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**BUILDING INFORMATION MODELLING (BIM).
DEFINING USER'S PROFILES FOR ACCESSING THE BIM MANAGEMENT
SYSTEM FOR EFFICIENT RENOVATION IN BUILDING**

Supervisor: Prof. Bruno Daniotti

Co-Supervisor: Prof. Vittorio Caffi

Master Thesis by:

Rahul Manjunatha – 883358

Nguyen Le Trung – 897931

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ABSTRACT

According to the current situation of building in Europe, there is a significant amount of building over 50 years old, which causes high energy consumption due to the degradation of building envelope and building components. In addition, due to the EU's (European Union) goal to cut down 80% of primary consumption by 2050 (European Climate Foundation, 2010), backed up by the definition and implementation of Zero Energy Building (ZEB) and nearly Zero Energy Building (nZEB) targets, there is an obviously high demand for building renovation activities in Europe. To satisfy this target, the Architecture, Engineering and Construction (AEC) industry in Europe need to overcome a significant transformation in design and management technologies from using 2D and 3D CAD models towards a semantically enriched digital model, that is Building Information Modelling (BIM).

BIM technologies brings an undeniable benefit of managing information in digital environments along the whole building life-cycle, which cause using enriched information effectively from initial stages of any construction project. Therefore, BIM is used mainly for new buildings by several stakeholders in the AEC industry; however, there are some obstructions need to be solved for implementing BIM technologies in energy efficiency renovation processes. The first problem is devising an effective and reliable way to rapidly capture 3D digital models of an existing buildings and use this information for following design stages of renovation in advance. Hence, the cost efficiency, time saving, and energy efficiency are maximised for renovation process, which is also increasing the productivity of all stakeholders involved in building life-cycle. After that, for energy efficient renovation, there is a need of a good BIM facility management tools to improve the connection between BIM and Building Automation and Control Systems (BACS) in the building for supervising the result of design and forecast the performances in building operation. However, the construction stage of renovation project must minimise the impacts on inhabitants, who usually continue living inside the building during the whole stages. Therefore, the most challenged things in BIM for building renovation as an interoperability platform are collaboration and scaling abilities. To address all of these problems, specific methods and tools for all stages of renovation processes (from initiative, design stages, construction to management and end of life in a building life-cycle) need to be proposed as well as developing a BIM implementation guidelines for renovation project, and creating an Common Data Environment (CDE) with different connected BIM Tools.

This thesis focuses on defining the user's profiles for accessing the BIM management system for efficient renovation in building by observing the way of collaboration between identified stakeholders. In detail, each stakeholder when log in to the management system will provide the access to specific information and function according to the logged profiles and to what they need for their tasks. There are 4 main groups of profiles, which are designers and architects, construction companies, service companies and inhabitant in the building. The information is shown particularly for different stakeholders based on their involvement in each task of each stage of the renovation process. Creating a user's profile in general is a good way to make a general baseline for BIM implementation guidelines as well as a good BIM management system to use through the whole renovation process. The output of this thesis will be defining the users' profile for accessing the BIM management system and the functions allowed for each type of users.



To achieve this goal, there is a very important step need to be performed. It is analysis and definition of relevant activities and involved stakeholder in building renovation, as well as defining which tasks that is beneficial from BIM and involved to BIM technologies. Hence, deep analysis of building renovation process is necessary, which focus on the information workflows between involved stakeholders that related directly or indirectly to whole process. Furthermore, this work also improve the communication and data sharing between involved actors as well as avoiding data duplication and conflicting by an efficient data organisation. Afterward, it is an outline of how BIM support the rationalisation of information flow for different renovation process stages in a building life-cycle (initiative, initiation, concept design, preliminary design, developed design, detail design, construction, use and end-of-life). The output of this step is the essential information to determine a user's profiles in BIM management system for each group of stakeholders.

This thesis result is a small contribution for the project of a BIM-based toolkit for efficient renovation in building (BIM4EEB). Due to the complexity of renovation project, which usually start from an existing building with too many different conditions, the information workflow and user's profiles is varied between projects. However, the result shows a big picture of the collaboration, relative tasks of each stakeholders in building renovation process as well as the link between BIM technologies and energy efficient renovations. It is a good reference baseline to develop a good BIM management system for a new building life-cycle that start from a renovated existing building.

Keywords: Building Information Modelling, Built Environment, Building Renovation, BIM Management system, Efficient Renovation, BIM-based toolkit

SOMMARIO

Secondo l'attuale situazione dell'edilizia in Europa, c'è una quantità significativa di edifici di oltre 50 anni, che causa un elevato consumo energetico a causa del degrado dell'involucro dell'edificio e dei componenti edilizi. Inoltre, a causa dell'obiettivo dell'UE (Unione Europea) di ridurre l'80% del consumo primario entro il 2050 (European Climate Foundation, 2010), sostenuto dalla definizione e dall'implementazione degli obiettivi di Zero Energy Building (ZEB) e quasi Zero Energy Building (nZEB), c'è ovviamente una forte domanda per le attività di ristrutturazione degli edifici in Europa. Per soddisfare questo obiettivo, l'industria europea dell'architettura, dell'ingegneria e delle costruzioni (AEC) deve superare una trasformazione significativa nelle tecnologie di progettazione e gestione, passando da modelli CAD 2D e 3D a un modello digitale semanticamente arricchito, ovvero il Building Information Modelling (BIM).

Le tecnologie BIM apportano un innegabile beneficio nella gestione delle informazioni in ambienti digitali lungo l'intero ciclo di vita dell'edificio, il che comporta l'utilizzo di informazioni arricchite in modo efficace fin dalle fasi iniziali di qualsiasi progetto di costruzione. Pertanto, il BIM è utilizzato principalmente per i nuovi edifici da diversi stakeholder dell'industria AEC; tuttavia, ci sono alcuni ostacoli che devono essere risolti per implementare le tecnologie BIM nei processi di rinnovamento dell'efficienza energetica. Il primo problema è l'ideazione di un modo efficace e affidabile per acquisire rapidamente modelli digitali 3D di un edificio esistente e utilizzare queste informazioni per seguire in anticipo le fasi di progettazione e ristrutturazione. In questo modo, l'efficienza dei costi, il risparmio di tempo e l'efficienza energetica sono massimizzati per i processi di ristrutturazione, il che aumenta anche la produttività di tutti i soggetti coinvolti nel ciclo di vita dell'edificio. Dopo di che, per una ristrutturazione ad alta efficienza energetica, c'è bisogno di un buon strumento di facility management BIM per migliorare il collegamento tra BIM e i sistemi di Building Automation and Control Systems (BACS) nell'edificio per supervisionare il risultato della progettazione e prevedere le prestazioni nel funzionamento dell'edificio. Tuttavia, la fase di costruzione del progetto di ristrutturazione deve ridurre al minimo l'impatto sugli abitanti, che di solito continuano a vivere all'interno dell'edificio durante l'intera fase. Pertanto, le cose più impegnative nel BIM per la ristrutturazione degli edifici come piattaforma di interoperabilità sono la collaborazione e le capacità di scalabilità. Per affrontare tutti questi problemi, è necessario proporre metodi e strumenti specifici per tutte le fasi dei processi di ristrutturazione (dall'iniziativa, alle fasi di progettazione, alla costruzione, alla gestione e alla fine del ciclo di vita dell'edificio), nonché sviluppare linee guida per l'implementazione del BIM per i progetti di ristrutturazione e creare un ambiente comune dei dati (CDE) con diversi strumenti BIM collegati.

Questa tesi si concentra sulla definizione dei profili degli utenti per l'accesso al sistema di gestione BIM per una ristrutturazione efficiente dell'edificio, osservando le modalità di collaborazione tra gli stakeholder identificati. In dettaglio, ogni stakeholder quando si connette al sistema di gestione fornirà l'accesso a specifiche informazioni e funzioni in base ai profili registrati e a ciò di cui hanno bisogno per i loro compiti. Ci sono 4 gruppi principali di profili, che sono progettisti e architetti, imprese di costruzione, società di servizi e abitanti dell'edificio. Le informazioni sono mostrate in particolare per i diversi soggetti interessati in base al loro coinvolgimento in ogni compito di ogni fase del processo di

ristrutturazione. La creazione del profilo di un utente in generale è un buon modo per creare una base generale per le linee guida di implementazione del BIM e un buon sistema di gestione del BIM da utilizzare durante l'intero processo di ristrutturazione. L'output di questa tesi sarà la definizione del profilo degli utenti per l'accesso al sistema di gestione BIM e delle funzioni consentite per ogni tipo di utenti.

Per raggiungere questo obiettivo è necessario compiere un passo molto importante. Si tratta dell'analisi e definizione delle attività rilevanti e degli stakeholder coinvolti nella ristrutturazione degli edifici, nonché della definizione dei compiti che sono vantaggiosi per il BIM e coinvolti nelle tecnologie BIM. Di conseguenza, è necessaria un'analisi approfondita del processo di ristrutturazione degli edifici, che si concentra sui flussi informativi tra gli stakeholder coinvolti che si riferiscono direttamente o indirettamente all'intero processo. Inoltre, questo lavoro migliora anche la comunicazione e la condivisione dei dati tra gli attori coinvolti, evitando duplicazioni di dati e conflitti da parte di un'efficiente organizzazione dei dati. In seguito, si tratta di uno schema di come il BIM supporta la razionalizzazione del flusso di informazioni per le diverse fasi del processo di ristrutturazione in un ciclo di vita dell'edificio (iniziativa, avvio, progettazione concettuale, progettazione preliminare, progettazione sviluppata, progettazione dettagliata, costruzione, uso e fine vita). L'output di questa fase è l'informazione essenziale per determinare i profili di un utente nel sistema di gestione BIM per ogni gruppo di stakeholder.

Il risultato di questa tesi è un piccolo contributo per il progetto di un toolkit basato sul BIM per una ristrutturazione efficiente nell'edilizia (BIM4EEB). A causa della complessità del progetto di ristrutturazione, che di solito parte da un edificio esistente con troppe condizioni diverse, il flusso di informazioni e i profili degli utenti variano da un progetto all'altro. Tuttavia, il risultato mostra un quadro generale della collaborazione, dei compiti relativi di ogni stakeholder nel processo di ristrutturazione degli edifici e del legame tra le tecnologie BIM e le ristrutturazioni ad alta efficienza energetica. È un buon punto di riferimento per sviluppare un buon sistema di gestione BIM per un nuovo ciclo di vita di un edificio che parte da un edificio esistente ristrutturato.

Parole chiave: Building Information Modelling, Built Environment, Building Renovation, BIM Management system, Efficient Renovation, BIM-based toolkit



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We wish to thank all participants of the project BIM4EEB for sharing necessary documents and data, which give us a clear view about the status of efficient building renovation in Europe. We wish the project completes successful to achieve the goals of low carbon emission in building sectors.

We are grateful to the entire departments of "School of Architecture Urban Planning Construction Engineering" for their continuous support and friendly environment which eased my nervousness and pressure up to an appreciable amount. Additionally, to all the Authors, which books, scientific papers, journals etc. were a source of inspiration and motivation in putting our thoughts together whilst writing this thesis report.

We would love to share all our privilege for being students of Politecnico di Milano. It had been our honour to be a part of such a wonderful university, professors and students. The environment on the university campus is so inspiring and friendly that it took no time for us to get accustomed to be a part of such a university which is so rich in culture and heritage. Now we are gifted with wide-stretched horizons of knowledge, eagerness to learn and with the new way of thinking and understanding different situations. Thank you.



PREFACE

The dissertation is an original intellectual work carried out by the authors, Rahul Manjunatha and Nguyen Le Trung. The thesis was carried out as part of the master's programme in Building and Architectural Engineering at Politecnico di Milano. The following thesis has been developed further by the author, Rahul Manjunatha which consist of public works and Use-cases as additional chapters into this thesis. The data using to analyse in this thesis is the result of collaborative research from the project BIM4EEB's team.

As international students, the opportunity to studied Building Process and Information Management at Politecnico Di Milano as well as the knowledge we gained on other subject in the course entuses us to search deep for a topic that will be our final dissertation project which will improve the BIM implementation in efficient renovation in building sectors.

Thanks to Prof. Bruno Daniotti for trusting and provide us this master thesis, we also would like to thank my co-supervisor, Prof. Vittorio Caffi for encouraging and guiding us all the time with his points of view and innovative ideas.

Our ambition with this master thesis is both to develop my understanding and implementation of BIM in efficient renovation in building, the BIM Tools and BIM Management System, and contributing to the project BIM4EEB.

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Rahul Manjunatha and Nguyen Le Trung



ABBREVIATION

2D	2 dimension
3D	3 dimension
AEC	Architecture, Engineering and Construction
AECO	Architecture engineering construction operation
AIA	American Institute of Architecture
AIM	Asset Information Models
API	Application Programming Interface
BACS	Building Automation and Control System
BAS	Building Automation Systems
BCR	Benefit Cost Ratio
BDS	Building Description System
BEM	Building Environmental Model
BIM	Building Information Modelling
BIM4EEB	BIM-based toolkit for efficient renovation in building
BLM	Building Lifecycle Management
BLMP	Building Lifecycle Management Platform
BMS	Building Management System
BPM	Building Performance Model
BPM	Building Product Model
CAD	Computer-Aided Drawing
CD	Concept Design
CDE	Common Data Environment
CDR	Construction Document Review
CMU	Carnegie Melon University
COBie	Construction Operations Building information exchange
CON	Construction
DBMS	Database management system
DD	Detail Design
DED	Developed Design
DPP	Discounted Payback Period
EC	European Commission
EDMS	Electronic Document Management System
EMCS	Building Energy Management and Control System
EN	European Norm
EOL	End-of-Life Stage
EU	European Union
FM	Facility Management
GBM	Generic Building Model
GLIDE	Graphical Language for Interactive Design
HVAC	Heating Ventilation and Air Conditioning
ICT	Information and Communication Technology
IFC	Industry Foundation Class
Infor.	Information
INON	Initiation
INVE	Initiative



IRR	Internal rate of return
IVI	Infrared and visual inspection
LCA	Life-cycle Assessment
LCC	Life-cycle Costing
LOD	Level of development
MC	Multi-criteria
MEP	Mechanical, Electrical & Plumbing
NBIMS	National Building Information Modelling Standard
NBS	National Building Specification
NIBS	National Institute of Building Science
NPV	Net present value
nZEB	nearly Zero Energy Building
ORR	Overall rate of return
PCM	Phase-change Material
PD	Preliminary Design
PLM	Product lifecycle management
POS	Post-occupancy survey
RIBA	Royal Institute of British Architects
RUCAPS	Really Universal Computer-Aided Production System
SPP	Simple Payback Period
UK	United Kingdom
USE	Use Stage
ZEB	Zero Energy Building

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CHAPTER 1

INTRODUCTION



1. INTRODUCTION

These days, when decarbonisation of energy use in the European building stock is speeded up before 2050, the European Commission (EC) is concentrating on delivering solid actions to the adoption of the transition towards a low carbon future [1]. It creates a high demand of renovation for current existing buildings in Europe, that most of them is over 50 years old and have low energy efficient building performance [2]. To achieve this goal, BIM is an excellent technology for implementation the renovation works quickly and efficiently; and, a BIM toolkit specialised for renovation process need to be proposed. This thesis provides a study about the information workflow for a building life-cycle starting from an existing building as the preliminary analysis to define the user's profiles for BIM management system, which is also a humble part related to the project BIM4EEB, a project funded by Horizon 2020 of EC.

1.1. BACKGROUND

Today, the development and completing of BIM technology is a big change in architecture engineering construction operation (AECO) industry. With the offer from European parliament, 28 European Member States are encouraged to use of BIM for publicly funded construction and building projects in EU by 2016. Therefore, BIM is used widely by all stakeholders of AECO industry for its ability of collaboration and interoperability, but also creates a challenge in controlling, tracking, monitoring the process, operation and maintenance of the building.

The ongoing renewal rate of the existing building is about 1% annually, compared to the goals (2.5%) for redeveloped the entire EU asset by 2050 [3], there is a need of a fast, guided and semantic procedures for building renovation works. BIM technology is adopted in various field of construction, but not deeply and totally in renovation process due to following reasons. First, the BIM model creation process for existing building is time consuming and costly due to the complex of digital information in a building. Secondly, for a renovation process, it is important and struggled to link the static building information itself to other dynamic sources of information collecting from sensors and user behaviour for BACS. Therefore, a toolkit needs to be developed for sharing, exchanging and updating information as well as improving communication and collaboration among different stakeholders involved in a renovation process. As a result, this toolkit will solve the following objectives; they are: maximising efficiency in building renovation, accelerating the market uptake across Europe towards a digital built environment, speeding data gathering and processing and ensuring interoperability among different stakeholders and tools, harmonising and providing common data exchange formats.

This thesis solves a small question in process of researching about a new toolkit for efficient renovation in building. In reality, most of existing building do not have a BIM management system for operation and maintenance through a whole building life-cycle as a new building today. To develop a typical BIM management system in a BIM toolkit and BIM retrofit strategies that focus on the ability of scalability and replicability with efficient time and

cost for BIM implementation, the whole process of building renovation is analysed. It is essential to determine all task and involved stakeholders in each task as well as the availability of BIM involved in each action. After that, the information workflow following BIM is determined as preliminary data for defining the user's profiles. Each user's profile represents a group of stakeholders, showing the necessary data as well as acquired required function to access the BIM management system. From that, methods and tools are proposed to solve current obstruction for adopting BIM technology in different stages of renovation processes, as well as developing a guideline and platform for a renovated building.

1.2. MOTIVATION FOR RESEARCH

In AECO industry today, BIM is adopted successfully in all field of construction industry, but not fully in renovation works. The idea of proposing a BIM-based toolkit for efficient renovation in building as the project BIM4EEB is a key factor for the transition towards low-carbon future in building stock sector. According to this purpose, with the support of academic supervisors from Politecnico di Milano, the thesis is implemented to generate a preliminary analysis of a big picture.

The main research purposes to start this thesis are as follow:

1. This thesis seeks the BIM-based methods and tools that is currently used in renovation work in European based on the implementation of BIM from literature and academic knowledge.
2. This thesis process provides a template for both academics and stakeholders to understand deeply about relationship between actions, actors and information workflow in a renovation project from initial stage to end-of-life stage, a big picture about a building life-cycle starting from a renovated building.
3. This thesis summarises the BIM-tools and BIM tool categories that is available in the market today, as well as its benefit and involvement into a building renovation process.

1.3. OBJECTIVES OF THE PROJECT

This thesis aims to propose a preliminary analysis about the relationship between actions, stakeholders and BIM tools in building renovation process. According to stages of building processes that have been defined in EN 16310 [4], there are 9 main stages in renovation process. They are as following time sequences: initiative, initiation, concept design, preliminary design, developed design, detailed design, construction, use and end of life for both building in private and public sector. Unfortunately, the documentation and maintenance history of an existing building is poor and interrupted due to some reasons from both owners, inhabitant and the maintenance workforces. Hence, the work of renovation needs an analysis to take consideration of information workflow in all relative activities to determine a methodology for implementing this kind of project. From that reasons, this thesis focus on 4 main following objectives.

First, it is renovation process analysis and definition of relevant activities and involved stakeholders. This task is a deep analysis of the building process in case there is any renovation interventions happens; and it also focus on the different information workflows for each

involved actor that participate directly or indirectly to the work itself. Since construction consists of natural complex work with a lot of information, it is necessary to improve the communication and data sharing in a reliable and fast way for the involved stakeholders, which the conflict between datasheets and data duplication is totally avoid. BIM can improve the data exchange by efficient managing information during different renovation process, and by connecting all involved actors through a single data exchange platform. The output of this objective is identifying the relevant activities and stakeholder as well as the information workflow in the renovation process.

Second, the involvement of BIM into renovation process need to be defined. Some activities can be managed more efficient if an appropriate BIM tools is used. Based on the information workflow, and the definition of activities, BIM tool category is determined for some group of works in each stage with a set of BIM tool available in the market within. The output of this objective is a summarised set of BIM tool that is suitable for renovation work, which provide function to solve the professional work as well as the ability of communication between all relevant stakeholders.

Third, the output of 2 previous steps is deeply analysed to define the user's profiles for accessing the BIM management system. Particularly, the BIM management system allow different functionalities and information accessible to different user's profiles, which are divided to 4 main groups as designers and architects, construction companies, service companies, and occupants. For each of the group, different information and functions are provided by the BIM platform.

Finally, we have the Use-case matrix which illustrate the of User profile-Use cases workflow in the first section explaining the actions and process to arrive at the listed use-cases and followed by the Use-case matrix which sums up the overall User profile-Use cases workflow.

1.4. OUTLINE OF THE PROJECT

This thesis is divided into 06 chapters with following respectively objectives:

Chapter 1: Introduction

This chapter describes the background of current situation in high demand for building renovation work in European as well as BIM adoption in building renovation. It explains the motivation for the research, the objectives of this master thesis, the outline of the project and finally the methodology to get its objectives.

Chapter 2: Building Information Modelling (BIM)

The purpose of this chapter is to define the Building Information Modelling, with its general definition, and how it is viewed in the AEC industry. It also explains how to use its tools, how to get benefit from using each BIM Tools category. This is related to the term using in the main analysis of this thesis.

Chapter 3: Building Renovation

This chapter discusses about the renovations in the Buildings and understands its growth and importance in the construction sector. To comprehend the methodology for the assessment of renovation alternatives also including the role of LCA approach in the housing renovation.

Chapter 4: Literature Review

Here we firmly discuss about the BIM technologies and tools employed in the building renovation and refurbishment, and the benefits of BIM implementation. Also discussing the challenges in BIM implementation for building renovation. We have chosen two different case studies with different characteristics in order to compare and understand the context with our study related to BIM4EEB project.

Chapter 5: Analysis

In this chapter we have discussed our final results and analysis of our thesis which was to understand the user's profiles of all the 19 involved actors in the BIM4EEB in case of private & public works.

Chapter 6: Use case Matrix

In this chapter, from the above developed User profile it is further analysed to develop the conditions required for the Use cases and to arrive at the use case matrix.

Chapter 7: Conclusion & Prospects

In this chapter, we conclude our result and analysis, the research methodology, and the research prospects in the future.

1.5. METHODOLOGY

To get the final objectives of the thesis, a methodology for analysing the workflow of building renovation has been adopted through all related stages of building process including initiative, initiation, concept design, preliminary design, developed design, detailed design, construction, use, and end of life. The analysis step is the following Table 1.1, which is taken more than once during the work period of the thesis. First, the building renovation workflow is collected based on European standard EN 16310-2013 [4], which developed in detail by the project BIM4EEB. Then, the workflow is analysed to define relative stakeholder, relative input and output information for activities, related BIM tool available in the market, the priority of using BIM technology in each action. Finally, an user's profile for BIM management system are determined based on information workflow, and required function, required BIM tool categories for each stakeholder (Figure 1.1).

