoring data help reduce the energy waste and identified problems in the lighting system in case study 2.

Automated utility service according to user requirements can improve customer/user satisfaction in the workplace and reduce facility management workload, ultimately saving FM working costs. There is an approach discussed in case study 1 where user can select their expected thermal condition in a specific space through a space booking service. In this service, BIM was mentioned at the process stage, but BIM data can be utilized for spatial information and equipment information as already was already integrated as a service resource. For a holistic view of booked and free space of a floor area in a glance, BIM 2d view can be utilized as BIM integration already made for other services in the same system in case study 1.

Some other minor uses of BIM can help the co-working service; for example, in marketing service, commercial co-working space providers can promote their business by enabling the virtual tour of built asset model through a web browser for the customer to check the office layout before booking the room or space. In addition, customers also check the available and free space for booking in the BIM model layout.

Integration of BIM in the workplace management system makes the total system enrich with detailed asset information. In addition, BIM provides the workplace management system 2D and 3D representation options of the facility, which help to maximize the efficiency of various services of the workplace management system such as space management services, asset management services, reactive and preventive maintenance schedule and execution plan. The Integrated Workplace Management System is an approach where all operational services such as facility management, asset management, real estate management of a built asset can be managed within a single platform. BIM integration in Integrated Workplace Management System makes it possible to increase functionality and improve every service efficiency. Moreover, the operational cost will decrease as all service management will be possible from the same platform.

7.2 Challenges of BIM Adaption

BIM has enough potential to be adapted in the operational service management of built assets, whether working or co-working service places. However, co-working service places require intensive focus on some services such as efficient space management, energy management, indoor environment quality management, user-requested service management. Along with this thesis study, it is also found that BIM adaption can improve those services that especially require in co-working services. However, integrating BIM in the workplace management system has some challenges.

The intensive literature review and case studies in chapter 4 and Chapter 5 showed that BIM adaption is possible for various service management of co-working service places, but the discussed framework needs more development to apply in the real-practice cases with expected benefits. For example, the IoT and BIM integration frameworks were proposed in case studies 1 and 2, but only for indoor environment monitoring and energy consumption monitoring. Additionally, those frameworks were implemented in the pilot projects. Case study 3 showed a practice case example, but it is only for space management service.

Data interpretability from BIM to other service systems is a common issue in integrating BIM in operational service management systems. In addition, different service providers develop their platform with different system architecture and support limited file formats, which make the BIM integration process clumsy with their service platform, and seamless data exchange faces difficulties. Therefore, OpenBIM standard practice needs to ensure seamless data interpretability and necessary API (Application Programming Interface) development is required to integrate BIM with different service systems in the operational service management of the built asset.

Information quality and information availability in BIMs are critical factors in BIM adaption in operational service systems. In terms of new projects where the BIM process applied from planning and design face information requirement for operational phase need to consider from the very early stage of the project so that all necessary information will be available. In actual practice, it is not maintained in most projects that need to input much information in the BIM model to be useful in the operational service of built assets. For existing buildings where the BIM process was not applied in the construction process, preparing new BIM models to fulfil facility management or asset management requirements is a challenging and cost-intensive task.

BIM adaption in Integrated Workplace Management System (IWMS) can do all necessary services in one platform in operational service management of co-working service space or other large scale workplaces, including educational institutes. However, implanting IWMS is initially cost-intensive and needs knowledgeable professionals to maintain all necessary updates to be functional with its efficiency. Moreover, implementing IWMS or facility management systems or asset management systems should be beneficial in terms of ROI (Return of investment); otherwise, it will not be considered beneficial financially. Addinaly, if the BIM models need to prepare only for any operational service system, it will increase the initial service system implementation cost.

Chapter 8

Conclusion

8 Conclusion

This thesis study aimed to investigate the potential of BIM in the service management in the operational phase of the built assets from co-working service place perspectives. After analysing the findings from the intensive literature review and three case studies in the previous chapter, this thesis study found that BIM can improve service management in the operational phase of co-working service places.

BIM can improve the operational services of workplace management through integration with other service systems. BIM can also help the operational service management of built assets without integration only as an information resource of built assets, but the improvement of service management through this way is not significant. Few facts are crucial for BIM adaption in operational service management to make remarkable improvements. Those crucial facts are following:

- Enrich BIM models with the required quality information for the operational service management phase of the built asset.
- An integrated service management system (such as IWMS), where BIM integration is possible as a built asset information source with the required data interpretability facilities.
- BIM data and 2D & 3D representation facilities need to be accessible by the various services of the integrated service management system. For example, space management services, indoor environment monitoring, energy management service.

The potential of BIM can be utilized with maximum efficiency in operational service management of built assets by ensuring the above requirements. In case studies 1 and 2 of this thesis, IoT and BIm integration showed BIM potential for different services individually, but in reality, the individual system for every single service for a built asset is not implementable in general practice. Thus Integrated workplace management system approach(cover all necessary operational services of a built asset) and BIM integration can make a platform where the potential of BIM can be utilized properly. However, BIM integration in other operational service management systems increases service efficiency, such as facility management service, asset management service, and real estate management service, but IWMS (details in section 4.5.2) approach covers all those services in one platform.

Though the BIM has enough potential to improve the service management in operational service of co-working service place the ultimate benefits of BIM adaption in operational phase depends the built asset also influenced on financial benefits. The size of the built asset, the remaining service life of the asset, and the type of built asset can consider issues from a financial perspective. Addressing financial feasibility was not the objective of this study.

After finding the fact according to the thesis objectives, it can be stated that BIM has enough potential to improve the service management of co-working service places.

Declaration of Authorship

I hereby declare that the attached Master's thesis was completed independently and without the prohibited assistance of third parties, and that no sources or assistance were used other than those listed. All passages whose content or wording originates from another publication have been marked as such. Neither this thesis nor any variant of it has previously been submitted to an examining authority or published.

Helsinki, 06/09/2021

Location, Date

Signature of the student

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