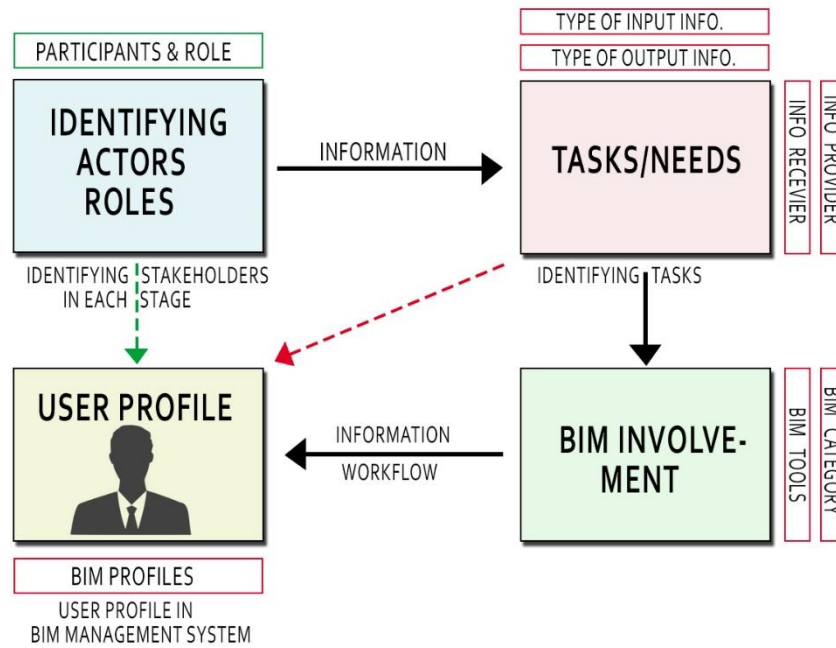


Figure 1.1. Methodology of the thesis

Table 1.1: Methodology of the thesis by sequences

Step 1	Collecting detailed data for all activities in all stages of building renovation workflow
Step 2	Identify the stakeholder in each stage, and the relationship between the stakeholders in each activity in the perspective of information analysis. For example, in a single task, who is the information provider, who is the information receiver.
Step 3	Identify the input and output information for each action in detail.
Step 4	Determine the priority of using BIM technology in each action with the scale from 0 to 5. In detail, 0 is not necessary to use BIM, 1 is useful but not recommended, 2 is recommended, 3 is desirable, 4 is highly desirable, 5 is mandatory. The priority is explained based on research hypothesis and BIM benefit for each action.
Step 5	Determine the BIM tools and BIM tool category available in the market that fit for using in each activity in the workflow.
Step 6	Based on previous analysis, summary the data for user's profiles including information, BIM category and required function.
Step 7	Conclusion and discussion about the result



CHAPTER 2

BUILDING INFORMATION MODELLING (BIM)

2. BUILDING INFORMATION MODELLING (BIM)

This chapter describe BIM definition and how it is adopted into building renovation process. It also explains how to use and the benefit of BIM in renovation process, the BIM management system, and the term of energy efficient building renovation.

2.1. DEFINITION OF BUILDING INFORMATION MODELLING (BIM)

Nowadays, BIM is a leading keyword in the construction industry. There are a lot of definition about BIM by colleagues working in this field. Some define BIM as a set of design software, some consider it as an advanced 3D digital model of the building while other think it as a new workflow for the building life-cycle. All of them are partially true about BIM. Therefore, to understand about BIM definition in detail and why it is broadly used in the world, the explanation from specialists in the industry, who is key player in building design software industry as Autodesk, Trimble, big government association like National Building Specification (NBS), is showed in Table 2.1 as below.

Table 2.1. BIM definition by different specialists

Source	Definition
BS ISO 29481-1:2017 [5]	use of a shared digital representation of a built object (including buildings, bridges, roads, process plants, etc.) to facilitate design, construction and operation processes to form a reliable basis for decisions
BS 8536-1:2015 [6] BS 8536-2:2016 [7]	process of designing, constructing or operating a building or infrastructure asset using electronic object-oriented information
BS ISO 16757-1:2019 [8]	construction of a model that contains the information about a building for all phases of the building life cycle
National Institute of Building Science (NIBS) [9]	A BIM is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward.
General Services Administration (GSA) [10]	Building Information Modeling is the development and use of a multi-faceted computer software data model to not only document a building design, but to simulate the construction and operation of a new capital facility or a recapitalized (modernized) facility. The resulting Building Information Model is a data-rich, object-based, intelligent and parametric digital representation of the facility, from which views



	appropriate to various users' needs can be extracted and analyzed to generate feedback and improvement of the facility design.
Autodesk [11]	Building Information Modeling (BIM) is an intelligent 3D model-based process that gives architecture, engineering, and construction (AEC) professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure.
Trimble [12]	BIM is an acronym for Building Information Modeling. It is a highly collaborative process that allows multiple stakeholders and AEC (architecture, engineering, construction) professionals to collaborate on the planning, design, and construction of a building within one 3D model. It can also span into the operation and management of buildings using data that owners have access to. This data allows owners and stakeholders to make decisions based on pertinent information derived from the model— even after the building is constructed
AECOM [13]	BIM is produced as a 3D model, but can also include information like quantity of materials and their cost, an asset's installation date — even how to operate it. Ultimately, infinite data can be added to the model as a project progresses. This information can be shared with every person involved in a project
BIM Handbook [14]	BIM as a modelling technology and associated set of processes to produce, communicate, and analyse building models.

BIM Definition in general

However, when breaking down the definition of BIM, there are 3 important parts: Building, Information and Modelling. They are both the digital modelling represent all components of the building, a process through all phases of building life-cycle which all relevant stakeholders can get benefit from contained information. The substance of BIM is showed in Figure 2.1 as below.

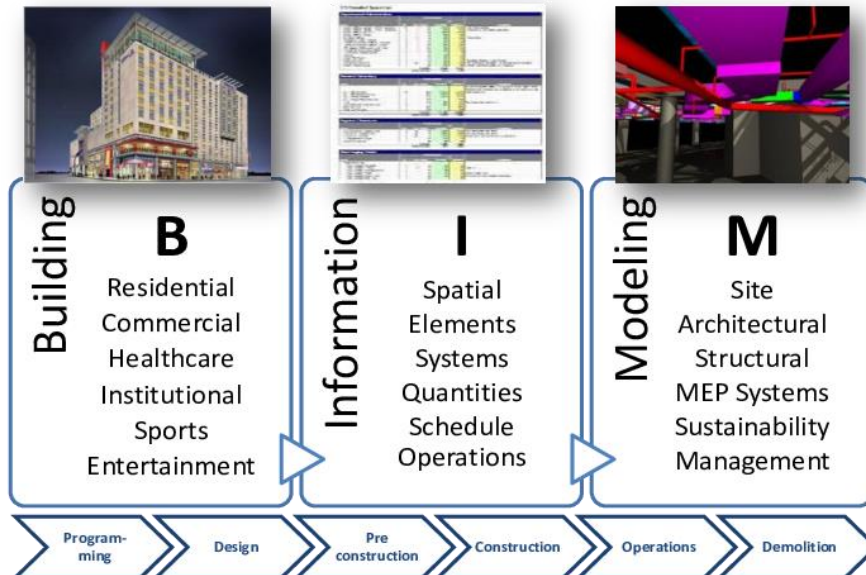


Figure 2.1. A visual representation of BIM concept [14]

Building

Building models is the objectives of the BIM process. The building models are characterised by building components that represented with digital representations (objects) that carry computable graphic and data attributes that identify them to software applications, as well as parametric rules that allow them to be manipulated in an intelligent fashion [14]. However, with great benefits of BIM for the construction industry, it is applicable for any parts of the construction industry including railways, highways, bridges, tunnels and utilities, not only for built environment itself.

Information

Information is the most important part of BIM. Information of building components should describe how they behave, as an input data for analyses and work processes, such as quantity take-off, specification, and energy analysis. The sharing of data instead of sharing files for collaboration is the essential components of BIM. A 3D Building model does not contain only geometrical data, but also non-graphical information, documents and drawings, which is go from the construction phases to the operation phases of a project.

Modelling

Quick and consistent modelling between all disciplines of the construction industry is the key factor for the success of BIM itself. It moves the industry forward from separated modelling of each design part (architecture, structure, building services...) to a integrated and interoperable design workflow where the collaboration and coordination take maximised advantage of computing capabilities. The consistency of the model does not only reduce the risk but also enhances the quality of modelling activities for the whole industry.

2.1.1. The development of BIM through history

Today, Building Information Modelling (BIM) is a term that can be found everywhere in the AECO industry. The adoption of BIM is significant only after 2012 by key players of the industry such as contractors, engineers and architects (Figure 2.2). But, the term of BIM is originated from a long time ago, in 1975, when Prof. Charles Eastman, an architect at Berkeley and later working in computer science at Carnegie Mellon University (CMU), published a paper describing a prototype called Building Description System (BDS) [16]. It is about the ideas of first parametric design in high quality computable 3D representations with a “single integrated database for visual and quantitative analysis”. Eastman’s research imagines BIM as exact as what we define BIM today, in which he describes a building database that contain individual library elements which can be retrieved and added to a model [17]. The program that Eastman designed do not only use a graphical user interface with orthographic and perspective views, but also provide a sortable database that can be retrieved categorically by attributes including material and supplier. For construction, Eastman also claims that drawings are inefficient and cause redundancies of object that is represented in several scales. Especially in renovation, the hardcopy drawings fail to represent the building as renovation occur and drawings are not updated. Finally, he concluded that BDS would improve drafting and analysis efficiencies and

cut the cost of design by more than fifty percent. It was the first experiment that identified the most fundamental problems in building design in next decades.

The percentage of companies using BIM jumped from 28% in 2007, to 49% in 2009, and to 71% in 2012.

For the first time ever, more contractors are using BIM than architects.

Source: *The Business Value of BIM in North America: Multi-Year Trend Analysis and User Ratings SmartMarket Report*, McGraw-Hill Construction, 2012.

BIM Adoption by Player (2009-2012)

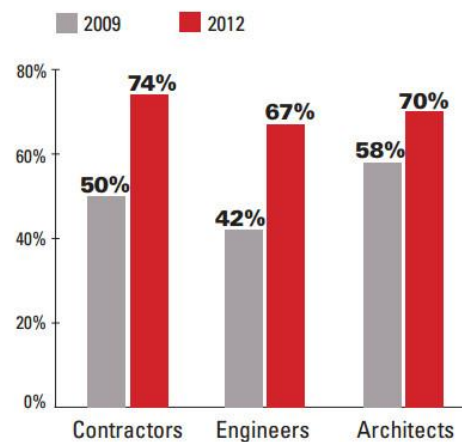


Figure 2.2. BIM adoption by player in construction industry in period 2009-2012 [18]

Therefore, following the view of Eastman, many specialists in construction field collaborated with ICT researcher to come up with computer software that solve the issues of project drawings, building virtual modelling and its management. The development of BIM definition considered as a computer program in the period 1975-2013 is showed as figure 2.3 below.

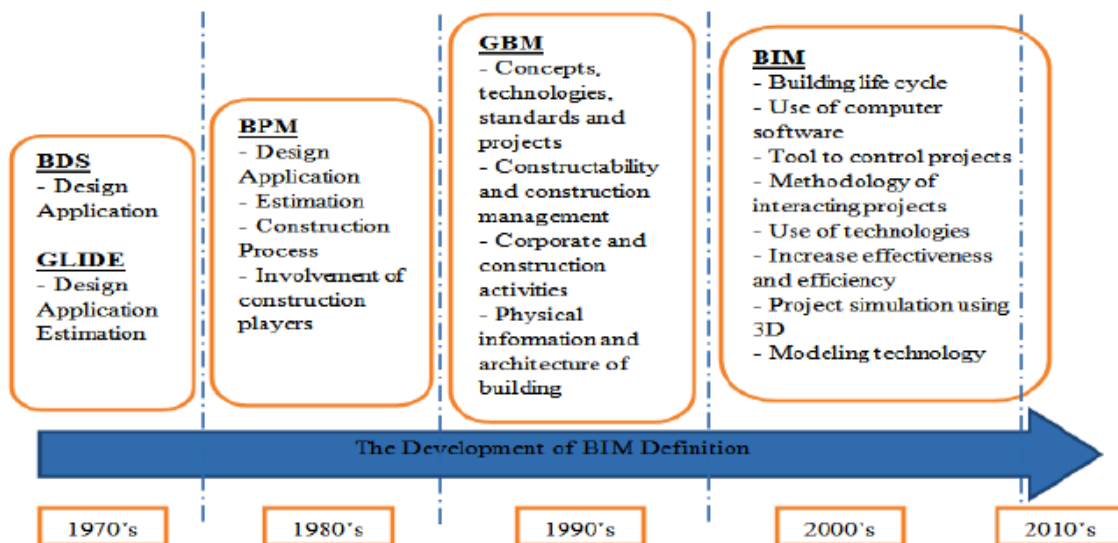


Figure 2.3. The development of BIM definition from 1975 to 2013 [15]

Charles Eastman work had not stopped yet. In 1977, he created Graphical Language for Interactive Design (GLIDE) in the CMU Lab, and it exhibited most of the characteristics of the modern BIM platform where it incorporated with many parts of BDS [19]. An example of GLIDE is showed in figure 2.4, which demonstrate a spiral staircase in model and drawing. GLIDE has been expanded to cover certain elements of building and used as a tool in checking the accuracy of data cost estimating and evaluation of structural design [15].

```

POLY PROCEDURE spiral.step(POLY centre;
    REAL riser,radius,r,angle,th)=
    BEGIN
    POLY support =
        triangle(radius*0.95,-riser*0.8,th);
    POLY collar = column(12,riser,r);
    POLY plate = wedge(radius,th,angle);
    ! return the result of shape operations;
    CUT centre FROM COMBINE collar WITH
        COMBINE support WITH plate
    END;

To make spiral staircase, (dimensions in inches)
SET PROCEDURE spiral.stair(ht,radius,angle)=
    BSET; INTEGER numsteps; REAL riser;
    numsteps ← ht/8.0;
    riser ← ht/numsteps;
    POLY centre = column(12,ht+32.0,5.0);
    POLY step = spiral.step(centre,
        riser,radius,3.0,angle,0.625);
    FOR i TO numsteps
        DO COPY step={0,riser*i \0,angle;i}
    ESET;

SET stair1 = spiral.stair(100.0,46.0,30.0);
    
```

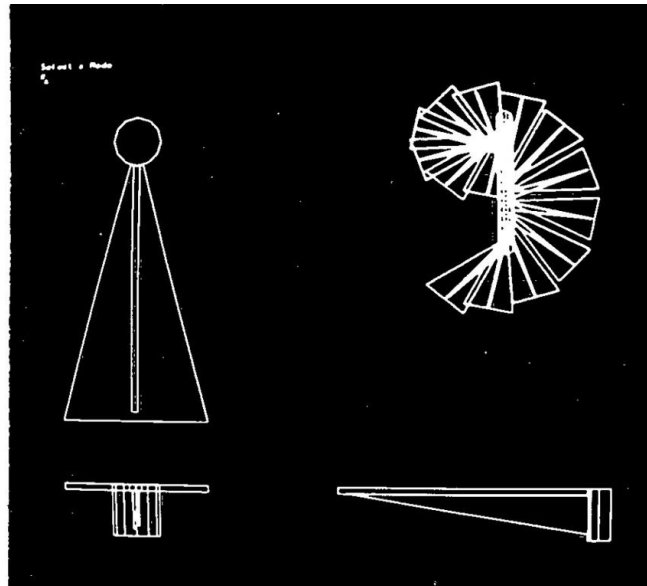


Figure 2.4. Example of GLIDE Project in Demonstrates the Spiral Staircase [19]

Then, in the 80s, some systems were being developed and applied to construction projects everywhere. In the UK, Really Universal Computer-Aided Production System (RUCAPS) was used as the first CAD program in the history of BIM for prefab construction in the renovation project of Heathrow Airport's Terminal 3. It is regarded as a forerunner to today's BIM software [14]. Therefore, many BIM software are developed by different ICT company; the timeline of BIM software history from 1957 to 2012 is showed in Figure 2.5.

1957 — Pronto, first commercial computer-aided machining (CAM) software
1963 — Sketchpad, CAD with graphical user interface
1975 — Building Description System (BDS)
1977 — Graphical Language for Interactive Design (GLIDE)
1982–2D CAD
1984 — Radar CH
1985 — Vectorworks
1986 — Really Universal Computer-Aided Production System (RUCAPS)
1987 — ArchiCAD
1988 — Pro/ENGINEER
1992 — Building Information Model as official term
1993 — Building Design Advisor
1994 — miniCAD
1995 — International Foundation Class (IFC) file format
1997 — ArchiCAD's Teamwork
1999 — Onuma
2000 — Revit
2001 — NavisWorks
2002 — Autodesk buys Revit
2003 — Generative Components
2004 — Revit 6 update
2006 — Digital Project
2007 — Autodesk buys NavisWorks
2008 — Parametricist Manifesto
2012 — formit

Figure 2.5. Timeline of BIM software history from 1957 to 2012.

Then, a new program called Building Product Model (BPM) had come up in 1980, which had covered design application, estimation, construction process and involvement of construction players [20]. It was a conceptual model that using objects attributes and different types relation of projects. The model was able to describe data in particular buildings by using different types of application software but under the same conceptual information structure [15]. Contrast with BDS and GLIDE, BPM acted as a project library that consists of information of projects from planning to the completion of construction. It is a high level computer interpretable communication for Computer Aided Design (CAD) in construction [21]. As such, it can be used as a compilation and discussion of concepts, technologies, standards as well as projects [22].

However, the communication under BPM only focused on product information while the AEC industry requires the integration of information and knowledge that used for design and construction management [21]. To solve this problem, a new term was defined in 1995, it is Generic Building Model (GBM), which can integrate information from current and future design that could be used throughout the life cycle in construction process. Therefore, the project information was improved, and the construction activities incorporation is enhanced.

Due to the natural complexity of the AEC industry, the term Building Information Modelling (BIM) had been used to fulfil the AEC industry's challenges. The used of BIM had been expanded from expanded from the pre-construction phase to post-construction phase. Figure 2.6 showed the involvement of BIM to the whole building life-cycle. BIM is used as a

tool to control the information as well as organisation, duties and processes that need from the stage of planning, design, construction, maintenance and lastly demolition. In 2006, BIM was defined as a new methodology to manage and increase the AEC performance in completing and managing projects [23]. Then, after developing, now, BIM was known as a new way approaching design and documentation by helping the collaboration of construction players to insert, extract, update or modify the information of facility [24].

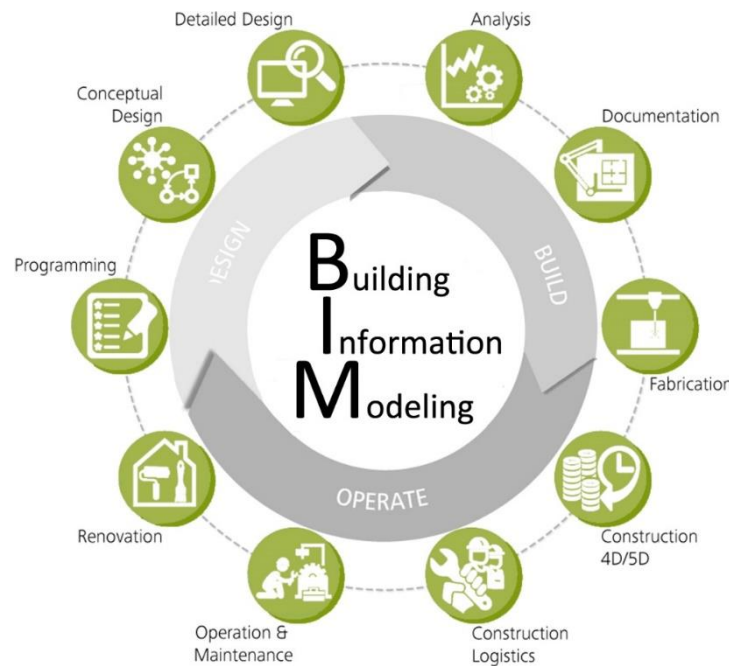


Figure 2.6. BIM in building life-cycle.

In conclusion, the development of BIM is a long way history from 1975 till now, from basic term of BDS, to GLIDE, BPM, GBM and now BIM, which start as a methodology for designing to the whole building life-cycle including pre construction and post construction phases. BIM is a methodology of using software technology in construction, pushing the construction information to digital era. This technology had helped the construction players in improving collaboration and communication among them. It had also improved the management of documentation in order to achieve more effective and efficient performance in construction projects [19].

2.1.2. BIM dimensions and forms of the model

A BIM model is a multi-dimensional model, which each dimension is a specific type of information in a model. Based on this definition, there will be various dimension in a model; but, according to the fundamentals of BIM from trusted source, there are mainly seven recognized dimensions. These BIM dimensions are presented with pointed out key benefits as below and shortened in the Figure 2.7.

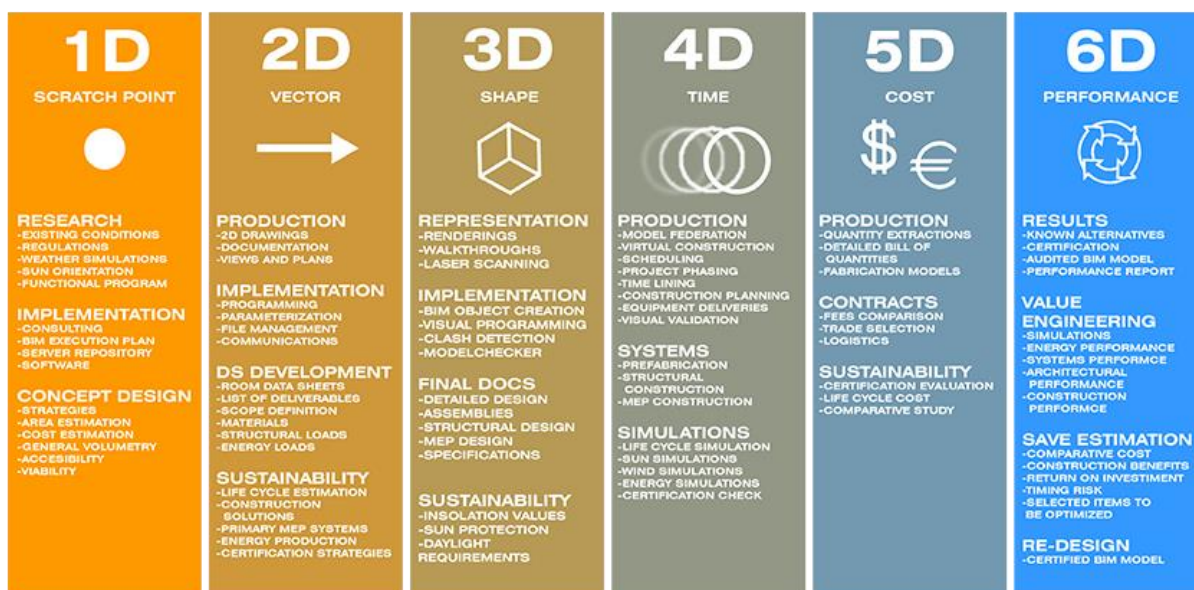


Figure 2.7. BIM dimension from 1D to 6D

1D Dimension

1D represents for pre-construction research (existing conditions, regulations, weather conditions...), implementation of the project (consulting, BIM execution plan...), and concept design (strategies, area estimation, viability, accessibility, general requirements...).

2D Dimension

2D represents the 2-dimensional drawings such as plans, elevations and sections.

3D Dimension = Geometry

A 3D BIM model contains 3D objects that builds up the information model. These objects represent the building or buildings spaces, in a virtual reality. These 3D objects contain information, as a minimum, on length, width and height. Other information can be applied, such as material and finish. Key benefits of a 3D information model are improved coordination, enabled visualization and general information gathering. 3D modelling requires 3D modelling software and LOD definition. [25]

4D Dimension = Time

The 4 dimension refers to adding time to the 3D, often called 4D modelling or model-based scheduling. This is done by linking objects from the 3D model, to a task in the construction schedule, using a 4D scheduling tool like Vico Office, Synchro or Navisworks. This approach is changing how complex projects are planned, making it possible to visualize the whole construction project or just some phases of it, and see who timing of tasks affect the workflow. This includes comparison of planned versus actual schedules; timebased clashes, such as verifying the planned sequence towards constrained activities (i.e. demolition, permanent construction and temporary construction), site utilization planning and more [25].

5D Dimension = Costs

5D modelling or model-based estimating is the 4D model in addition to cost information. A model-based schedule or 4D schedule is associated with information on cost, which allows the owner to know the exact amount the contractor should be billing at a given time. Over the past years the method has been redefined, where the 5D estimations is done in the form of a take-off, where the model is used to extract quantities of materials and associate costs with those materials for estimating purposes [25].

6D Dimension = Sustainability Performance

The 6th dimension is devoted to Facilities Management and focuses on leveraging the model information to reduce owners' cost over the life cycle of the building or structure. Sometimes 6D BIM models are referred to as Asset Information Models (AIM).

A 6D model does not necessarily contain all the information from previous dimensions. Over the design and construction phase, information for the operation of the facility is gathered. The model should contain information on the colour of a wall, types of doors, frequency of maintenance on the roofing felt, type of light bulbs etc., but size of reinforcing bars is generally not necessary. Time and cost are included, but the objective here is to gather information on frequency of maintenance and analysing the operational cost [25].

7D Dimension = Facility Management

The seventh dimension is used to extract and collect relevant information related to the operation and maintenance status of the facility throughout its life cycle. 7D is the main field where BIM model's data can definitely make the difference. Starting a Facility Management program based on reliable extracted information from an as-built BIM provide the most effective solutions for the management of a building [26].

(n)D Dimension

Model based analysis or nD modelling refers to information models that are used for various analysis driven by qualitative costs, often related to the tenants/users of the facility, environmental and sustainability issues. These analyses can also be fire safety, acoustics, orientation of the building, with regard to wind direction, heat gain for natural ventilation, daylight analysis or Life-cycle costing (LCC). In these types of models, time and cost is only relevant if the type of analysis requires it. Model-based analysis enable better and more accurate decision making early on in the design process. Various add-ons to a general 3D modelling software are needed as well as specialized personnel, for nD modelling to be successful.

2.2. ROLE AND RESPONSIBILITIES OF STAKEHOLDERS IN BIM

The adoption of BIM provides chances for the construction field to overcome its problems such as project delay, cost overrun and poor quality of project [27]. In addition, players in construction industry use BIM to achieve better integration of project information, construction process improvement and to enhance collaboration among them from the early phase of projects [28]. Hence, different from traditional way in the AEC industry, the use of BIM definitely changed the roles and responsibilities of construction players [29]. The table

2.2 below present the roles and responsibilities of stakeholders in BIM-based project nowadays.

Table 2.2. Roles and responsibilities of construction stakeholders [27]

No.	Construction stakeholders	Role and Responsibilities of Construction Players in Project using BIM
1	Client / Owner	Defining a suitable method of using BIM
2	Architect	To develop conceptual design To develop detail design and analysis To develop construction level information To develop construction documents.
3	C&S and MEP Engineer	To develop detail design To develop shop drawings with detail elements
4	Contractor	Perform constructability analysis Scheduling and planning using 4D model Produce cost reliability
5	Quantity Surveyor (QS)	To extract quantities and produce cost estimation from the 3D model
6	Facility Manager	To put the information of building into the 3D model for the purpose of FM

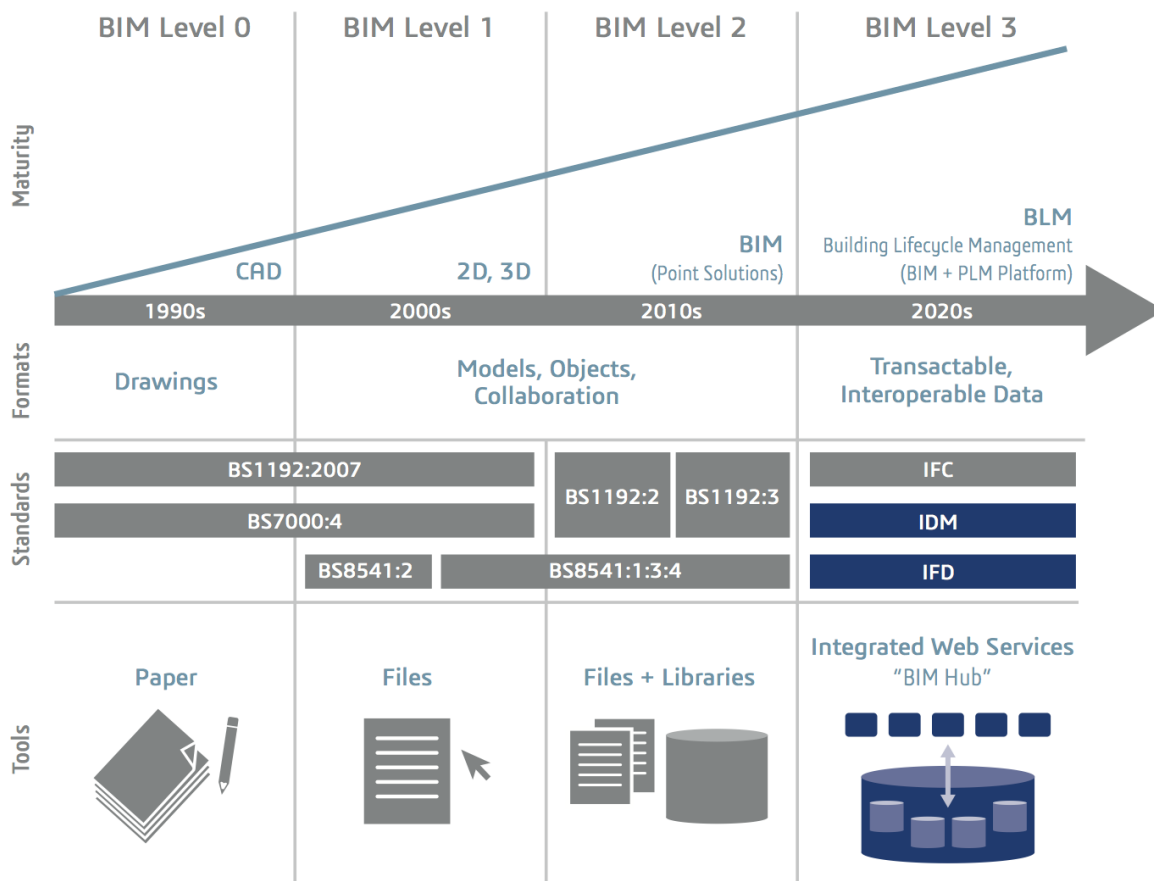
2.3. BIM PROCESSES

Following the definition of BIM technology provided by the National Building Information Modelling Standard (NBIMS), they vision for BIM is “as improved planning, design, construction, operation, and maintenance process using a standardized machine-readable information model for each facility, new or old, which contains all appropriate information created or gathered about that facility in a format useable by all throughout its lifecycle” (NIBS, 2008). Following that, the NBIMS Initiative categorizes the BIM in 3 ways:

- as a product
- as an IT-enabled, open standards-based deliverable, and a collaborative process
- as a facility lifecycle management requirement

These categories support the creation of the industry information value chain, which is the ultimate evolution of BIM [14]. This enterprise-level (industry-wide) scope of BIM is the area of focus for NBIMS, bringing together the various BIM implementation activities within

stakeholder communities. Another way to characterise BIM is to define a progression of levels of maturity of application of information technology in construction that expresses the degree of collaboration in the process as well as the levels of sophistication of use of the individual tools. In this view BIM is seen as a series of distinct stages in a journey that began with computer-aided drawing and is taking the industry into the digital age [14]. Since the UK Government BIM Task Group adopted the concept of “BIM Levels”, the following figure 2.8 and four levels of it defines (from Level 0 to Level 3) have become widely adopted definition of the criteria for a project to be deemed BIM-compliant. The BS standards number, describe the definition of each level, is also included in the figure.



The BIM Maturity Model by Mark Bew and Mervyn Richards adapted to reflect BLM's relationship to Level 3.

Figure 2.8. The BIM maturity model by Mark Bew and Mervyn Richards

BIM Maturity Levels

The following definition of each BIM maturity level describe its general concept from NBS of UK Government [30].

Level 0 BIM

In its simplest form, level 0 effectively means no collaboration. 2D CAD drafting only is utilised, mainly for Production Information (RIBA Plan of Work 2013 stage 4). Output and distribution are via paper or electronic prints, or a mixture of both. Most of the industry is already well ahead of this now.

Level 1 BIM

This typically comprises a mixture of 3D CAD for concept work, and 2D for drafting of statutory approval documentation and Production Information. CAD standards are managed to BS 1192:2007, and electronic sharing of data is carried out from a common data environment (CDE), often managed by the contractor.

- To achieve Level 1 BIM, the Scottish Futures Trust states you should achieve the following:
- Roles and responsibilities should be agreed upon
- Naming conventions should be adopted
- Arrangements should be put in place to create and maintain the project specific codes and project spatial co-ordination
- A "Common Data Environment" (CDE) for example a project extranet or electronic document management system (EDMS) should be adopted, to allow information to be shared between all members of the project team
- A suitable information hierarchy should be agreed which supports the concepts of the CDE and the document repository.

Level 2 BIM

Level 2 BIM is distinguished by collaborative working and requires "an information exchange process which is specific to that project and coordinated between various systems and project participants" [31].

Any CAD software that each party uses must be capable of exporting to one of the common file formats such as IFC (Industry Foundation Class) or COBie (Construction Operations Building Information Exchange). This is the method of working that has been set as a minimum target by the UK government for all work on public-sector work.

Level 3 BIM

Level 3 has not yet been fully defined, however the vision for this is outlined in the UK Government's Level 3 Strategic Plan. Within this plan, they set out the following 'key measures' to be secured with further funding:

- The creation of a set of new, international ‘Open Data’ standards which would pave the way for easy sharing of data across the entire market
- The establishment of a new contractual framework for projects which have been procured with BIM to ensure consistency, avoid confusion and encourage, open, collaborative working.
- The creation of a cultural environment which is co-operative, seeks to learn and share
- Training the public sector client in the use of BIM techniques such as, data requirements, operational methods and contractual processes
- Driving domestic and international growth and jobs in technology and construction.

Thus, BIM moves the industry forward from current task automation of project and paper-centric processes (Level 0) (3D CAD, animation, linked databases, spreadsheets, and 2D CAD) toward an integrated and interoperable workflow where these tasks are collapsed into a coordinated and collaborative process that take maximal advantage of computing capabilities, web communication, and data aggregation into information and knowledge capture (Level 3) [14].

2.4. BIM DATA EXCHANGE AND INTEROPERABILITY

AECO industry contains of many collaborative activities, which many stakeholders use different application with overlapping data requirement to support various relevant tasks such as design, construction, operation and also maintenance. To improve the effectiveness of these activities, the collaborative workflows need to be enhanced, which mean all of collaborative work between different players in the industry need to be processed in a smoothly sharing and information exchanging platform. BIM is the key solution for that. In addition, the interoperability is also important in BIM technology. It is the ability to exchange the data between different applications, which strengthens the workflows and facilitates automation.

2.4.1. Interoperability problems

Hence, following McGraw-Hill and Dodge surveys on BIM, it identifies interoperability as a critical issue for advanced BIM users [32]. The interoperability (especially data loss) problems are attributed mainly to the following four technical reasons [33]:

- Limited coverage of a data model: The data of interest are not within the scope of a data model or an exchange file format. [14]
- Translator problems: A translator does not support the data of interest, although the data are specified in a data model. [14]
- Software bugs or implementation issues: The data are successfully exchanged and read into a software application, but the software application has a problem loading or visualizing the data due to a software bug or other implementation issues. [14]
- Software domain problems: The data of interest is outside of the scope of a software application. [14]

In addition, the interoperability problems are caused by procedural factors, and collaborative factors when many participants work on a project, that use different BIM models through all phase of a construction project. These reasons are listed following:

- Version control and concurrent engineering issues
- Level of development (LOD) issues: a single BIM model impossibly includes all details required by different uses of BIM models through all phase of a construction project. There should be a guideline available for appropriate levels of detail or development of BIM models for different BIM uses. BIM model data on different LODs require additional data adjustments [14].

And finally, a human factor is a natural reason causing this interoperability issues:

- Unwillingness to share information: Team members are unwilling to share information with others due to intellectual property, security, or contractual issues, but sometimes, without a rational reason [14]. BIM experts around the world identified willingness of project participants to share information as one of the critical success factors for BIM projects [34].

2.4.2. Type of data-exchange in AECO industry

In traditional way for implementation of a construction project, the interoperability between software and collaboration between participants is processed through a file-based data exchange method. There are 3 main methods for data exchange, which is defined below based on the BIM Handbook 2018, a technical literature.

Direct links

The data exchange between two application through an Application Programming Interface (API) of one system can be deployed when a data model is not mature enough to support data exchange between two applications. Some may write a temporary file in the exchange between two independent applications; others may rely on real-time exchanges calling one application from the others [14]. There is benefit of this way of data exchange, that is the software company can support their software better through direct links. For example, an analysis tool is directly embedded into a design application. However, the capabilities of supporting through public exchange is not that easy, and the data exchange between software from different developers depend on the arrangement between two or more companies. Hence, many exchanges fail because the translator between companies developed with different use cases in mind, and the interface are maintained as long as the business relationship hold [14].

File-based data exchange

It is the traditional method of data exchange in AECO industry, which is a method through a model file either using a proprietary exchange format or a publicly open standard format. A proprietary format is a data schema developed by a commercial organisation for interfacing with that company's application [14]. There are some

example for it as DXF and RVT defined by Autodesk, PLN by Graphisoft... Otherwise, data exchange in a standard exchange format involves using an open and publicly managed schema. IFC and CIS/2 are examples of standard data formats for AEC [14].

Model-server based data exchange

It is a method to exchange data through a database management system (DBMS). In term of BIM technology, it is referred to as a model server, a BIM server, an IFC server, a data repository, a product data repository, or a common data environment (CDE). The latter one is the most priority of studying of this thesis, since it has a big advantage of not relying on the version control and concurrent engineering issues. Moreover, the model-server based data exchange approach has the potential to reduce many interoperability problems by adding artificial intelligent functions to a model server and by enabling an automated analysis of the status and quality of data and filling missing and conflicting information based on the analysis results [14].

2.4.3. IFC

The Industry Foundation Classes (IFC) is a schema developed by buildingSMART, an international organisation, to define an extensible set of consistent data representations of building information for exchange between AEC software applications. Hence, the IFC is designed to address all building information, over the whole building lifecycle, from feasibility and planning, through design (including analysis and simulation) and construction, to occupancy and operation [35].

2.5. BIM AS A LIFECYCLE PLATFORM

BIM create an evolution of using IT in the creation and management of the facility's lifecycle, provide the benefit of information sharing to post-construction phases. For a building lifecycle, there are many stakeholder that participate and get benefit from BIM including real estate, ownership, finance, all area of AEC industry, manufacturing, fabrication, facility maintenance, operations, planning, regulatory compliance, asset management, sustainability and disposal of the facility lifecycle [14]. With the growing of environmental, sustainability and security demand, the need of an open and reusable critical infrastructure data has raised beyond the need of current services and products. All of relevant stakeholders will need this data in the future.

To determine BIM as a lifecycle platform, let's look at the term product lifecycle management (PLM) that is origin from 1980s. It is the process of managing a product throughout its lifecycle, which aims to improve product quality and reduce waste as well as risks through integration of design and engineering processes and reuse of information [14]. BIM use bases on the same concept with PLM, then BIM can be considered as a Building Lifecycle Management (BLM), which is a term defined by Autodesk Inc. in 2002. The concept of BLM ranges from the planning, design, construction, operation and maintain phases of the building lifecycle, emphasizes the key of the Building lifecycle management is how to manage and use the digital data and it is a big change and innovation in the building information management field [36]. To achieve design-construction-management process integration, BLM

use the digital way to create, manage, and share the capital asset information and based on the integrated virtual building information model and collaboration [36]. According to Counsel House Research report, BLM, combining BIM and online collaboration, have been considered as the important driving force to improve building design, construction, management process in the future [37,38].

BIM management system

The building activity generates a great number of data and information of various kinds. The management and the communication of these data by the various participants is complex [38]. The BIM management system used the standardization of the industry – IFC and based on the concept of BLM with related technology, will create information management platform and facilitate the sharing process for a better qualification and validation of data [36]. Based on BIM central database, all stakeholders of the construction phases could access to the BIM management system to obtain necessary information up to their demand and do appropriate function through all phase of the project; otherwise, the management system improve stakeholders’ decision making, control and implementation of the project. To understand clearly about the BIM management system as a Building Lifecycle Information Management Platform, that mentioned in this thesis, figure 2.9 show the complete lifecycle information management more clearly.

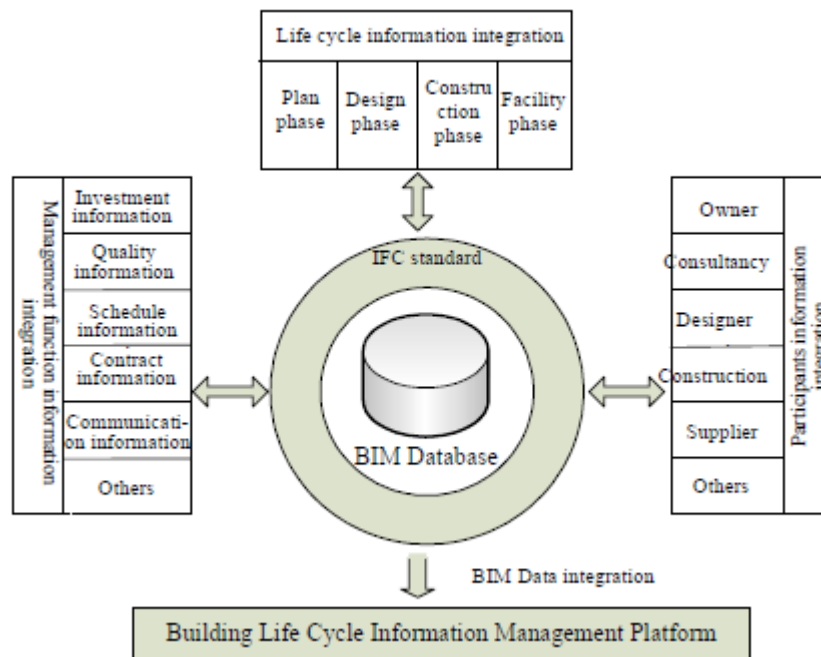


Figure 2.9. BLM platform based on BIM central database.

Hence, to understand the BIM management system, the information integration and design principles is defined based on a research paper from China University of Mining and Technology [36].

Information integration of BIM management system as a BLM platform

- **Life cycle information integration:** Each stage of the Construction life-cycle information is integrated through full exchange and control, which makes construction project management information in different process of the project transmit accurately and adequately and participates in every stage obtain effective communication and cooperation. The BLM platform (BLMP), established to realize the BLM idea, should include the building lifecycle information sharing, exchange, reuse, knowledge management, communication and cooperation, and support to the business decision-making and the strategic target realized as well.
- **Management functions information integration:** Construction projects have multi-management goals which mutual influence and restriction, such as cost, time, quality, safety, environmental protection, contract, communication etc. These goals and management functions should be overall planned and considered in the project life cycle, In order to achieve global optimization of project.
- **Participants information integration:** With the foundation of advanced information technology and the idea of cooperation to win-win, the participants of projects build a project management information integration platform which provides a way of coordination and communication for each participant, eventually achieving the purpose of reducing cost, Speeding Schedule, quality guarantee, control risk to multi-win-win situation.

Design principles of the BIM management system as a BLM platform

- **Dynamic and expansibility:** Construction projects have various types, a lot of stakeholders, and in different places and different objective condition, the project management modes are also different. The system must be able to adapt to the highly flexible, dynamic and distribution environment and should be expanded flexible, including openness, modularization, distributivity, dynamic updates and expand etc. For instance, network protocol, the operating system and application software all follow the common international standards, such as IFCs standard, etc. On the other hand, according to the needs of different users' to customize and select the appropriate function module, the system is extensible and dynamic, such as the workflow customization, business management module split and free combination, etc.[39]
- **Ease of use:** The friendly design fully considers that the construction projects users are diverse and multifaceted, even if not professionals can also quickly master the system. With B/S mode, after connecting to the Internet, the user can access and operating system according to the respective spheres of competence, not subject to the limitations of space and time.
- **Data security:** Because BLMP users are from different project parties, rigorous security management and access control are designed in integration system, the rational allocation of user privileges and with encryption software and hardware to

improve system security to prevent illegal invasion and operation; system data can be automatically or manually backup, import and export, to ensure the security of system data.

- **Maintainability:** As we all know, software maintenance costs account for a large part of the software life-cycle costs, therefore we must be fully aware of the importance and urgency of the system maintenance and improve the soft maintainability, including understandability, modifiability and testability.

From the concept of BLMP and development of a BIM management system for renovation project, in this thesis, the user's profile for accessing BIM management system is defined.

2.6. BIM ENVIRONMENTS, PLATFORMS, AND TOOLS

As the main objectives of this thesis is a BIM management system for efficient renovation in building through a BIM-based toolkit, it is necessary to understand some term to denote software in this field. They are BIM environments, BIM platforms and BIM Tools, and they are defined as following based on the BIM Handbook 3rd Edition [14].

BIM environment

A set of BIM applications that are interfaced to support multiple information and process pipelines in a project, an organisation, or a local construction sector. BIM environments encompass the various BIM tools, platforms, servers, libraries, and workflows within the project or the organisation.

BIM platform

A core BIM information generator with functions to maintain the integrity of a model based on the parametric and object-based modelling capability. It provides a primary data model that hosts the information from various BIM applications. Thus, strong interoperability capabilities are needed, and they typically incorporate interfaces to multiple other tools with varied levels of integration. Generally, know object-based parametric BIM applications such as Revit, ArchiCAD, Tekla Structures, Vectorworks, Bentley AECOSim, and Digital Project fall into this category. Most BIM platforms internally incorporate tool functionality such as rendering, drawing production, and clash detection. Most platforms provide different set of interfaces, libraries, and functions for different domains and trades. Examples include Revit Structure, ArchiCAD MEP, and different Workbenches in Digital Project.

BIM tool

A BIM information sender, receiver, and processor used within a BIM process in association with BIM platforms. Note that many of these tools may not be generally regarded as BIM tools unless they are used within the context of a BIM process. Example BIM tools include applications such as specification generation tools, cost estimation tools, scheduling tools, and Excel-based engineering tools that do not include geometric definitions and are all text-based. AutoCAD for drawing production or other AutoCAD-

based applications can be also regards as BIM tools as far as they are used in the context of a BIM rendering, navigation, visualisation, facility management, early design generation, project management, and various types of engineering and simulation. Third-party applications are also included.

The big picture about BIM environment, platforms, and tools are described in figure 2.10 below. BIM environment carry more type of information than a model data alone, some important data in project management such as video, images, audio records, emails can be included. Hence, an application needs to be considered as both environment, platform and tools to achieve the goal of exchanging and managing objects and set of objects based on data rather than based on file.

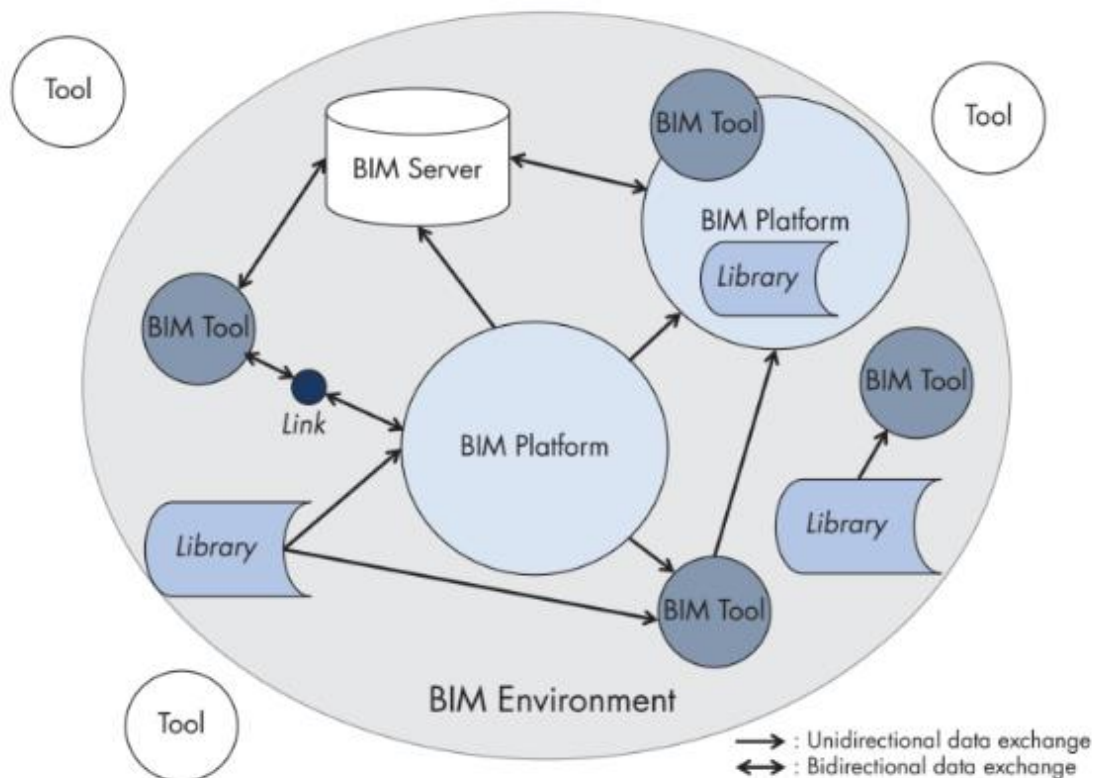


Figure 2.10. BIM environments, platforms, and tools [14]

There are some examples of the BIM platform that available in the market below. They are:

- Allplan by Netmetschek Group
- ArchiCAD by Graphisoft
- Bentley Systems by Bentley
- DESTINI Profiler by Beck Technology, Ltd.
- Digital Project by Gehry Technologies
- Revit by Autodesk

- Tekla Structures by Tekla Corp. (acquired by Trimble)
- Vertorworks by Diehl Graphsoft
- AutodCAD-Based Applications

2.7. BIM TOOL IN CATEGORIES AND EXAMPLES

Then, since this project related to a BIM-based toolkit for efficient renovation in building, it is necessary to understand the term, definition, and purpose of each BIM tool categories. They are listing as below based on the BIM Handbook 3rd edition in 2018 [14].

2.7.1. BIM Design Application / Tools

BIM design tools is one of the most important categories in BIM environment, they have 2 main function, which are parametric model generation and editing for the purpose of model definition and drawing production. There are some aspects that list below need to be considered for a BIM design tools, they are:

User Interfaces

Compared to CAD, BIM design tool is more complex, but has greater functionalities. Some BIM design tool have a relatively intuitive and easy-to-learn user interface, while others emphasis on functionality that is not always well-integrated into overall system. Criteria to be considered here include consistency of menus across the system's functionalities following standard conventions; menu-hiding that eliminates irrelevant actions not meaningful to the current context of activities; modular organisation of different kinds of functionality; and online help providing real-time prompts and command-line explanation of operations and inputs. Despite user interface issues may seem minor, a poor user interface results in longer learning times, more errors, and often to users' not taking full advantage of the functionality built into the application.

A BIM application needs to be able to present a large range of information: geometry, properties, and relations between them to other applications. Typical uses include structural, energy, lighting, costs, and other analyses during design; clash detection and issue tracking for design coordination; purchasing and materials tracking; and task and equipment scheduling for construction. User interfaces of importance depend on the intended use of the BIM application, defined by patterns of workflow [14].

Drawing Generation

How easy is it to generate drawings and drawing sets and to maintain them through multiple updates and releases? Assessment should include quick visualisation of the effects of model changes on drawings, strong associations so that model changes propagate directly to drawings and vice versa, and effective template generation that allows drawing types to carry out as much automatic formatting as possible [14].

Ease of Developing Custom Parametric Objects

This is a complex capability that can be defined at 3 different levels that mention before:
BIM

Complex Curved Surface Modelling

Support for creating and editing complex surface models based on quadrics, splines, and nonuniform B-splines is important for those firms that currently do this type of work or plan to in the future. These geometric modelling capabilities in a BIM application are foundational; they cannot be easily added on later [14]

BIM Object Libraries

Each BIM platform has various libraries of predefined objects that can be imported for use in that platform. These can be helpful by eliminating the need to define them yourself. In general, the more predefined objects, the more productive are users. There is a further level of discrimination regarding how good the objects are for different uses. During design, BIM objects may be generic and not a object; in construction, the product is likely to have a specific product ID.

Extensibility

Extensibility capabilities are assessed based on whether a BIM platform provides scripting support, and a broad and well-documented application programming interface (API). These capabilities are needed depending on the extent to which a firm expects to customise capabilities, such as custom parametric objects, specialized functions, or interfaces to other applications.

Interoperability

Model data is generated to share with other applications for early project feasibility studies, for collaboration with engineers and other consultants, and later for construction. Collaboration is supported by the degree to which the BIM application provides interfaces with other specific products and, more generally, its import and export support of open data exchange standards. An easily customisable import and export facility is highly beneficial. Both tool interfaces and the more general aspects of interoperability are considered.

Multiuser Environment

More and more systems support collaboration among a design team and a cloud-based work environment. They allow multiple users to create and edit parts of the same project directly from a single project file and manage user access to these various information parts. These issues will become predominant as cloud services evolve.

Effective Support for Managing Properties

Properties are an integral part of the data needed for most BIM support tools. Property sets need to be easily set up and associated with the object instances they describe. The properties vary by their use: fabrication, object performances, logistical issues, and so on. Thus property set assignment and management is part of system workflow.

Other capabilities

Support for design application capabilities beyond the basic include clash detection, quantity take-offs, issue tracking and incorporation of product and construction specifications.

Examples

- Autodesk Revit by Autodesk
- ArchiCAD by Graphisoft
- Bentley Building by Bentley
- Other BIM software from other developers

2.7.2. BIM Model Checker

Since the expanding of BIM in the construction industry, the issue of BIM model quality is getting more important than anything else. Therefore, the automation in BIM design application is increasing to limit the error causing by manual entry, and to save both time and cost. The manual checking today forces the BIM users to make a visual checking that is inefficient and error prone. Hence, BIM model checker is developing to automated rule checking, which can be useful for following function such as functional simulations, code-compliance checking, automated permitting while it must conform to semantic content and syntax requirements defined for the receiving application.

Otherwise, automatic checking by prechecked ruleset and manual checking is clearly superior to manual checking only. The rule checking systems need to have the following functionality, and the steps of it defined by the BIM Handbook 3rd edition is described as below [14]:

- 1 Identify rulesets that are to be applied
- 2 Identify the aspects of the model needed to provide the data for the rules to be tested, usually defined as a model view.
- 3 Use methods to select the parts of the building model that the check is applied to.
- 4 Apply the rule or rulesets to the building instance model.
- 5 Identify all instances in the selected part of the model where failures occurred.

Hence, there are some examples of the BIM Model Checker listed below:

- BIM Assure by Singapore's Building Construction Authority
- Solibri Model Checker by Solibri
- Autodesk Revit Model Review by Autodesk
- SmartReview APR by International Building Code.

2.7.3. BIM Model Integration Tools

The BIM model integration tools provide the ability of merging multiply BIM models from different disciplines in the construction industry such as architecture, structure,

mechanical... to a single federated model to check for the clashes in a sophisticated view. Otherwise, with the definition of 4th dimension in BIM, the BIM model integration tools also has the ability as a construction management functions, which can operate on a single integrated model. Normally, BIM model integration tools also provide some functions such as construction planning, work zones definition, scheduling and 4D simulation, quantity take-off and estimation, production monitoring and control.

There are some examples of BIM Model Integration Tools:

- DP Manager by Trimble
- Autodesk Navisworks Manage by Autodesk
- iTWO by RIB
- Vico Office by Trimble

2.7.4. BIM Model Viewer

To visualising and navigating easily the BIM models, there is many developers provide BIM model viewer. Normally, BIM model viewer is used for reviewing the design by a participant or by a team of participants. For this purpose, the model viewer tends to keep it visualisation in simple with annotation functions; while others is integrated with advanced function such as clash-detection. Today, some game engines is used to develop the model viewer due to its fast and high quality visualisation and for quick navigating in big and complex building projects. Most of the model viewer includes the mobile version, which allows stakeholders in construction phases check, review and present the 3D model conveniently.

There is some example of BIM Model Viewer:

- Adobe Acrobat 3D by Adobe
- Allplan BIM+
- Autodesk BIM 360 Glue
- Autodesk Design Review
- Autodesk Navisworks Freedom
- BIMx
- Fuzor
- Kubity
- Oracle AutoVue
- ProjectWise Navigator
- Solibri Model Viewer
- Tekla BIMSight
- VIMTREK

- xBIM Xplorer

2.7.5. BIM Server

Since the development of BIM technology, the method of data exchange evolves quickly from file-based exchange to a BIM server. Like most database management system, a BIM Server need to support access control and information ownership through a BIM management system. Hence, following the BIM Handbook 3rd edition [14], the base requirements for a BIM server can be summarise as follow:

- **Manage users** associated with a project, so their involvement, access, and actions can be tracked and coordinated with workflows. User access control provides access and read/write/create capability for different levels of model granularity. Granularity of model access is important, since it identifies how much model data must be impounded for a user to revise it [14].
- **Import and parse BIM models** in a proprietary data format such as *.rvt or *.dgn or in an open standard format such as *.ifc into object-level data instances. The imported files can be saved in their original file formats as well and managed in association with the project data [10].
- **Query and export object-level data instances** in a BIM server as an independent BIM model file in a proprietary data format such as *.rvt or *.dgn or in an open standard format such as *.ifc [14].
- **Manage object instances** and read, write, and delete them based on update transaction protocols [10].
- **Control versions of stored data. Version control** – a capability to keep and manage a record of transactions and changes of data is a critical requirement for concurrent management of data especially in a multi-user environment [10].

The general system architecture and exchange flows of an idealised BIM server are shown in figure 2.11 below.

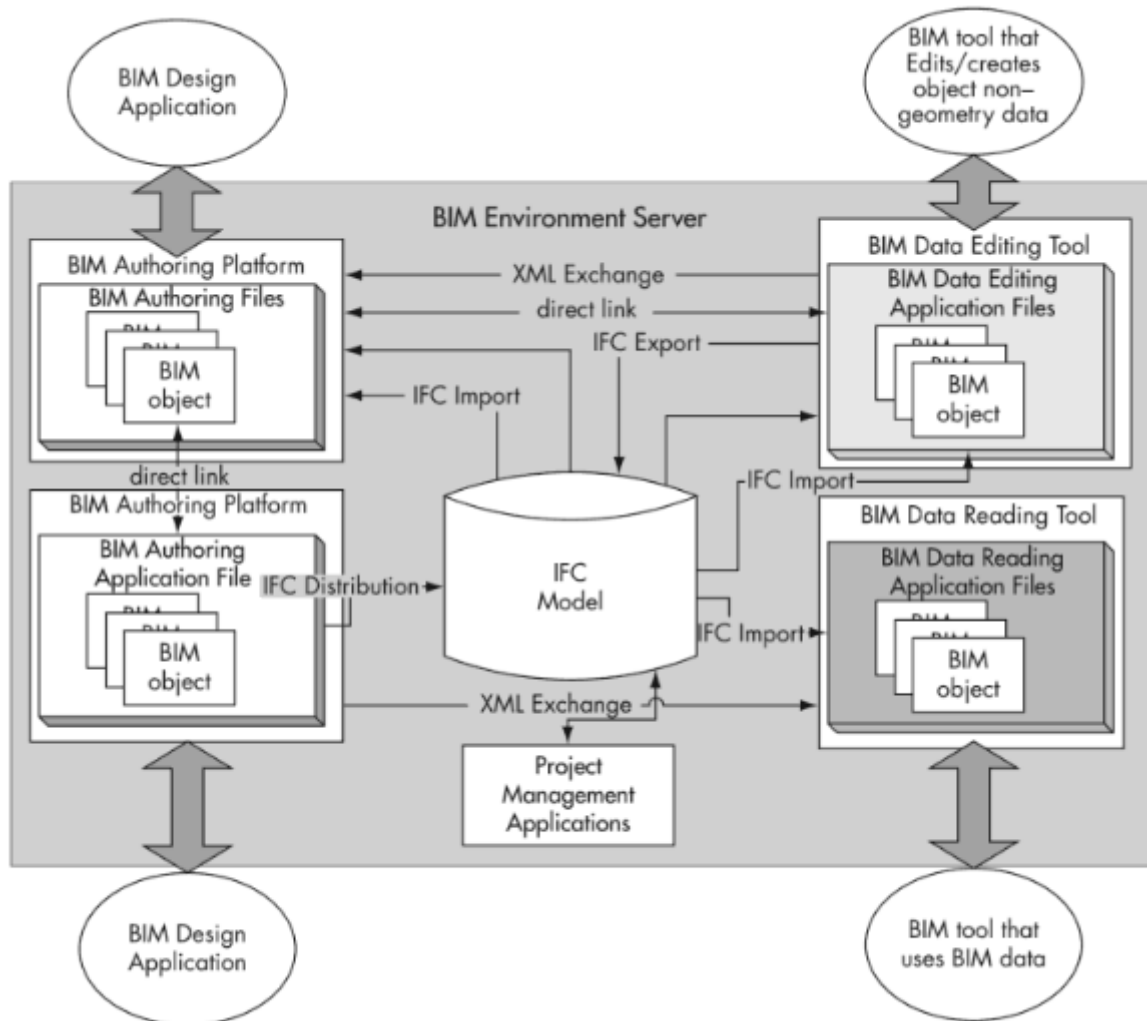


Figure 2.11. Example internal structure of exchanges supported by a BIM server [40]

In addition, a BIM server may support these following functions based on the BIM Handbook 3rd edition in 2018 [14]:

- **Visualise BIM data in the server**
- **Support visual query of BIM** data for enabling the users to visually query, review, and select the information they need directly from a visualised 3D model store in a BIM server
- **Support web- or cloud-based functions** with a high level of security for protecting data from hacking and virus attacks.
- **Support product libraries** for incorporating product entities into BIM models during design or fabrication detailing.
- **Support storing product specifications** and other product maintenance and service information, for linking to as-built models for owner handover.
- **Store e-business data** for costs, suppliers, orders shipment lists, and invoices for linking into applications.

- **Manage unstructured forms of communication and multimedia data:** email, phone records, and notes from meetings, schedules, photographs, faxes, and videos.

However, these functions of a BIM server can be divided into 3 groups, that based on the requirement of the market, based on their different functionalities. They are:

- **A design-engineering-construction market:** This is the kernel market that is project-oriented, needs to support a wide range of applications, and be able to support change management and synchronisation.
- **A made-to-order market,** primarily applied to engineered-to-order products, such as process plant unit, steel fabrication, curtain walls, escalators, and other prefabricated and modular units for a given project. However, this system must track multiple projects and facilitate production coordination across them. This is quite like PLM systems market.
- **A facilities operation and management market,** addressing the monitoring of facility operations, possibly capturing sensor data from one or more facilities, with real-time monitoring and lifetime commissioning.

Following that, a BIM server is adapted to responsible for managing different types of data based on different market. There are some examples of BIM server that available in the market listed below:

- Express Data Manager by Jotne IT
- EuroSTEP Share-A-Space Model Server
- Open BIMserver by TNO Netherlands
- Bentley i-Model by Bentley
- Graphisoft BIM Server and BIMcloud by Graphisoft
- Dassault 3D Experience by Dassault
- BIM 360 Design by Autodesk
- Konstru

2.7.6. BIM Cost Estimation Tool

In a construction project, the owner often deals with cost overruns that make them go over their budget, delay the project, or even cancel the whole project. To mitigate the risk of overruns and unreliable estimates, owners and service providers and contingencies to estimates or a “budget set aside to cope with uncertainties during construction” [41]. They typical range of contingencies that owners and their service providers apply to estimates vary from 50 to 5% depending on the project phase [42,43]. The data adapted from 2 research of Munroe and Oberlender and Trost is showed in Figure 2.12 [40]. Hence, it increases significantly the risk of project over cost.

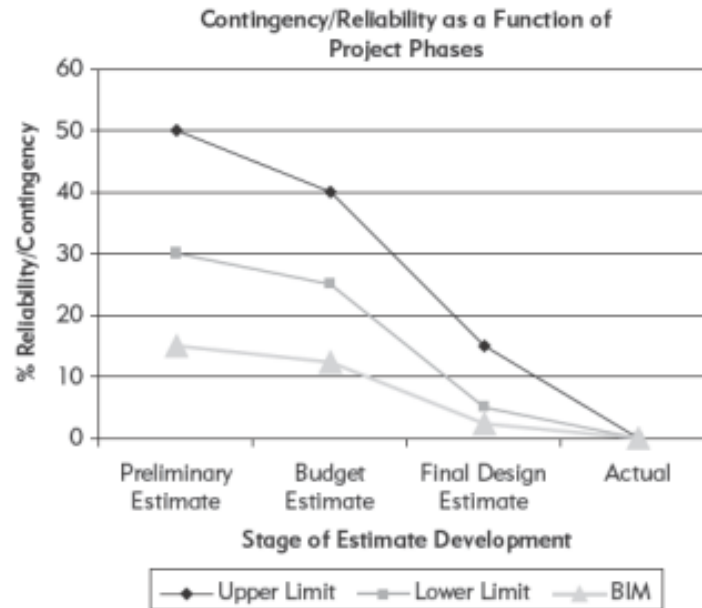


Figure 2.12. Chart showing the upper and lower limits that owner typically adds to the contingency and reliability of an estimate over different phases of a project and the potential targeted reliability improvements associated with BIM-based estimating. [40].

The reliability of cost estimates is impacted by a number of factors, including market conditions that change over time, the time between estimate and execution, design changes, and quality issues [44]. BIM provides more reliable source for cost estimator to perform quantity take-off, estimating, and updating cost faster up to the change of design in construction phases. As shown in Figure 2.13, at the conceptual and feasibility studies, the influences on cost is much higher than later phases of a project. Hence, through a BIM application, BIM cost estimation in specific, the cost estimator and owner can manage cost to provide:

More reliable estimates early in the process with conceptual BIM estimating

Faster, better-detailed, and more accurate estimates with BIM quantity take-off tools.

Hence, owner can use the BIM cost estimation tool to get a baseline of their project cost and do financial forecast if any changes happen in the future. These estimates are usually under the unit of cost per square meter in early stage, when the detailed building model is not fully developed.

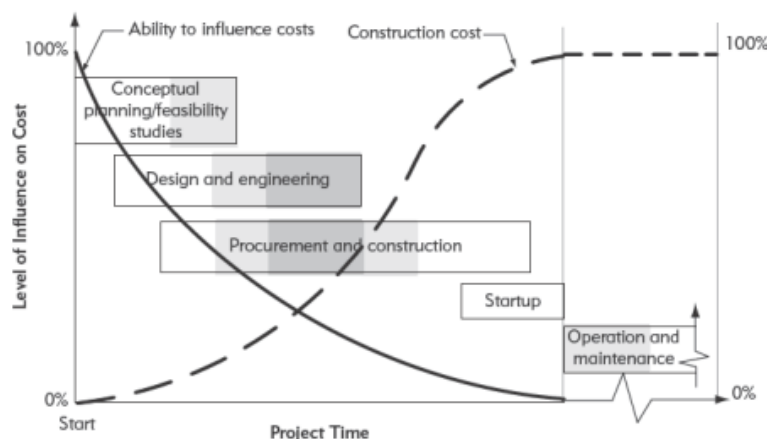


Figure 2.13. Influence on overall project cost over project lifecycle [40]

There are two types of BIM cost estimation tool that is available in the software market today; they are plug-ins to BIM platform, and independent software that use OpenBIM file exchange. Below is the example of BIM cost estimation tools:

Plug-ins to BIM platform:

- Innovaya Visual Estimating
- RIB iTWO
- Vico Takeoff Manager

Independent software using OpenBIM file exchange:

- Nomitech CostOS
- Exctal CostX

2.7.7. BIM Tools for Facility Management | Asset Management

Facility management, which is considered as post-construction phase, either rely on traditional method of 2D drawing to represent the information or numerical data in spreadsheet. From the traditional owners' point of view, managing spaces, equipment and facility asset may not require 3D information; but, with the increasing of the complexity of the building and building systems, 3D can add more value to the facility management functions.

With the BIM model, the facility information can be determined in the early phase of the project, which help the owner utilise space components by defining it in 3D, therefore reduce the time needed to create the database for facility management comparing to traditional method of manual space creation in 2D information. The ability of BIM tools for facility management to define the spaces and link them to current asset management system is a powerful advantage for the owner. Figure 2.14 shows an example of how space data in BIM model can be displayed quickly and cleanly in a mobile-based device.



Figure 2.14. Space data in the BIM model of Medina airport displayed on hand-held device
 (Source: TAV Construction)

The available BIM facility management tool available in the market now is summarise in the table 2.3 below based on BIM Handbook 3rd Edition [14].

Table 2.3. BIM Facility management Tool that useful to owners [14]

Tool	Company	Main Functions
Maximo	IBM	Asset management Work management Procurement and materials management Service management Contract management
EcoDomus FM	EcoDomus, Inc.	Filtering information by locations and disciplines Online 3D navigation Product documentation review Laser scanning interface BIM and Building Automation System Surface finish queries
ARCHIBUS	ARCHIBUS	Space management Move management Project management



		Maintenance Real estate and leasing management Asset management
FM:Systems	FM:Systems Group, LLC	Space management Move management Project management Maintenance Strategic space portfolio planning Energy or water usage monitoring Real estate and leasing management Asset management Mobile tools
AssetWORKS Solutions	AssetWORKS	Space management Move management Project management Maintenance Energy management Capital planning Operations and maintenance Real estate management
FAMIS	Accruent	Estate acquisitions Lease Project management Operations and maintenance Facilities management Asset management Inventory control Space management
WebTMA	TMA Systems	Request management

		Materials management Time management Contract management Executive dashboard Capital planning Custodial management General inspections Room inspections Utility service management IT service management Knowledge base Facility scheduler Key management Event scheduler Fleet management GIS solution BIM interface
Corrigo	Corrigo Inc.	Cloud-based FM solutions
Building Operations	Autodesk	Mobile-first facilities asset and maintenance management software for contractors and owners

2.7.8. BIM Tools with 4D Capability

In the construction phase of a project, construction planning and scheduling involves sequencing activities in space and time, considering procurement, resources, spatial constraints, and other concerns in the process [14]. Traditionally, the form of bar chart was used to plan a project; but in the spreadsheet, it is hard to show how or why an activity link to a given sequence or the longest path to complete a project. Since 1980s, with the development of 3D geometric models, an approach known as 4D CAD had been developed to solve these problems. With BIM technology, in a 4D model, the construction scheduling is linked to individual BIM objects, represented in 3D, allowing the visualisation of construction work of a building in sequence. Figure 2.15 show an example of how to use 4D model to simulate the sequence of activities in pre-construction phases.

Hence, 4D BIM tools allow constructor to simulate and evaluate planned construction sequences and share them with others in a project team. As a part of the project team, the knowledge and experiences of contractor is beneficial in building modelling. They can provide rapid feedback regarding constructability, sequencing and estimated construction cost if 4D simulation is integrated early in the project, which make benefits for both design team and the owner. Following the BIM Handbook 3rd edition [14], there are 5 benefits of using a BIM model with 4D capability:

- **Communication:** planners can visually communicate the planned construction process to all project stakeholders. The 4D model captures both the temporal and spatial aspects of a schedule and communicates this schedule more effectively than a traditional Gantt chart.
- **Multiple stakeholder input:** 4D models are often used in community forums to present to laypersons how a project might impact traffic, access to a hospital, or other critical community concerns.
- **Site logistics:** Planner can manage laydown areas, access to and within the site, location of large equipment, trailers, and so forth.
- **Trade coordination:** Planners can coordinate the expected time and space flow of trades on the site as well as the coordination of work in small spaces
- **Compare schedules and track construction progress:** Project managers can compare different schedules easily, and they can quickly identify whether the project is on track or behind schedule.

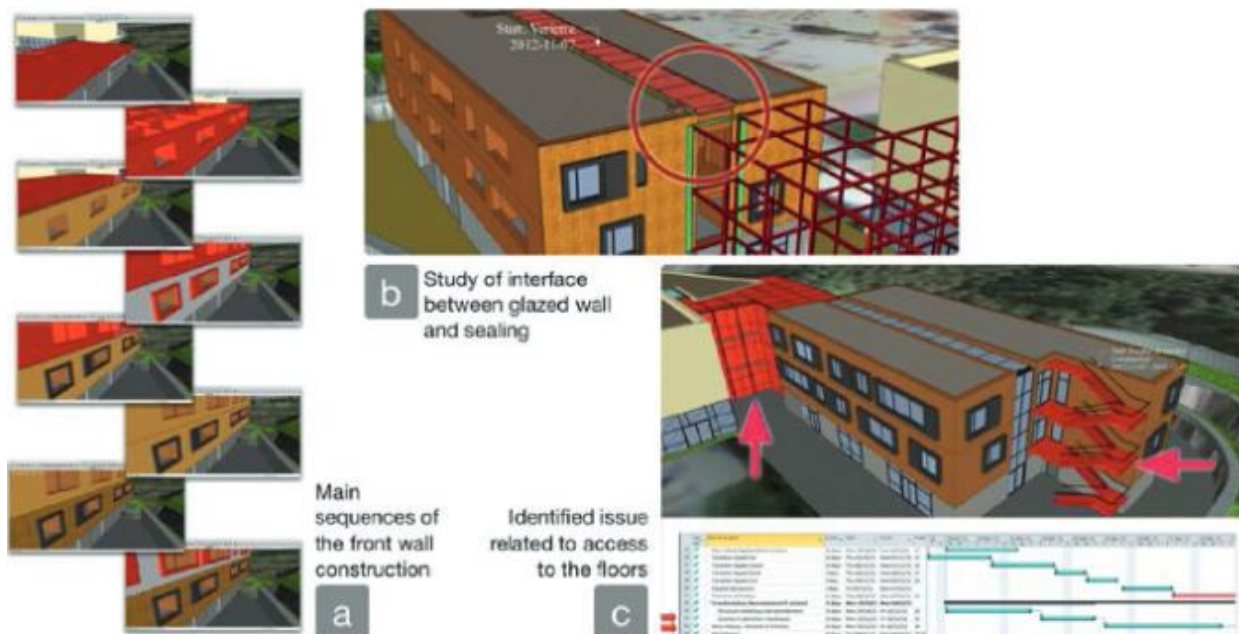


Figure 2.15. 4D simulation from the pre-construction model of a project [45]

However, most BIM platforms don't have built-in phasing or scheduling capabilities, and a stand-alone 4D BIM tools are needed. For 4D BIM Tools, these following criteria is important to evaluate:

- **BIM import capabilities:** with some 4D BIM tools, only geometry, geometry hierarchy is imported from BIM model. It is sufficient for basic 4D modelling, but other additional data may be needed so users can view object properties or filter, or query based on this data.
- **Schedule import capabilities:** The tool will need to support connections to the database and extraction of the schedule data.
- **Merge/update for 3D/BIM building models:** If a project involves models created in multiple BIM tools, the 4D modelling process will require import and merging of these models. The 4D tool must provide this capability.
- **Reorganisation:** Tools that support easy reorganisation of model components will greatly expedite the modelling process.
- **Temporary components:** There are temporary components appeared in the construction process such as scaffolding, excavation areas, storage areas, cranes. In many cases, users have to create these components and import them with the model geometry. Ideally, the 4D tool would have a library that allow users to quickly add these components.
- **Animation:** Some 4D tools allow users to animate objects over a specified time period to allow visualisation of equipment movement.
- **Analysis:** Tool support specific analyses, such as time-space conflict analysis, to identify activities happening in the same space.
- **Output:** Tool need the ability to easily output multiple snapshots for specified periods of time or create movies with predefined views and time periods. The custom output features will facilitate sharing the model with the project team.
- **Automatic linking:** Building components automatically link to schedule items based on field or rules. This is useful for projects with standard naming conventions.

Hence, there are tools that available in the market now. The following example is the selected BIM platforms with 4D Capability and dedicated 4D BIM Tools:

- Revit by Autodesk
- Tekla Structures by Trimble
- DP Manager, and add on to Digital Project BIM platform by Digital Project Inc.
- ProjectWise Navigator and ConstructSim Planner by Bentley
- Visual 4D Simulation by Innovaya

- Navisworks Manage by Autodesk
- Synchro PRO by Synchro Software
- Vico Office Schedule Planner and 4D Manager by Trimble

2.7.9. BIM Surveying Site Conditions

In the initial stage of renovation process, or in the middle of the construction phases, the ability to quick capture field conditions is an important advantage for participants in the project. For the contractors, the field-verify the installation of building component to ensure that dimensional and performance specification are met is critical part in their jobs. While with the renovation project, the method of quick capturing current building not only external geometric data, but also the building system inside the wall and ceiling is a key factor to determine a quick, efficient, and scalable renovation in building. For engineering purposes, capturing field conditions in the traditional way in that level of accuracy is only achieved by experienced surveyors with selective survey equipment. But, with the development of technology, there are 2 main potential technologies using for site capturing as following, which provide a more cost-effective alternative for many construction site survey applications, and their outputs – point cloud data files – can be merged with BIM models for rapid and easy interpretation of their data [14].

Laser scanning technologies:

Laser scanners (active sensors) operate by an emitting laser beam to a known direction and then waiting for the reflection to measure distances from the sensor to the object. By measuring the direction, the laser was emitted and the distance to the object was determined, the scanner can determine the 3D location of the surface that the laser has reflected off [46]. This technique work effectively for renovation process to capture existing building as well as capturing as-built construction details to get inspected. The primary product of the laser scanning is a point cloud – a set of data points in a user defined coordinate system that represents an external surface of the measured objects [47]. Software for pre-processing and point cloud export is usually supplied together with the scanning system [48]. Hence, the end result can then be imported directly into a BIM system. That is the biggest advantage in quick capturing a building for multi purposes.

Photogrammetry:

Passive sensors, like digital cameras, deliver 2D image data, which can be afterwards transformed into 3D information. The photogrammetric method generally employs minimum of two images covering the same static scene or object acquired from different points of view. Similar to human vision – if the object can be seen in at least two images, the different relative position of the object in the images allows a stereoscopic view and the derivation of 3D information of the scene seen in the overlapping area of the images. Using automatic location of common points in both images, the digital photogrammetric system is also able to build up a digital model of the scene [46]. Hence, the result of this technique is the same with laser scanning, which is a point cloud representing the geometry of the scene. However, point clouds

from photogrammetry are usually less dense and accurate than those from laser scanning. The accuracy of photogrammetry can be improved by increasing the number and/or the resolution of the images [14].

Point Cloud Processing

For the definition, a point cloud is a set of points in a three-dimensional coordinate system and represents the external surface of an object. The point cloud itself has a great predictive value and can carry highly detailed spatial information about a surveyed object. This unorganised structure is not very suitable for further analysis since spatial inquiries have high computational demands in this framework. For designing and further work a model composed of simple structures is needed [14]. Hence, when dealing with BIM, the point cloud can be directly loaded into BIM software. Otherwise, BIM software support most of common point cloud data format, which a 3D model in the desired format can be created straightforwardly using BIM software instruments. It solves the data transfer problem and level of detail from using quick capturing techniques into a complete BIM model [46]. Figure 2.16 shows an example of the point cloud data using photogrammetry techniques by different digital cameras.

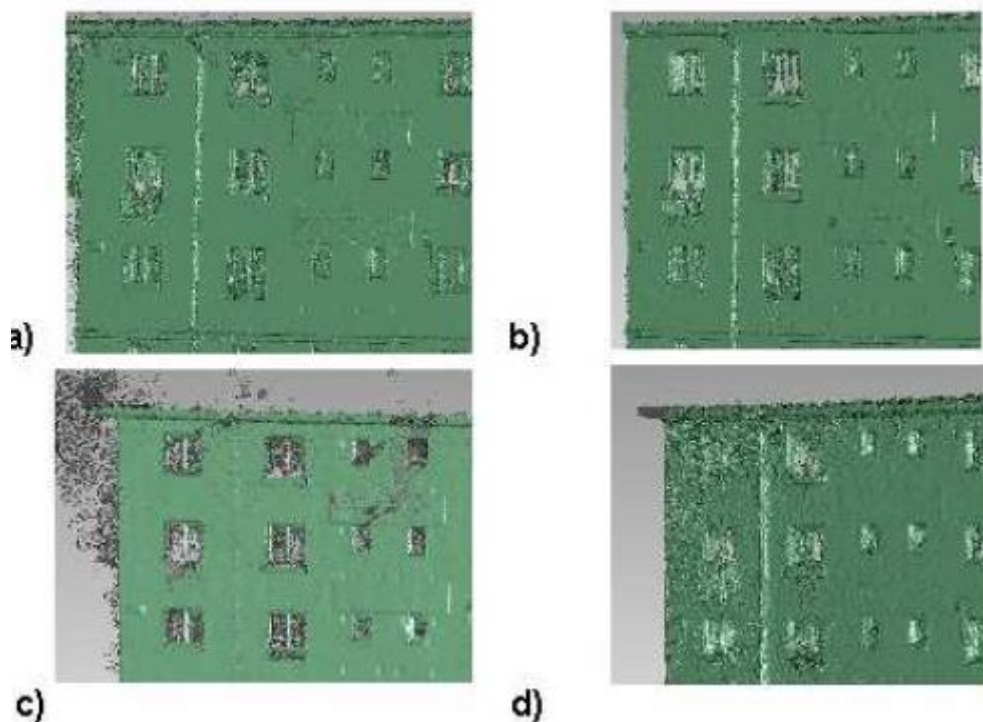


Figure 2.16. Point cloud from: a) Pentax 645D; b) Canon EOS 450D; c) Sony Cybershot; d) iPhone 5s [46]

In conclusion, laser scanning and photogrammetry are very sophisticated technologies, using for detail and complex building and project. Laser scanning requires expensive equipment, while photogrammetry need advanced software to provide algorithms to deal with photo by common digital camera. There are many current researches about this topic to complete the technology, however, some tools are already available in the market such as:

- Reality Capture software:

- Autodesk RECAP by Autodesk
- Trimble RealWorks by Trimble
- Leica Cloudworx by Leica
- Bentley Descartes by Bentley
- Point Cloud Data processing tool
- Bentley ContextCapture for photogrammetry
- Bentley Acute3D
- Indoor Reality

2.7.10. BIM Specification Application

Beyond drawing and detailed 3D model, there are many necessary information needed in a construction project; one of them is the technical specifications of related components in construction such as materials, finishes, quality grades, construction procedures, and other type of information for managing the realisation of an outcome building. We called them as project specifications. Normally, specification is organised according to types of materials within a project or classes of work [14]. For each material, type of product, or type of work, the specification defines the quality of the products or materials and identifies any special work processes that need to be followed.

There is some application, which is cross-reference with a BIM design tool is available in the market now:

- e-Specs
- linkman.e
- Speclink.e



CHAPTER 3

BUILDING RENOVATION

3. BUILDING RENOVATION

3.1. BUILDING RENOVATION DEFINITION

Renovation is mostly performed to meet the specific requirements of an owner and can include envelope and structural upgrades and spatial layout changes [49]. Renovation projects reflect about 1/3 of the total cost spent on construction projects. In addition to privately owned properties, increasing investment in renovation projects attract the attention of public owners and governmental institutions in order to improve and maintain their built and infrastructural facilities.

The volume of renovation projects is growing in the construction sector although their performance falls behind compared to new construction in terms of cost, time and quality. Several researchers have highlighted that renovation projects carry several risks and uncertainties which are different from those in new construction and which effect renovation project performance. [51]

In renovation projects inventory models are particularly useful. An inventory model is defined as “all historic, survey, measurement, etc. data, information [and even knowledge] about an existing building in an accessible and usable format” [51], An inventory model can improve data management, planning, decision-making, and increase the profitability of renovation projects [52].

It is also understood that the building models should not be generated in all cases because it relies on what the model is going to be used for. The intended model use sets the boundaries for the model content, the level of detail, and the accuracy of the model. Irrespective of the purpose and detail, the information should be easily accessible, machine readable, up-to-date, and in open file-format. The model could also be used as a checklist for initial information. The maintenance of the model must therefore be a natural part of the FM.

3.2. METHODOLOGY AND CRITERIA FOR THE ASSESSMENT OF RENOVATION & RETROFIT ALTERNATIVES

The Methodology and criteria have been classified according to the evaluation criteria under consideration: environ-mental, economic and multi-criteria assessment:

3.2.1. Environmental assessment

Under the environmental assessment Insulation of the envelope, replacement of windows, and air sealing appear to be the most common passive strategies. Sometimes also focusing on the improvement of building services, whilst the use of renewable energy remains low. Energy performance is one of the main topics considered with respect to energy-efficient refurbishment [53]. Thus, software tools are widely employed in order to quantify the efficiency of the actions.[54]. However, energy consumption, as well as carbon emissions, needs to be considered over the lifespan of a house. In addition to operational energy, embodied energy needs to be considered. This is defined as the energy sequestered in buildings and building materials during all processes of production, onsite construction, and final demolition and disposal. When attempting to conduct a deep renovation in order to obtain an energy-

efficient building, the introduction of the LCA emphasizes the embodied energy of the building as a key issue that should not be neglected in the evaluation [55]. LCA is a systematic approach enabling the quantification of potential environmental impacts of a building over its life cycle, from conception of the structure to the end of its service life, and from raw material extraction to the management of the building's demolition waste. This approach is being increasingly applied in energy-efficient renovation in order to evaluate retro-fitting solutions [56]

3.2.2. Economic assessment

A variety of typical economic analysis methods can be used to evaluate the cost-effectiveness of retrofitting investments, such as net present value (NPV), internal rate of return (IRR), overall rate of return (ORR), benefit cost ratio (BCR), discounted payback period (DPP), and simple payback period (SPP) [54]. NPV has been identified as the most widely used technique for optimal building energy assessment, when the future cashflow is considered [56]. It is the main method for the Life Cycle Cost (LCC) calculation, which is defined as a technique that enables comparative cost assessments to be made over a specified period of time, taking into account all relevant economic factors, both in terms of initial costs and future operational costs (ISO 15686-5, 2008)

3.2.3. Multi-criteria assessment

Multi-criteria analysis methodologies have been increasingly developed in order to achieve sustainable assessment, and whilst economic and environmental impacts are generally considered, social impacts - which are consequences of positive or negative pressures on social endpoints i.e. the well-being of stakeholders (UNEP, 2009) are still put aside were among the first authors to propose a multi-criteria (MC) model to be used at the process of building design in order to explore the trade-offs between building thermal performance and other criteria such as capital cost and usable area of the building. [56].

With respect to a discussion of methodological approaches, it is investigated that feasibility of applying multi-objective optimization techniques, which is a scientific area that offers a wide variety of methods with great potential for resolving complicated decision [56], to the problem of improving energy efficiency in buildings developed a genetic algorithm-based decision support system for housing condition assessment that suggests optimal refurbishment actions that take into account the trade-off between cost and quality.

3.3. THE ROLE OF THE LIFE CYCLE APPROACH IN HOUSING RENOVATION

3.3.1. Life cycle assessment (LCA)

LCA was initially developed for industrial products in the 1970s. Its first application in the building sector was concerned only with energy issues. Over recent decades, the relevance of considering environmental-related product information by LCA has been broadly recognized. Some building LCA studies focus on materials or only address the production phase of a building. Nevertheless, a LCA of a building is a complex task due to several factors, including the long lifespan (often more than 50 years), the number of involved stakeholders, and the singularity of each building. When the energy performance of a building improves because of retrofit measures, additional materials and components are applied, resulting in



higher embodied energy. Thus, when assessing environmental impacts throughout the life cycle, it is critically important to consider both the embodied energy of the retrofit measures and the post-retrofit building energy consumption. [56]

3.3.2. Life cycle assessment (LCA)

In the mid-1980s, attempts were made to adapt LCC to building investments. Using LCC to give an indication of the financial benefits over the life of the measures. The LCC is decided to calculate life cycle costs as the basis for the selection of energy-efficiency measures of their buildings. To do so, the model be look LCC – a tool for cost and energy calculations for alternative investments was developed. The approach taken was based on the logic that economically optimal design interventions minimize the sum of construction and operating expenses (energy costs accrued from space conditioning) over the lifetime of the building. LCC has also been applied to identify opportunities for improvements in the current housing stock. [56]



CHAPTER 4

**BIM TECHNOLOGIES &
TOOLS FOR BUILDING
RENOVATION, RETROFIT &
REFURBISHMENT**

4. BIM TECHNOLOGIES & TOOLS FOR BUILDING RENOVATION, RETROFIT & REFURBISHMENT

The literature review discusses about the BIM technologies and tools employed in the building renovation and refurbishment, and the benefits of BIM implementation with the challenges in BIM implementation for building renovation. The chapter also includes two different case studies with to compare and understand the context with our study related to BIM4EEB project.

4.1. BIM TECHNOLOGIES AND TOOLS FOR BUILDING RENOVATION, RETROFIT & REFURBISHMENT

BIM provides integrated output from different building systems which allows for well-informed retrofit & renovation decisions and improved communication among different parties. BIM model created for retrofitting & renovation can also be used at FM stage.[57]

Besides using BIM as a strategy to facilitate the analysis of energy performance of existing buildings, the literature provides other methods for achieving energy driven renovations. For instance, energy audits can be utilized for refurbishment of existing buildings to identify the energy usage and the associated costs with retrofitting [58]. The advancement of energy audit technologies offers more reliable information [59]. For example, Building Automation Systems (BAS) and Building Energy Management and Control System (EMCS) offer data that can be deployed for calibration of the parameters in an energy simulation model [60]. The accuracy of the collected data directly affects the reliability of the energy analysis for retrofit purposes [61].

Another strategy used to analyse refurbishment options is the environmental assessment tools [62]. These tools provide frameworks to check and enhance the energy performance of existing buildings. Performance assessment tools have gained popularity with the development of rating systems which benchmark energy performance of existing buildings against quantitative and qualitative performance indicators [63]. Other literature work describes the prerequisites, credits, and measurement methods required to achieve a certification for a refurbished building [64]; while others [65] quantified the financial benefits of improving the environmental performance of existing buildings.

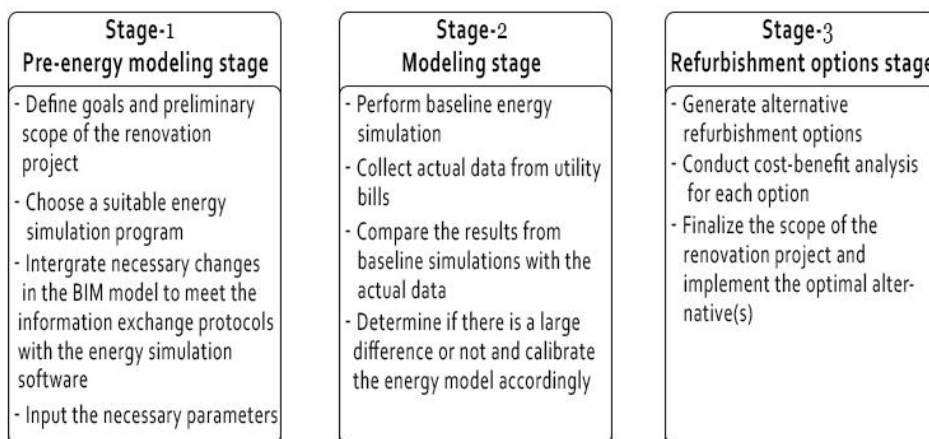


Figure 4.1. Strategy for analysing refurbishment options

In addition to the strategies provided by advanced energy auditing technologies and environmental assessment frameworks for refurbishment of existing building, computer simulation software can be used to model and simulate the energy performance of retrofit measures [60]. Some examples of these energy simulation platforms are EnergyPlus, eQUEST, BLAST, TRNSYS. Based on the literature review and discussions with energy modelling experts, a simplified process for an energy driven renovation using BIM technologies is put together. The 3 main stages are shown in figure 4.1 [66]

4.2. BENEFITS OF BIM IMPLEMENTATION FOR BUILDING RENOVATION

The potential areas of BIM usage in retrofitting are as follows:

1. Determining what level of green building certification systems (e.g. LEED) can be achieved using BIM as-built model,
2. Performing analyses related to building form, such as, orientation, massing, envelope, and daylighting, performing analyses on building functions (i.e. energy and water use, ventilation and lighting).
3. It is suggested that BIM offers the best solution for data management and flow throughout a retrofit project from the survey to the building site. [57]

Data from BIM model can be transferred to a cost estimating software to calculate the cost of retrofits. Moreover, BIM model created for retrofitting can also be used during FM. The main obstacle to BIM adoption in green building process, which includes retrofitting activities, is related to some interoperability problems between BIM tools and the perception that existing tools are easier to use. The two main types of tools that are used in retrofitting are energy performance modelling software and FM software. Both types of tools are still limited in utilizing the depth of data available in the BIM model and software integration needs improvement.

4.3. CHALLENGES IN BIM IMPLEMENTATION FOR BUILDING RENOVATION

Risk of BIM is related to legal and technical issues. The roles and responsibilities for data entry and maintenance of the BIM are still not clear. Also, there is diversity in BIM tools,

and interoperability issues are still being experienced. Licensing issues arise when project team members other than the owner and architect/engineer contribute data that are integrated into the building information model. Collaboration among stakeholders is still limited and needs to be improved. It is suggested to have collaborative, integrated project delivery contracts in which the risks of using BIM are shared among the project participants. There are also organizational and process-related challenges, such as cultural barriers towards adopting a new technology, undefined fee structures for additional scope.[57]

4.4. CASE STUDY 1

The case study 1 published on “Optimal Renovation Strategies for Education Buildings” [67] was carried out in 2018 which proposes a novel building information model (BIM)–building performance model (BPM)–building environmental model (BEM) framework to identify the most energy-efficient and cost-effective strategies for the renovation of existing education buildings to achieve the nearly zero-energy goal while minimizing the environmental impact. [67]

A case building, the University of Maryland’s Architecture Building, was used to demonstrate the validity of the framework and a set of building performance indicators—including energy performance, environmental impacts, and occupant satisfaction.

Building: The University of Maryland’s Architecture Building, USA

The original building was constructed in 1972, with several renovations and revisions performed after the initial construction. Major renovations occurred in 1998, where the computer rooms were renovated as well as the large auditorium space. In 2007, additional librarian offices were added to the library, and later in 2009, a visual resource centre was also added to the library. As estimated by the university, to completely replace the existing building and meet the modern codes and standard, the total cost (including all soft costs) would be \$36,391,731 (\$518/ft²) while renovating the existing building would cost approximately \$26,565,950 (\$379/ft²) [68]



Figure 4.2 Existing School of Architecture Building. [67]

4.4.1. Methodological Approach and Process

From the published article it is seen that the research methodology was a proposed BIM-BPM-BEM framework. The proposed framework from the Author:

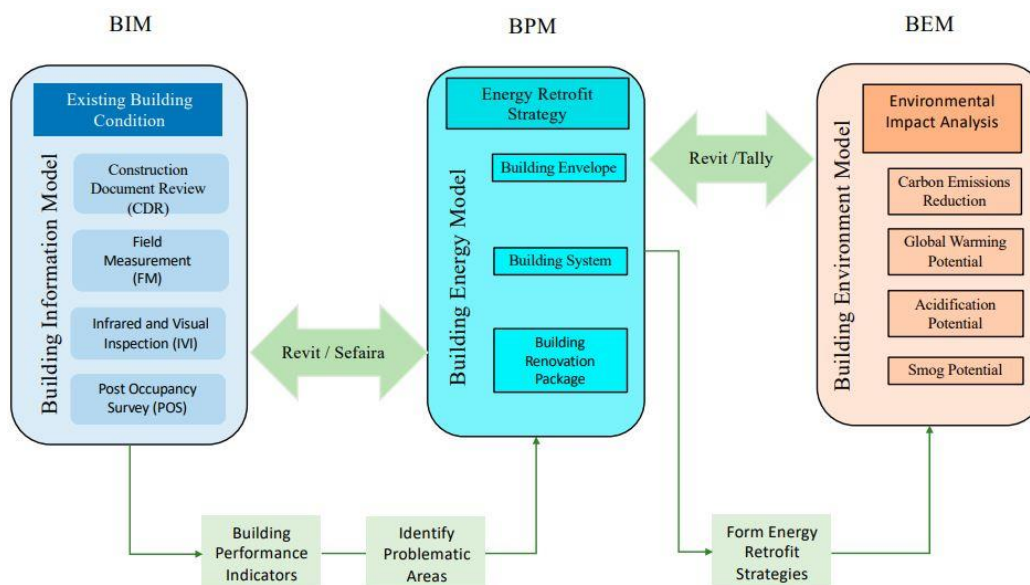


Figure 4.3. Research framework: building information model–building performance model –building environmental model (BIM–BPM–BEM) [67]

It was seen in the research project, based on original construction documents and on-site measurement, firstly, a virtual BIM model was constructed; the software chosen for this project was Autodesk Revit. Then, information and data from the BIM model were transferred to a building performance simulation program Sefaira. It is observed that Sefaira uses EnergyPlus as the primary simulation engine includes simulation capacities such as heat balance load calculations; integrated loads, system and plant calculations in the same time step; and a user-configurable HVAC system description [58–69]. Sefaira in this study also accounted for occupant behavior in regression forms. Multiple BPM models were created in the cloud and the results were compared compared. The material and building system information was extracted from the BIM model and translated into a BEM model. The software used in the project for data transfer and to run an environmental impact analysis is Tally that allows the modeler and designers to run a whole building life cycle assessment of the environmental impact from different design solutions.

The following sections present different parts of the methodology that was applied in this case project:

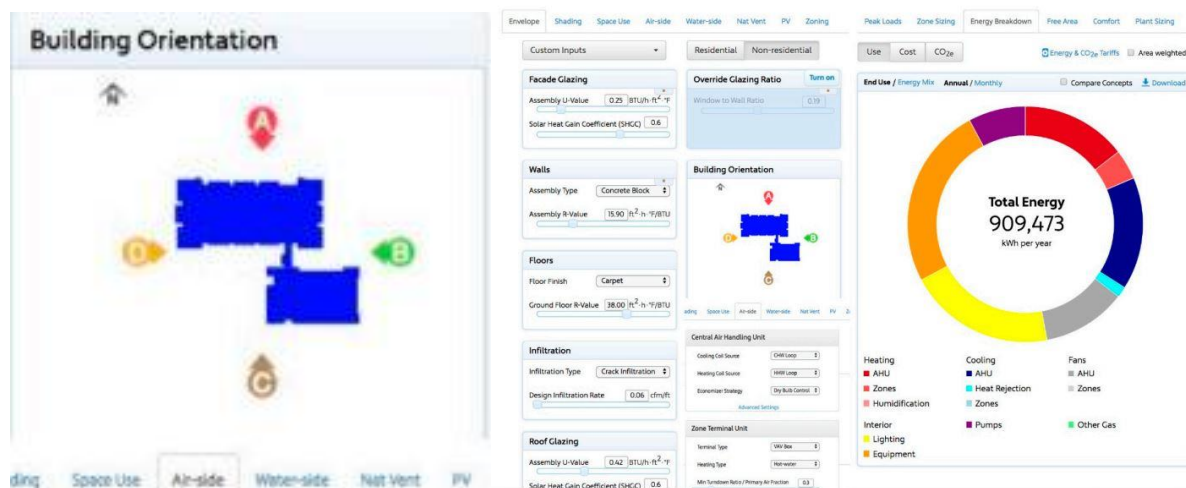


Figure 4.4. Sefaira online dashboard [57]

4.4.2. Building information model

The BIM stage in the research was comprised of four components:

1. The construction document review (CDR),
2. Field measurement (FM),
3. Infrared and visual inspection (IVI),
4. Post-occupancy survey (POS), and BIM model building.

The three main purposes of the BIM stage in the study were:

1. to generate an overall assessment of the existing building's (UMD's Architecture Building) conditions;
2. identify problematic areas and potential improvement opportunities according to alignments and discrepancies within CDR, FM, IVI, and POS;
3. and set up a BIM model based on information from IVI, POS, FM, and CDR and then prepare for data extraction to the BPM and BEM Models.

4.4.2.1. Construction Document Review (CDR)

Exterior Envelope of the Architecture Building

The original exterior wall was composed of composite brick veneer with two tiers of CMU (concrete masonry unit) backup and no insulation or air space in between (with an overall dimension of 305 mm (12 inches), which provides a very limited R-value for the exterior walls, estimated at 10.8 W/m² K (1.90 Btu/h·ft²·°F).

The original roof is made of concrete with 1-inch insulation board and composition roofing over it. The original construction of the roofing system, the estimated R-value is 28.3 W/m² K (5.0 Btu/h·ft²·°F).

The existing windows are the original units composed of single-pane uninsulated glass with painted steel frames. Most current windows units are not operable, with a Uvalue of approximately $7.3 \text{ W/m}^2 \text{ K}$ ($1.29 \text{ Btu/h}\cdot\text{ft}^2\cdot^\circ\text{F}$).

The existing doors generally have hollow metal frames. The current R-value of the window and door units did not meet current energy efficiency standards.

In general, the existing building exterior required a complete moderate repair and maintenance, considering the age of the building. The primary problem was that the existing building envelope standard fell quite below the current building energy code requirements. However, with the appropriate retrofit, there was a large potential for energy reduction with minimal costs.

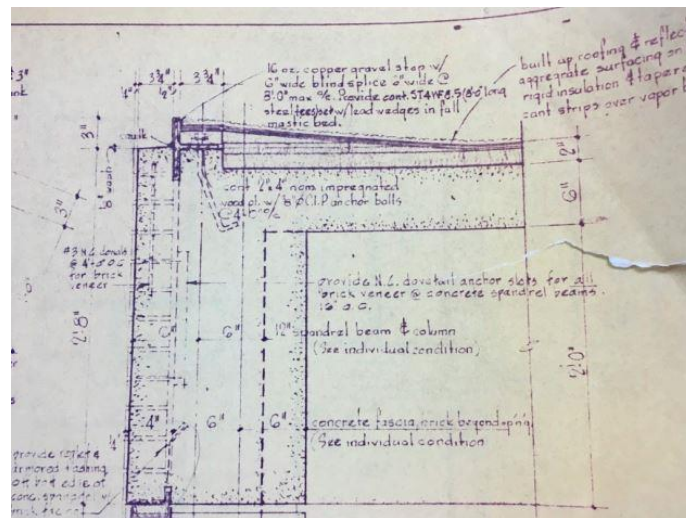


Figure 4.5. Original construction documents illustrating the roof assemblies [57]

Architecture Building System

The heating for the building was supplied by a satellite central utility plants: hot water was pumped into the building, and the centralized climate control system in the building controlled the indoor temperature in the winter by supplying the hot water with seven air handling units that supplied cool air to 16 different zones within the building. The annual energy consumption between 2015 and 2017 was, on average, 148 kWh/m^2 (47.13 kBtu/ft^2). With no ventilation system; air renewal is executed through the opening of windows and doors and natural infiltration. The existing building, in general, has enough daylight due the large skylights on the roof and large exterior windows.

4.4.2.2. Infrared and Visual Inspection (IVI)

An infrared thermograph camera, FLIR One, was used to identify the major thermal bridge, heat loss, and air infiltration in the Architecture Building's envelopes (walls, roofs). The infrared inspection around the windows' frame indicated the potential for air leakage and infiltration. Outdoor images revealed a maximum of an $8 \text{ }^\circ\text{C}$ ($46 \text{ }^\circ\text{F}$) difference between different sides of buildings, which could be caused by insufficient insulation. Indoor images

clearly illustrated that the thermal leaking happened primarily where the ceilings and walls connected [70]



Figure 4.6. Infrared images of interior and exterior conditions [67]

4.4.2.3. Field measurement (FM)—Indoor Environmental Quality

The major obstacles to an affordable energy retrofit is the fact that most older, existing buildings are not metered, making it difficult to identify which categories could gain the most from an energy retrofit. Under such conditions, different renovation strategy indicators, other than energy consumption, could be beneficial for the design team to identify problematic areas. In the study carried, the combination of a field auditing index and post-occupancy satisfaction index were used as building performance indicators. The temperature, humidity, CO2 levels, acoustic levels, and lighting levels were recorded. The five sets of data were normalized. Overall, thermal comfort and acoustic level (speech privacy) were the top two problematic areas based on field auditing. The equipment used for this project included the Supco IAQ55 indoor air quality/temperature/humidity CO2 tester, Graniger light meter, and RISEPRO digital sound level meter.

4.4.2.4. Post-Occupancy Survey (POS)

In order to further understand the overall space quality and problematic areas in the existing building, as well as common dissatisfaction points of the indoor environmental quality, a post-occupancy survey, the Indoor Environmental Quality Survey, was conducted online.

The survey comprised of time spent in the Architecture Building during February 2018. And asked the participants to rank their satisfaction level for light, noise, temperature, and acoustics, from very dissatisfied (1) to very satisfied (7), seen below in Table. The analysis was carried out on these numerical responses.

Table 4.1. The demographics of survey participants [67]

Age Range	Participation Percentage
16–22 years old	40%
23–36 years old	37.1%
37–45 years old	5.7%
46–55 years old	8.6%
56 years and above	8.6%

Table 4.2 Rating system for the Indoor Environmental Quality Survey [67]

Very Dissatisfied	1	2	3	4	5	6	7	Very Satisfied
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4.4.3. BIM Model Building and Identification of Problematic Areas

The BIM model was constructed from the original documents from the Architecture Building's library. The author constructed a three-dimensional virtual model using Autodesk Revit and have manually inputted all related material properties that were not part of the default Revit template. All information related to physical characters and conditions of the existing buildings were embedded in the three-dimensional objects. The Revit model was then prepared to simulate the energy performance of different renovation techniques and packages.

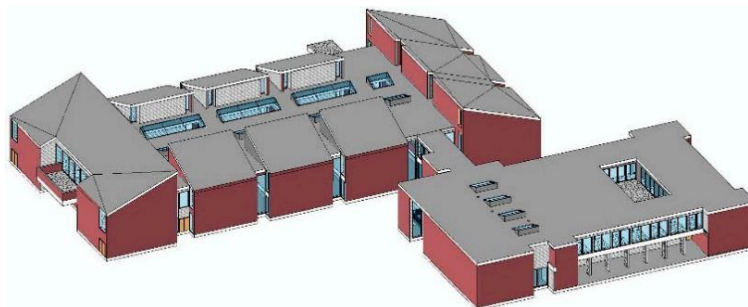


Figure 4.7. BIM model of the Architecture Building [67]

From the results of FM, POS, IVI, and CDR, two primary problematic areas were identified: sound transmission and overheating. These two problematic areas are then used as a guiding principle, together with the energy reduction goal, to evaluate the effectiveness of varied renovation strategies.

4.4.4. Building Performance Model (BPM)

The author is focused on the existing and future operational energy performance of the building. The BPM is composed of three steps: (1) identify and simulate building envelope retrofit techniques; (2) identify and simulate building system retrofit techniques; and (3) identify and simulate the building retrofit package based on results from 1 and 2. The primary purposes during the BPM stage were to create a ranking of the proposed renovation packages from energy-saving and cost-optimized perspectives. The Sefira system has been used to carry out the simulation. The construction and maintenance cost information has been provided by the Facility Management Office of the University of Maryland.

4.4.4.1. Energy retrofit Techniques—Envelope and Lighting System

To tackle the two primary problematic areas, a focus on retrofit techniques had resulted in exterior envelope upgrades and an interior partition retrofit. In the existing building, the exterior wall and partition walls were either made of CMU block or cast-in-place concrete without thermal and acoustic insulation. Renovation techniques identified for the building envelope and lighting system were:

1. T1: Substitution of present window with low-emissive units (with U-value of 0.25 w/m² k)
2. T2: Application of additional thermal insulation to the roof slab (R-50)
3. T3: Application of additional thermal insulation for the exterior walls (add additional 3-inch panels of expanded polystyrene insulation, R-38)

4. T4: Application of additional thermal insulation and acoustic insulation for the interior walls (add additional 2-inch panels of expanded polystyrene insulation, R-10)
5. T5: Replace all existing windows with double glazing window units
6. T6: Reduce air infiltration by using air-tight windows (air infiltration rate, 0.3 L/s·m², 0.06 cfm/ft²)
7. T7: Replace all existing lights with LED lighting
8. T8: Application of phase-change material (PCM) wall board on the inside face of exterior wall

In terms of cost, T6 was most cost-effective (saving) in comparison to other techniques, with T8 following in second. T2 and T7 were the most effective in reducing the peak heating and cooling loads. In terms of the initial construction cost, T6 had the lowest cost while T5 had the highest cost; T8 was difficult to predict due to the lack of enough data, and the remaining techniques share similar per-unit costs. When observed the construction feasibility, T7 represented the most practical strategy whereas T8 was the least feasible, due to the accessibility of phase-change materials.

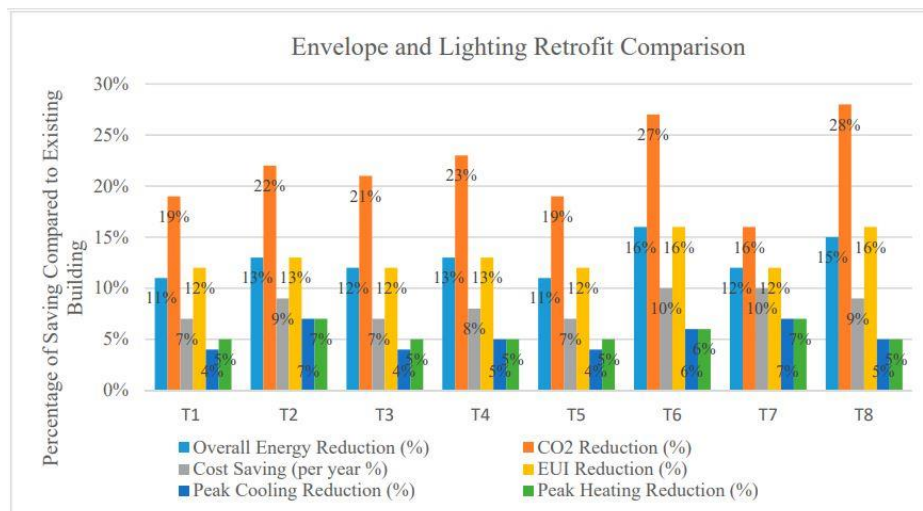


Figure 4.8. Envelope and lighting retrofit comparison [67]

4.4.4.2. Energy Retrofit Techniques—Building System

Renovation techniques identified for the building system included the following:

1. HVAC1: VAV with rooftop package unit
2. HVAC 2: VAV with central plant
3. HVAC 3: DOAS System (Package Terminal AC)
4. HVAC 4: DOAS System (Split System)
5. HVAC 5: DOAS System (Fan Coil Units and Central Plant)
6. HVAC 6: DOAS System (Water Source Heat Pump Fan Coils)

7. HVAC 7: DOAS System (Active Chill Beams)
8. HVAC 8: DOAS System (Passive Chill Beams)

HVAC 1 and 2 produce the highest energy-saving and CO₂ emissions reduction potential, with a relatively low cost.

Table 4.3. Comparison of building system retrofit techniques [67]

Retrofit Techniques (HVAC)	Total Energy Reduction (%)	CO ₂ Emissions Reduction (%)	Cost Saving (Per Year %)	Initial Cost
HVAC1 (VAV)	53%	70%	45%	low
HVAC2 (VAV)	57%	86%	44%	low
HVAC3 (DOAS)	18%	44%	6%	moderate
HVAC4 (DOAS)	18%	44%	6%	moderate
HVAC5 (DOAS)	35%	97%	6%	moderate to high
HVAC6 (DOAS)	26%	79%	1%	moderate to high
HVAC7 (DOAS)	5%	12%	2%	moderate to high
HVAC8 (DOAS)	26%	49%	15%	moderate to high

4.4.4.3. Retrofit Strategy Package Setup

Based on the results from the building envelope and building system retrofit techniques, six different packages were proposed according to their energy-saving potential, carbon emissions reduction potential, construction feasibility, and initial cost. A simulated final site energy use intensity was also provided.

Table 4.4. Comparison of building retrofit packages for achieving the nearly zero-energy goal [67]

Retrofit Package	Building Envelope Techniques								HAVC	Initial Construction Cost	Final Energy Use Intensity (EUD) kWh/m ² With PV Panel Installed on Roof
	T1	T2	T3	T4	T5	T6	T7	T8			
P1		x	x	x		x			HVAC 2	Low	0.082 kWh/m ²
P2	x	x	x	x		x			HVAC 2	Moderate	0.088 kWh/m ²
P3	x			x	x	x	x		HVAC 2	Moderate	0.082 kWh/m ²
P4	x	x	x	x	x	x			HVAC 2	High	0.088 kWh/m ²
P5	x	x	x	x	x	x	x		HVAC 2	High	0.078 kWh/m ²
P6		x		x		x			HVAC 2	Low	0.088 kWh/m ²
P7			x	x		x	x		HVAC 5	Moderate	0.196 kWh/m ²
P8	x	x	x	x	x	x	x	x	HVAC 8	High	0.23 kWh/m ²

4.4.5. Building Energy Saving due to Retrofit Packages

Among eight different packages, P4 and P5 produce large energy-saving benefits with a relatively high initial construction cost. Alternatively, P1 and P6 had produce considerably high energy-saving benefits with a relatively low cost. P2 and P3 produce the same results as P1 and P6 but with a moderate initial cost. Lastly, P7 and P8 produce less energy and cost saving compared to the other packages.

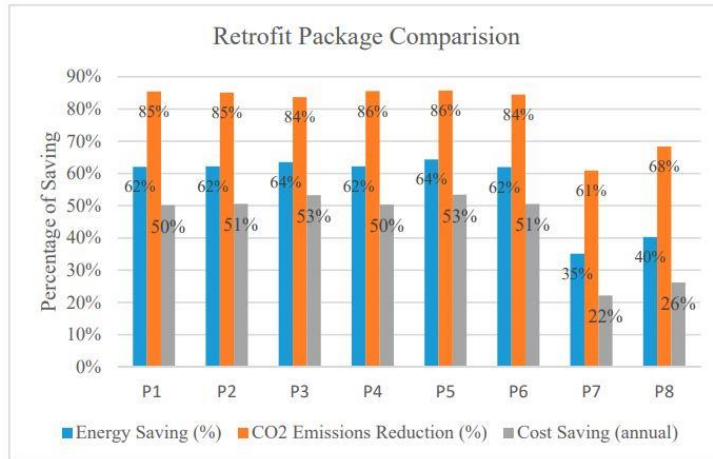


Figure 4.9. Renovation package environmental impact comparison [67]

The table below ranks the different renovation packages based on their potential to achieve the nearly NZE goal while minimizing the environmental impact and considering the initial cost and construction feasibility. P3 represented the optimal solution, considering all performance indicators; P5 offered an alternative solution if the budget is enough. Conversely, P1 could potentially achieve the nearly NZE goal with a low cost and high construction feasibility; however, the long-term environmental impact would be of great concern.

Table 4.5. Overall renovation package comparison [67]

Retrofit Package	Energy Saving (%)	CO ₂ Reduction (%)	Cost Saving (yr)	Initial Cost	Construction Feasibility	Ranking of Achieving Nearly NZE (Refer to Table 5)	Ranking of Lowest Environmental Impact (Refer to Figure 14)	Improvement in Speech Privacy	Improvement in Thermal Comfort
P1	62%	85%	50%	Low	High	2	7	Yes	Yes
P2	62%	85%	51%	Moderate	High	3	5	Yes	Yes
P3	64%	84%	53%	Moderate	Moderate	2	2	Yes	Yes
P4	62%	86%	50%	High	Moderate	3	8	Yes	Yes
P5	64%	86%	53%	High	Moderate	1	1	Yes	Yes
P6	62%	84%	51%	Low	High	4	6	Yes	Yes
P7	35%	61%	22%	Moderate	High	5	3	Yes	Yes
P8	40%	68%	26%	High	Low	6	4	Yes	Yes

4.4.6. Conclusion

The use of Building information modelling and Management allows to select suitable renovation strategies that consider all performance indicators: an energy consumption reduction, CO2 emissions reduction, environmental impact reduction, and indoor quality improvement.

A variety of renovation techniques were identified, and multiple retrofit packages were compiled with four primary goals: (1) to optimize the energy demand reduction to contribute to UMD's overall carbon neutrality goal; (2) improve speech privacy by adding additional acoustic insulation; (3) improve thermal comfort by mitigating overheating problems, and; (4) minimize the long-term environmental impact. [67]

The study also provides insights about the importance of interoperability among different software in facilitating data translation and transformation. Advanced digital technologies and platforms—such as BIM (Autodesk Revit), BPM (Sefaira), and BEM (Tally)—make it

possible for decision-makers to examine all performance indicators within the same framework and form decisions with a holistic understanding of all the advantages and disadvantages of the proposed renovation strategies. [67]

4.5. CASE STUDY 2

The case study 2 is an article published on “BIM in facilities management applications” was carried out in 2014 on a case study of a large university complex. The purpose which is to investigate the value of BIM and the challenges affecting its adoption in FM applications. The case study was conducted on Northumbria University’s city campus, which is based in Newcastle upon Tyne (UK) with a gross area of over 120,000 m². The case study was conducted in 2010. The models were completed by the five developers in five weeks at a cost of approximately £0.33/m². [71]

4.5.1. Workforce and process efficiencies

The University had updated its drawings and information in two separate environments (i.e. floor plan drawings in two-dimensional graphical representation – i.e. DWG format – and a database in MS Excel format). Both require manual update, creating duplication of workload. Using BIM for FM, the creation of geometric information and the inclusion of specific FM information allows automatic updating of required schedules; producing instant sections, elevations, three-dimensional visuals and renders, and generating drawing sheets from a single integrated environment. [71]

The staffs were able to identify BIM for FM models, with the augmentation of available BIM functionalities, can enhance key FM services such as room finding, fault reporting, development and refurbishment option generation, and assessment of building performance. Such services lead to reduction in response times, with detailed campus knowledge assigned to specific buildings, levels, rooms, etc. For example, with each request to replace a light bulb on the campus, the maintenance staff could check in real time the bulb type and manufacturer using the FM model before carrying out the task. Another example could be to check the paint colour code for a room where the wall finish has been damaged, thus saving staff time and material resources. The developed BIMs for FM were used to trial option appraisal for redevelopment and refurbishment as phased plans, sections, elevations and 3D rendered views that could be quickly displayed and assessed. Such functionalities provide time and costs efficiency in future FM option appraisal and represent a platform for more accurate strategic decision making from a management perspective. [71]

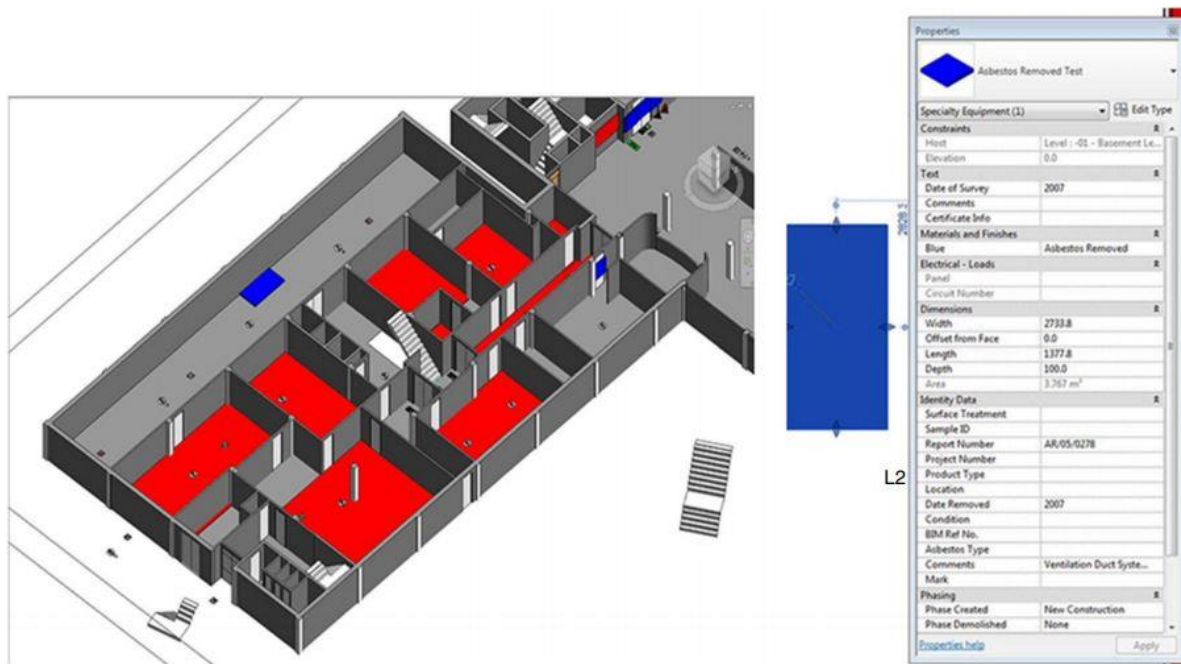


Figure 4.12. 3D view of removed (blue) and existing (red) asbestos in building model [71]

4.5.2. Accuracy of records of geometric information

The creation of a BIM had revealed that some areas of buildings on the campus failed to line up when the two-dimensional drawings and elevation scans were used as a basis to build the models (See the diagram below).



Figure 4.13. Generation of design options for internal refurbishment [71]

This had called upon the estate department to order new surveys to verify the building layout. Also once the FM team achieve the required BIM skills, the maintenance of geometric records will be accomplished in a more efficient way from both economic and quality perspective.

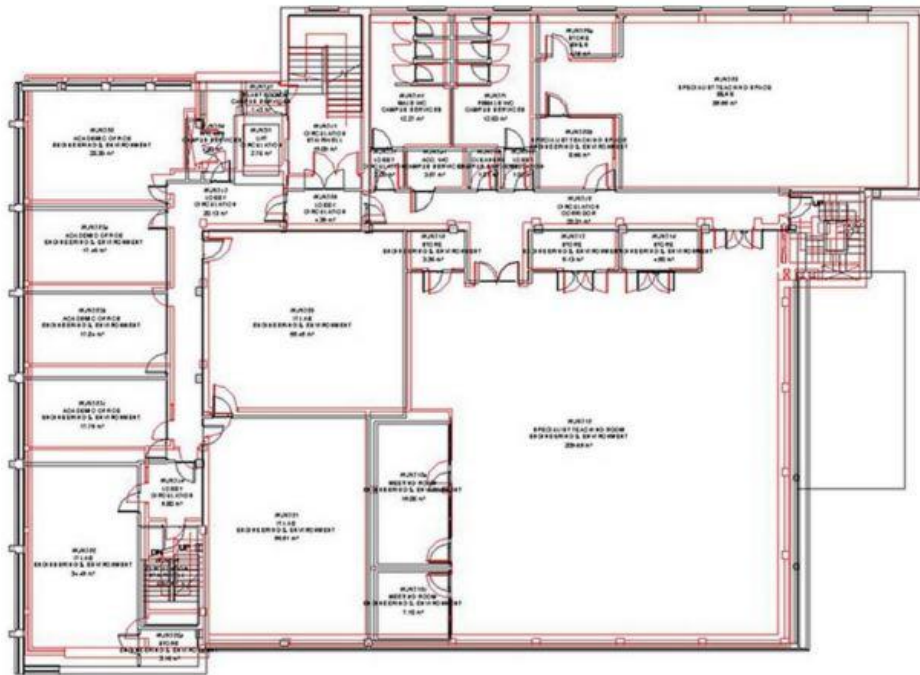


Figure 4.14. Improved accuracy of building records when implemented in BIM (red: original, black: updated) [71]

4.5.3. Implementation challenge and maintenance of models

Once the previously illustrated scenarios had demonstrated the value of BIM in FM, discussions with the FM estates department had understood the challenges associated with migrating from current FM processes to BIM-based processes. Several implementation challenges were identified. There was a need to communicate and understand the benefits of BIM for FM with empirical examples such as the ones previously illustrated. The FM team must also have the skills to be in position of maintaining and controlling the BIMs for FM. A concise BIM for FM specification must be developed to define the information required to suit the particular requirements of the business and FM functions – space management in this specific case study.

It was found on live projects that the geometry on FM models can be a lower level of development, so long as the data can be added or linked to the model. An example of the levels of development used in the case study is reported using the AIA LODs (AIA, 2012). These AIA LODs have generally been set up with new buildings in mind where there is a need for a higher level of development during the construction process. Such specifications and templates will also help to engage with the supply chain on future work on the university campus and enable compatibility with the organisation's FM procedures.



Figure 4.15. BIM models at AIA LOD 500 (left) and AIA LOD 100 (right) [71]

4.5.4. Conclusion

BIM in FM application is still considered an emerging field. The understanding of the challenges and value-adding potential of BIM in FM is fundamental at this early stage. The results from the case study demonstrated with practical examples how BIM can add benefits to the workforce, process efficiencies and to the accuracy of records of geometric information. Also FM organisations must be prepared to work with different information and data standards in the mid and long terms instead of adapting their business processes to fit a specific technology. The development of a BIM for FM specification that suits the need of the organisation's FM processes was identified as a key factor to exploit the benefit of BIM-based FM and enable organisations and their supply chain to work according to structured FM processes. Source: [71]

4.6. CONCLUSIONS FROM CASE STUDY 1 & CASE STUDY 2 WHEN RELATED TO BIM4EEB PROJECT

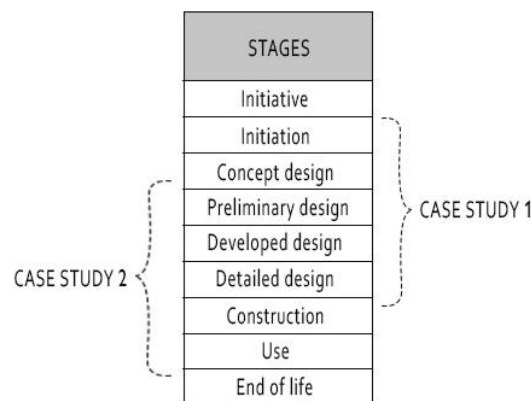


Figure 4.16. Concluded stages from 2 case study.

The figure above shows the two different case study, as case study 1 deals with stages between initiation and construction whereas case study 2 deals from preliminary design till use and little of end life.

It is clearly observed that both the case studies discussed above is carried out with a same goal which is BIM involvement in the Building Renovation process but with different aims to achieve at the end of the study. The case study 1 discusses more on energy-efficient and cost-effective strategies for the renovation to achieve the nearly zero-energy goal while minimizing

the environmental impact and a set of building performance indicators—including energy performance, environmental impacts, and occupant satisfaction [11]. This are similar goals which can be seen in the BIM4EEB with respect to Energy efficiency renovation. In case study 2, with BIM for building renovation and the challenges affecting its adoption in FM applications was the main aim and direction of research.

Both the studies indicate that the project had been completed with the available BIM software's and tools and BIM Management System. When compared to the stages of BIM4EEB project with the case studies, the project lacks in the management and listings regarding the Initiative and Initiation phase but are proved to be active in the use of BIM for the preliminary, developed & detailed design phases and the importance of interoperability among different software in facilitating data translation and transformation had made it possible for decision-makers to examine all performance indicators within the same framework and form decisions with a holistic understanding of all the advantages and disadvantages of the proposed renovation strategies.

The conclusion from case study 2 which were BIM for FM should meet the requirements of a building owner, meaning that clients need to understand and articulate their BIM requirements including the level of detail needed. The differing life span of technologies and buildings suggests that there is a requirement for open source standards that aid in maintaining the usability of models.

A few of the values and potentials which can identified from the case studies when involving BIM & FM and BMS for the renovation projects [71]:

- Increase of the efficiency of work orders execution, in terms of speed, to accessing data and locating interventions. Such value is derived from the capability of BIM to provide a data-rich visual and integrated data environment.
- Improvement in the accessibility of FM data that can be found within the model.
- Increase of efficiency for creating bespoke plans, elevations and visual renders all from the same model.
- The ability to attach legislative/statutory compliance data, which can be reported and scheduled out of the one model.
- The Potential for room finding and accurate fault reporting through the interrogation of the model.
- The ability to scenario plan refurbishment projects in a 3D environment

The following were the few challenges that are hindering the exploitation of BIM in a renovation project & mainly in FM. The main challenges are [71]:

- The lack of clear roles, responsibilities, contract and liability framework
- The rigid industry cultural approach to adopting new processes and technologies.
- Limited knowledge of requirements for the implementation of BIM in FM (e.g. what information is to be provided, when and by whom)
- The interoperability between BIM and FM technologies and the difference in their lifespan

- The need for rigorous BIM specifications for modelling requirements
- The lack of methodologies that demonstrate the tangible benefits of BIM in FM, which is reflected by limited demand for BIMs for FM by clients and operators

4.7. BUILDING MANAGEMENT SYSTEM (BMS) TO SUPPORT BUILDING RENOVATION

A BMS is a system that not only gives programmed observing and control of services such as lighting, plumbing, fire administrations, heating, cooling and ventilation, but moreover supports comfort and energy efficiency. The objective of a BMS is to upgrade building operational condition monitoring and control. The BMS is often a compelling arrangement to cost conscious building management strategies and it enables representatives and tenants of a facility to be more productive. A Building Management System minimizes energy utilization and maximizes indoor comfort. A fully optimized BMS can save energy costs to the extent of 15%–20% as compared to a building without a BMS [72].

4.8. CHALLENGES IN THE USE OF BUILDING MANAGEMENT SYSTEM DATA

The technological advances made in the development of building data acquisition systems are well acknowledged. However, there have been challenges in utilizing such data to meaningfully inform and improve subsequent project design and delivery. Data collected from acquisition systems grow very large in size and is too unstructured to put to immediate beneficial use without some form of structuring and analysis. Thus, the technological advances in BIM offer opportunities to overcome a number of these challenges by integrating BMS data and learning from energy performance data as feedback to various building life cycle stages.

One obvious objective of measuring building energy consumption such as through BMS is to ascertain how the building performs in use. It also helps in determining what the user needs to pay for the services provided. Besides the collective responsibility to reduce environmental pollution, “the polluter pays” approach has been a major driver compelling energy consumer to explore avenues to reduce their quotas of pollution arising from energy use. The monitoring and acquisition of energy consumption over a period provide opportunities for strategizing various means to achieving reductions in costs that accrue from energy bills. This is especially important as energy is used for a wide range of activity categories including air conditioning and heating, heating and pumping of water, lighting, powering of ICT, and the plethora of personal electronic devices etc. Ascertaining the various proportions of consumption attributed to these categories could be beneficial [72].

BIM-BMS linkage may prove useful for the facility manager in achieving desired energy consumption reductions. Such linkage will provide opportunity for harnessing feedback from the model to inform and improve asset performance and vice versa.[9] It will entail careful planning, mapping and integration of the facility management operations into the BIM approach. This includes the use of BMS to improve the design and operation of buildings concerned with the active control of energy-dependent systems. Research suggest that the



existing gaps in linking BMS data to BIM are contributory to the inconsistencies in graphical energy data generated from manual data input of repetitive energy management systems [72].



CHAPTER 5

**ANALYSIS FOR EFFICIENT
RENOVATION IN BUILDINGS
IN CASE OF PRIVATE &
PUBLIC WORKS**

5. ANALYSIS OF BIM FOR EFFICIENT RENOVATION IN BUILDINGS IN CASE OF PRIVATE & PUBLIC WORKS

An overview of the implementation of renovation in private & public premises

In the case of private works, which are generally profit-minded, the Owner/Client is typically driving the work (along with any financial partners), with the ultimate objective to provide a financial benefit on the investment (i.e. return on investment). The Client/Owner makes the decision to undertake (or not) the works based on a cost-benefit appraisal and available funding. But in case of public works, it is more driven to the benefits to the economy and social benefits.

In this private case, financing of the intended renovation works usually derives through the Owner/Client himself (private funds), or by banks and/or a group of private investors (third party financier). While in public case the fund is directed from the public agencies or government bank funded. In terms of bidding the Private bidding can be seen as a quality driven action, where the Client/Owner can decide to appoint a contractor based on fulfilment of certain criteria, which can reassure him that the selected contractor can complete the project in time and within budget [BIM4EEB project].

While identifying in the selection of the procurement strategy, private works can benefit from a faster procurement process, the Project Leader can source the suppliers/subcontractors (usually identified in the private entities' supply chain database) he 'prefers' to work with (typically evaluated by their previous work, experience/expertise, and reputation) and as long it is within the budget. In public works the procurement process is always late on schedule because of the formal procedures that has to be undertaken at each stage. As such, private projects can achieve better deals and procure materials/services when required, speeding up the overall process. For private works, where the regulation (European Union Procurement Directives) limitations are not that strict and thus the typical workflow process is applicable in different geographical regions [BIM4EEB project].

Considering the roles and responsibilities it is evident that in private projects a subgroup of stakeholders is involved in the overall process, but in public projects the Govt. authority/officials are the lead roles and sole responsibilities. In case of private, the building owner/ project leader is the key role that handles the main responsibilities during the renovation process, the project leader is addressing multiple roles and responsibilities [BIM4EEB project]

Stage of the activities, referring to the structure defined within *EN 16310:2013 - Engineering services - Terminology to describe engineering services for buildings, infrastructure and industrial facilities* [EN 16310, 2013].

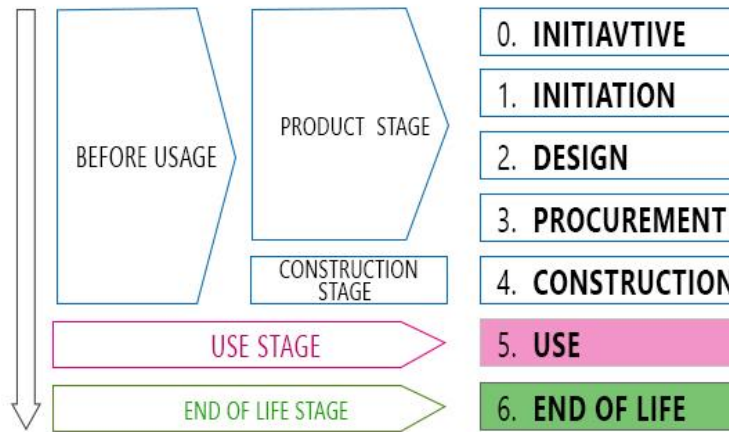


Figure 5.1 Stages in the lifecycle of a building asset (EN 16310)

The Figure below represents the steps involved which have been discussed in the following sections to achieve the results which is the User Profiles:

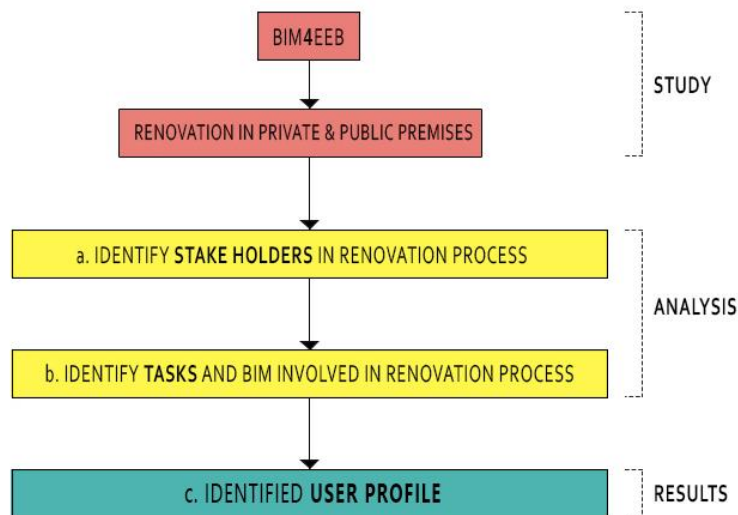


Figure 5.2. Steps to achieve the User profiles

The basic study was on BIM4EEB for renovation in private & public premises to understand the project attribute which are basically the terms and definitions of the involved stakeholder and their actions towards the assigned tasks accordingly with respect to the stage wise.

The second step was to analyse those stakeholders who are to be involved in the BMS of the project in all 9 different stages. And, to identify the tasks of those involved stakeholders & categorizing them with the identified BIM Tools [refer to Appendix].

From the above study and analysis, the user profile for the all the actors are illustrated in the below section.

5.1. IDENTIFY STAKE HOLDERS IN RENOVATION PROCESS

With respect to the WP2 (Work package 2) as defined in the BIM4EEB project, which points at examining the workflow of renovation process, focusing on how to enhance information workflows between distinctive stages through the utilize of Information and Communication Technologies and the usage of BIM.

Under this WP the main objective is to make strides communication, making data sharing simple, solid and quick for the involved stakeholders and dodging data duplication and conflicting datasets. The whole building process can be enhanced, in case each stakeholder along the life-cycle of a building (and built asset) is able to find required data & information and share the existing or new datasets in a clear and conflict-free approach. These accomplishments will be reached by adequately overseeing data amid the different construction process stages (planning, designing, development, use, management, maintenance and reuse) and interfacing the various actors involved (client, owner, designer, architects, contractors, engineers, advisers, surveyor and others).

From the BIM4EEB project, the project consists of 9 stages starting from the Initiative stage to End of life stage, with 19 Actors/stakeholder actively taking part in the tasks during the different stages of the project in case of private works.

Listed in the below table are the identified actors with the definitions to understand their roles and responsibilities in the project [table from BIM4EEB].

Table 5.1. Terms and definition of the principal stakeholders involved in a renovation process

Term	Definition	Source
Client	The party commissioning the design and construction of a project. The client may be an individual or a company. In the latter case, an individual should act as a single point of responsibility for decision and communication even if numerous bodies, or individuals, within the client organisation will contribute to decisions. The client may use an RIBA Client Adviser, a specially accredited individual, able to provide strategic advice in the early stages of a project in relation to the strategic definition or briefing aspects as well as the best methods for setting up the project team	[RIBA, 2013] Project Roles Table
Owner	A person, a group of people, a company or a public administration who owns a built asset	Authors
Inhabitant	A person that lives in a built asset	Authors
End-user	A person that uses a built asset	Authors
Client Adviser	A consultant providing strategic or specialist advice particularly during the early project stages	[RIBA, 2013] Project Roles Table
Technical adviser	A consultant employed by the client to provide specific advice, particularly on design and build or contractor-led procurement routes	[RIBA, 2013] Project Roles Table
Project Leader	The party responsible for managing all aspects of the project and ensuring that the project is delivered in accordance with the Project Programme	[RIBA, 2013] Project Roles Table

Lead designer	The party responsible for managing all aspects of the design, including the co-ordination of the design and the integration of specialist subcontractors' design, where applicable, into the coordinated design	[RIBA, 2013] Project Roles Table
Architectural designer	The party responsible for carrying out the architectural design	Authors
Structural designer	The party responsible for carrying out the structural design	Authors
Building services designer	The party Responsible for carrying out the building services design	Authors
Site surveyor	In the first-line management who monitors and regulates employees in their performance of assigned or delegated tasks. Supervisors are usually authorized to recommend and/or effect hiring, disciplining, promoting, punishing, rewarding, and other associated activities regarding the employees in their departments	Authors
Cost consultant/ quantity surveyor	The party responsible for producing Cost Information as the design progresses. This information will vary depending on the project but may include the overall Project Budget, estimates of the construction cost and life cycle cost analysis	Authors, adapting [RIBA, 2013] Project Roles Table
Health and safety adviser	Responsible for health and safety aspects as defined by legislation and in line with other project objectives and health and safety best practice	[RIBA, 2013] Project Roles Table
Local authority	An organization that is officially responsible for all the public services and facilities in a particular area	Authors
Facilities management (FM) adviser	Reviews the design proposals and comments on facilities management and in-use maintenance matters	Authors
Information manager	Manages the flow of information between parties – note that this is not a design role	Authors
Tenderer	A person or company that estimates the cost of a proposed project or someone who presents a payment to another	Authors

The table below are the stages & sub-stages of the renovation process on which the study as been implemented:

Table 5.2. Terms and definition of the stages in the life cycle of built assets

Term	Definition	Source
Initiative	Stage where the need for a construction or urban project emerges and is established	[EN 16310, 2013]
Initiation	Stage where the context of the facility or product to be developed is identified and the requirements are defined	[EN 16310, 2013]
Concept design	sub-stage where plans for the asset(s) are developed that offer options and solutions on a planning scale, to determine the general form and schematic layout of the asset(s) to be built within the allocated area	[EN 16310, 2013]
Preliminary design	sub-stage where a design of the asset is developed that offers a broad insight covering planning aspects, functional organisation, spatial structure and general appearance, enabling the client	[EN 16310, 2013]

	to make informed strategic choices between functional concepts and options envisaged	
Developed design	sub-stage where the design of the asset is further developed, providing detailed representations of the layout, the structure, associated technologies and the appearance of the asset and where suitable methods of construction, the use of materials and typical technical details as necessary for a good understanding of the asset to be built are examined	[EN 16310, 2013]
Detailed design	sub-stage where the project is fully described, so that equipment manufacturing and asset construction and installation of equipment can take place	[EN 16310, 2013]
Procurement	stage where fabrication / construction / installation sites are provided with equipment and materials and fabrication / construction / installation contracts are awarded	[EN 16310, 2013]
Construction contracting	sub-stage where contracts for supply of construction services, installations and materials are awarded	[EN 16310, 2013]
Pre-construction	sub-stage where the actual construction of the asset is prepared and scheduled, and project specific prefab parts and components may be produced	[EN 16310, 2013]
Commissioning	sub-stage where it is verified that installed equipment is ready for use	[EN 16310, 2013]
Handover	sub-stage where final checks of compliance with the contract documents are performed. At this point the project is handed over to the client and where the starting points and conditions for maintenance and operations are established	[EN 16310, 2013]
Regulatory approval	sub-stage where it is established and confirmed by the authorities that the built asset complies with the regulatory requirements and that the asset is released for use	[EN 16310, 2013]
Operation	sub-stage where the facility is being run and exploited and where the expected performance is monitored and managed	[EN 16310, 2013]
Maintenance	sub-stage where the asset is maintained according to predetermined objectives	[EN 16310, 2013]
Revamping	sub-stage where the built asset is updated for continued use	[EN 16310, 2013]
Dismantling	sub-stage where the built asset is taken down, removed and (partly) recycled after its functional and/or economic life span	[EN 16310, 2013]

The figure below exhibits the 9 stages of the renovation process as listed in the BIM4EEB project for renovation in public & private premises and the following describes the interrelation among the actors involved in each of the stages:

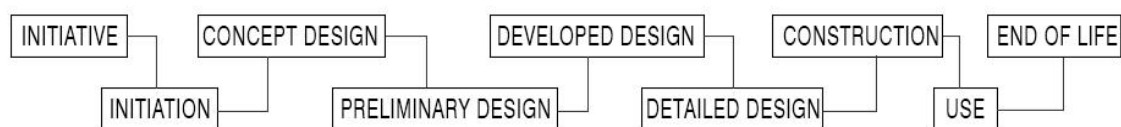


Figure 5.3. Stages of BIM4EEB project

1. The first stage of the project is the Initiative stage, the stage involves 3 actors and is the first decision making process. The three actors have been categorised into: Client/owner consultant (Client adviser), Decision Maker (Client/Owner) and Information Provider (Inhabitant/End-User). The client appoints a client adviser and interacts with the End-user upon which the decision for renovation will be determined.

The interrelation among the actors are same in case of public and private works. The figure below displays the interrelation among the actors:

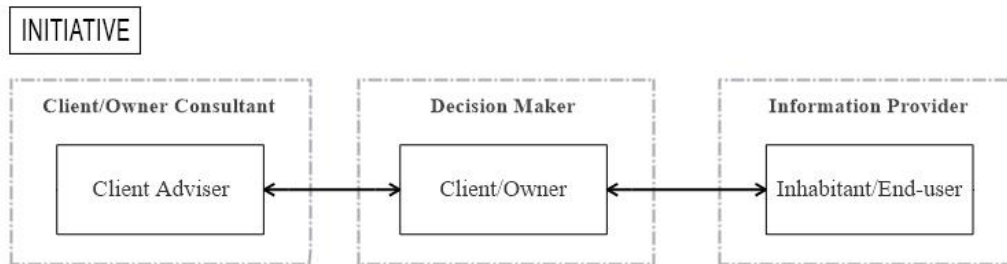


Figure 5.4. Stages 1 of BIM4EEB project

2. The second stage is the Initiation stage, upon which the decision for renovation is finalised. A total number of 12 actors are involved in the process which are categorised into: Financer (Bank or Third party), Decision Maker (Client/owner), Client/owner consultant (Client adviser, Information manager), Information Provider (Inhabitant/End-User), Project Management (Project leader), & Design team/Consultants (Cost consultant/ Quantity surveyor, site surveyor, lead designer, Health & safety adviser, local authority), Company/consultant (Contractor). It is clear from the figure below that the Project leader takes the key position from this stage on and escorts the further activities and tasks in the later stages. The interrelation among the actors are in case of public and private works remains same except in case of public works two addition actors take part in the process which are Contractor & local authority highlighted below. The figure below displays the interrelation among the actors:

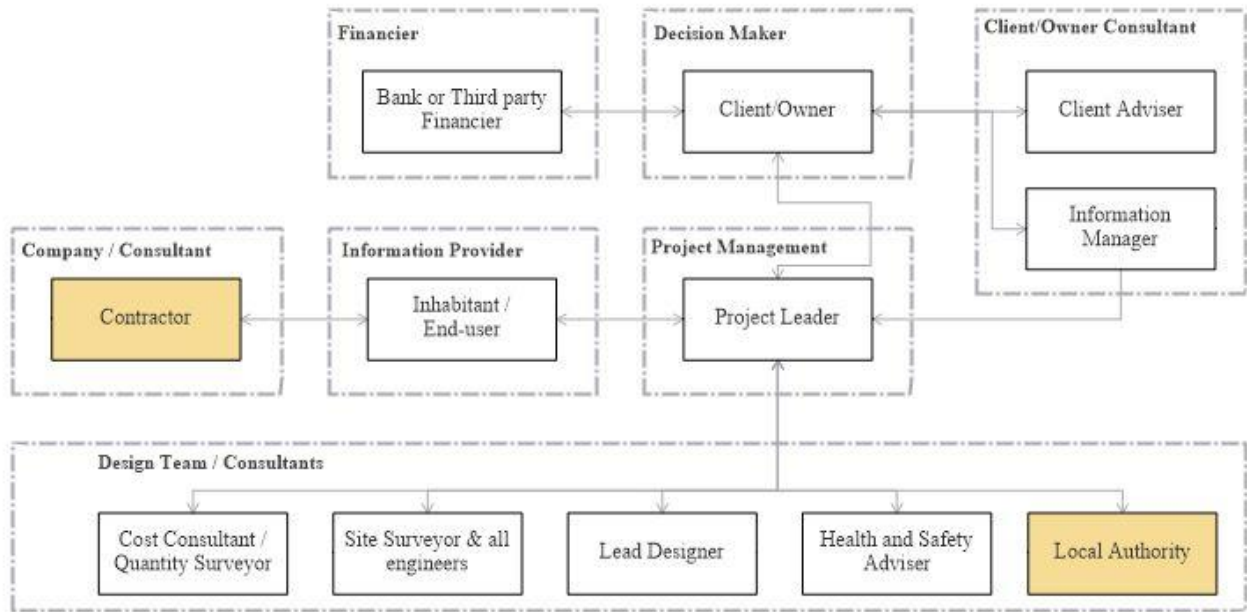


Figure 5.5. Stages 2 of BIM4EEB project

3. The third stage is the Concept Design, it's the start of the design process for which the 6 involved actors are: Decision Maker (Client/owner), Client/owner consultant (Information manager), Construction team (Tenderer), Project Management (Project leader), Design team/Consultants (lead designer, architectural designer). The architectural designer with the lead designer in association with the project management team develops the first conceptual design.

The interrelation among the actors are same in case of public and private works. The figure below displays the interrelation among the actors:

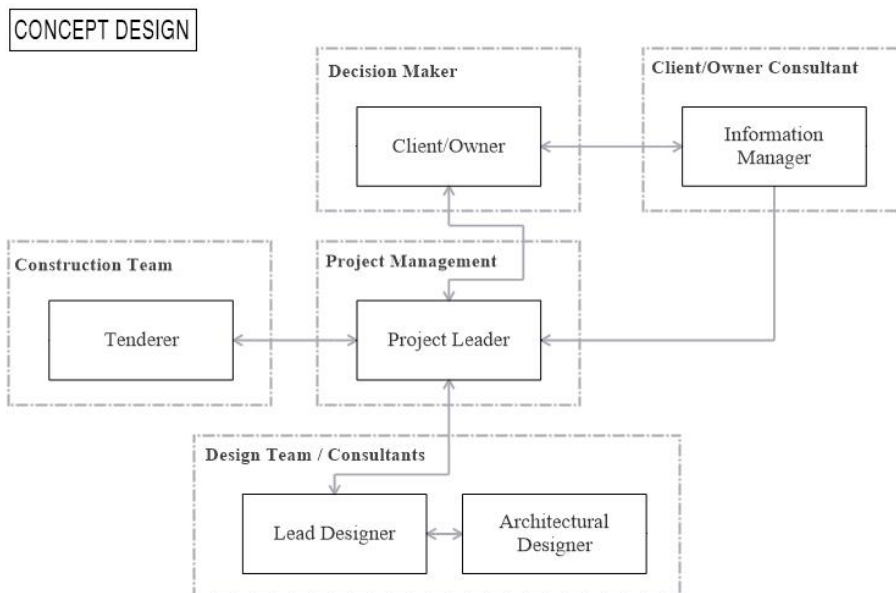


Figure 5.6. Stages 3 of BIM4EEB project

4. The fourth & fifth stages are the Preliminary Design & Developed Design, the two stages here are combined to have a better understanding of interactions among the actors. The 9 actors are listed into the following categories: Decision Maker (Client/owner), Client/owner

consultant (Information manager), Construction team (Tenderer), Project Management (Project leader), Design team/Consultants (lead designer, architectural designer, health & safety advisor, specialist consultant). The interrelation among the actors are same in case of public and private works. The figure below displays the interrelation among the actors:

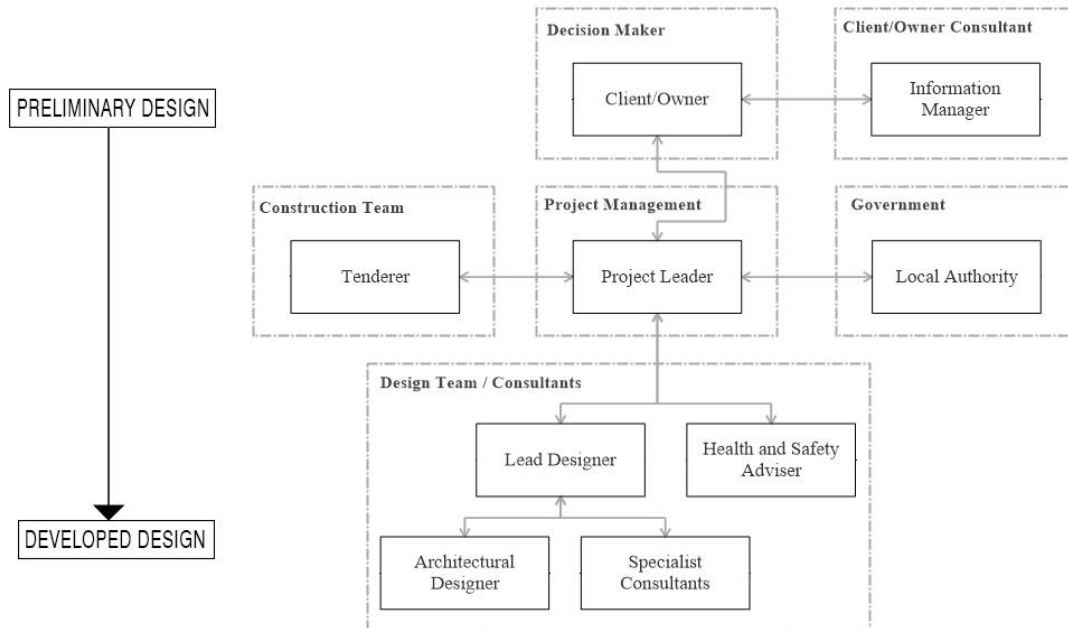


Figure 5.7. Stages 4 & 5 of BIM4EEB project

5. The sixth stage is the Detailed Design stage, the stage involves 10 different Actors and categorised into: Decision Maker (Client/owner), Client/owner consultant (Information manager), Construction team (Tenderer), Project Management (Project leader), Design team/Consultants (lead designer, architectural designer, health & safety advisor, specialist consultant, sub-contractors), construction team (Tenderer, contract administrator).

The interrelation among the actors are in case of public and private works are same except in case of public works three more additional actors are involved as highlighted below. The figure below displays the interrelation among the actors:

DETAILED DESIGN

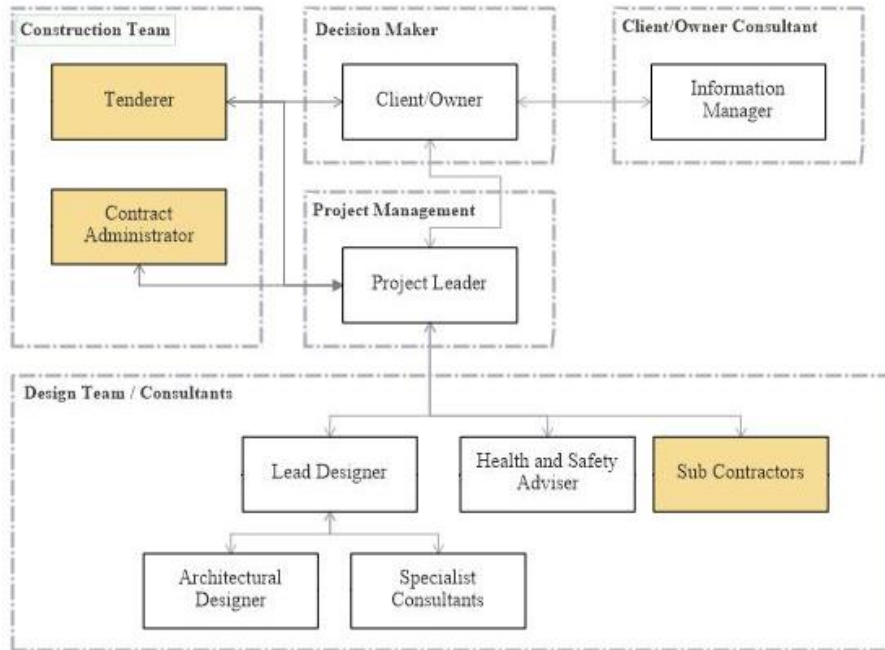


Figure 5.8. Stages 6 of BIM4EEB project

6. The seventh stage is the Construction stage, the 13 actors listed are categorised into: Decision Maker (Client/owner), Project Management (Project leader), Government (local authority), Construction team (contractors, healthy & safety adviser, contract administrator, structural engineer, HVAC engineer, electrical engineer, water and waste engineer), construction team (construction lead), project management (work supervisor), service company (tester).

The interrelation among the actors are same in case of public and private works except for public works three new actors are involved which are Construction lead, work supervisor and tester. The figure below displays the interrelation among the actors:

CONSTRUCTION

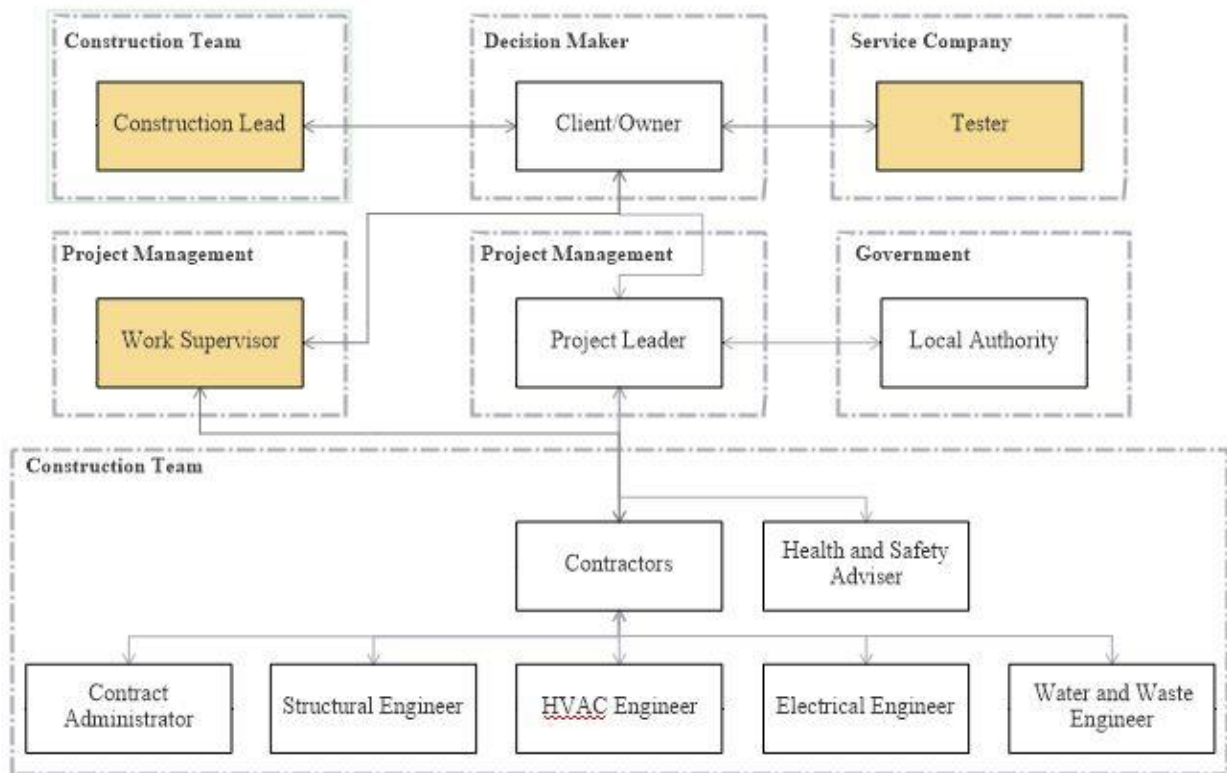


Figure 5.9. Stages 7 of BIM4EEB project

7. The Eighth stage is the Use stage which is As-built and includes FM system, the 8 involved actors are categorised into: Decision Maker (Client/owner), Project Management (Project leader), information provider (inhabitant/ end-user), consultant team (facility management adviser, sustainability adviser, technical adviser). The figure below displays the interrelation among the actors:

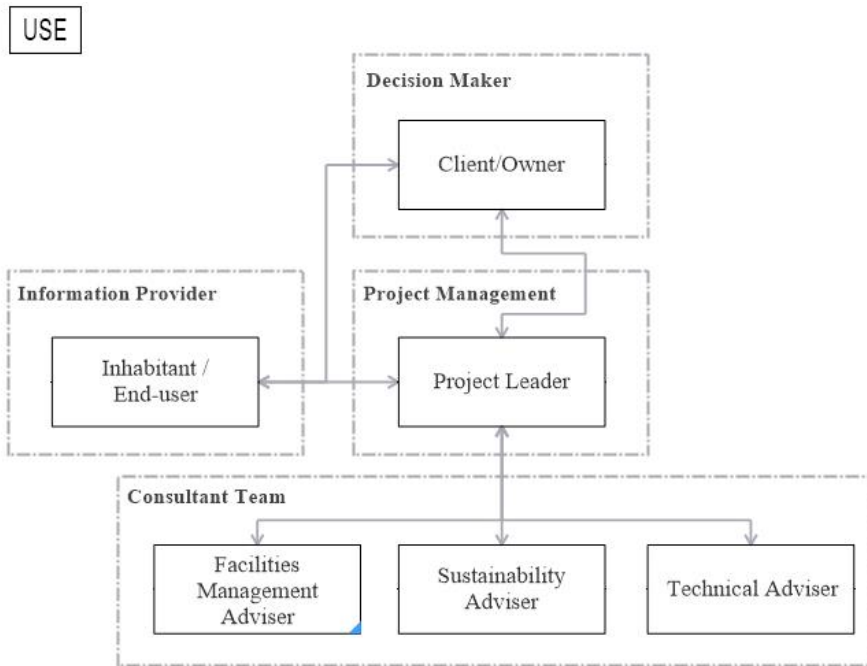


Figure 5.10. Stages 8 of BIM4EEB project

8. The ninth and final stage is the End of life stage, the 7 involved actors are categorised into: Decision Maker (Client/owner), Project Management (Project leader), Demolition team (contractor), government(local authority), consultant team (health & safety adviser, sustainable adviser & technical adviser). The figure below displays the interrelation among the actors:

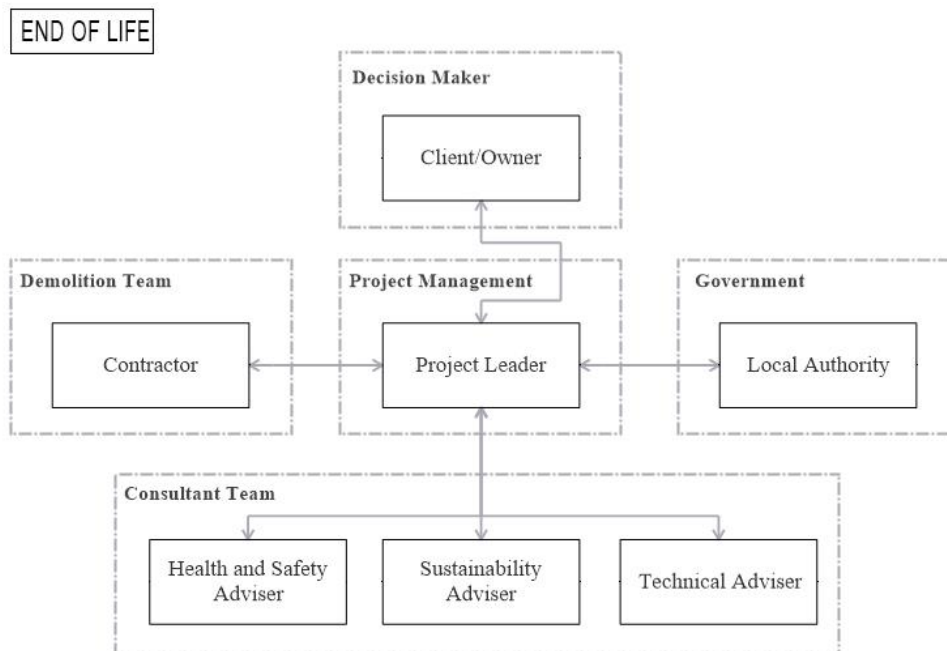


Figure 5.11. Stages 9 of BIM4EEB project

5.2. IDENTIFY TASKS AND BIM INVOLVED IN RENOVATION PROCESS

From the given BIM4EEB project it is defined the Actors and their respective roles and responsibilities following the EN 16310, 2013. With our further study and analysis from the given data to identify the User profiles based on the information workflow. The study was carried out in the following order to reach the end results. Refer to Appendix I & Appendix II of the thesis to relate the below mentioned description.

5.2.1. General Definition

5.2.1.1. BIM involved priority scaling

For every activity that is required in each stage of the building process a BIM involved priority scaling is given from 0 to 5 after analysing if the respective activity is significant to be involved in BIM management system.

The scaling priority is classified in the following way:

- Scale 0: Not necessary
- Scale 1: Optional
- Scale 2: Useful but not recommended
- Scale 3: Recommended
- Scale 4: Highly Desirable
- Scale 5: Mandatory

These ratings will help in scaling down the activities by measuring down the output of each actions taken by the actors which will directly or indirectly influence the project by optimisation of the building process, overcoming possible inefficiencies due to incorrect or redundant exchange of information among actors of the construction chain throughout the entire life-cycle of a building. The result is show in the Appendix I of this thesis.

5.2.1.2. Hypothesis for BIM priority scaling

Following the above adopted scaling system, a hypothesis is defined to justify for each of the activities which are scaled accordingly.

5.2.1.3. Benefit of BIM integration

In this section it describes what are the essential possibilities & benefits on integration of BIM over performing the same activity in a traditional way and to understand how efficiently and certainly a task can be carried out with BIM integration.

5.2.1.4. Type of input information

To identify what kind of input information is essential for the respective action to be carried out.

5.2.1.5. Information provider

Identifying the information provider for the respective action.

5.2.1.6. Type of Output information

To know what kind of information is processed out for the particular action.

5.2.1.7. Information Receiver

Identifying the information receiver for the respective action.

5.2.1.8. Information Receiver

Identifying the information receiver for the respective action.

5.2.1.9. BIM Category and Tools

All the above steps assist to acknowledge the BIM category and tools which are vital to carry out the respective actions in the BIM management system.

From the studies carried out, the following are the list of the BIM category definition and commercial tools which are listed in the Task identification and the main criteria for identification of User profile [73]:

- **Model Viewer:** A software application allowing users to inspect and navigate Modelling Project Information according to ad-hoc or standard Model View Definitions. As opposed to Model Servers, models accessed by a model viewer (MV) are read-only and cannot be modified.
- **Asset management:** BIM-enabled asset management is characterized by linking virtual objects and spaces within a model to an external database for the purpose of operating and maintaining a Facility or a portfolio of facilities.
- **Financial information of building:** A Model Use representing how BIM models are linked with financial networks, booking systems, and a variety of web-based services.
- **BIM Server:** A software solution (installed on a local server or hosted in the cloud) allowing Multi-Discipline Models to be centrally collated and managed. Model Servers are a type of Federated Modelling Environments and typically depend on non-proprietary open formats similar to Industry Foundation Classes (IFC).
- **Point cloud data:** A set of data points in 3D which are typically created by 3D Laser Scanners to capture an object, space or a whole building. Point Clouds can be transformed into meshes, surfaces and even 3D objects using specialised tools. Point cloud files can be typically imported into most BIM Software Tools to generate As-Built Models or model parts.
- **Design Tools:** Digital tools generate, modify, analyse, or optimise an object or a space. CAD represents all pre-BIM digital tools and their 2D/3D deliverables.

- **Model checkers:** Design Model (D Model) is an object-based 3D model generated by the Design Team (individually or as a group) for the purposes of design analysis, Clash Detection and documentation.
- **Cost estimation:** The use of specialized calculations to identify and analyse projected construction costs. Cost Estimation can be a manual or a fully automated process.
- **4 different BIM Integration tools:**
- **Integration tool for Construction model:** Construction Model (C Model) is an object-based 3D model generated by the Contractor or Construction Team for the purposes of construction analysis, Construction Scheduling and plant design.
- **Integration tool for On-Site (Field BIM):** A Model Use representing how 3D models and related databases are accessed in the field (i.e. on the construction site). Through a tablet, laptop, smart phone or wearable equipment, the user **would** inspect designs, send requests for clarifications, mark drawings/models, complete a checklist, report an issue, or conduct information-rich, site-based activities.
- **Integration tool for Demolition planning:** A Model Use where 3D models are used to plan or monitor demolition activities of existing structures (or parts of existing structures).
- **Integration tool for Record model:** Using BIM Software Tools to generate an accurate representation of an existing Facility; its spaces, assets, physical condition and surrounding environment. The Record Model may link to other records (documents, drawings, images, etc.) and include equipment manufacturer data, maintenance schedules, warranties and space conditions/damages.
- **Planning and control:** Operation competencies and topics cover the daily, hands-on individual efforts required to deliver a project or part/aspect of a project. Operation topics do not typically cover the specifics of software tools or equipment used to generate Project Deliverables but focus on the deliverables themselves and the workflows enabling them.
- **Surveying site condition:** A Model Use where 3D models are used to establish the dimensional relationships, including horizontal distances, elevations, directions, and angles, on the earth's surface. surveying is typically used to locate property boundaries, generating maps and establishing construction layout.
- **4D capabilities:** The fourth modelling dimension (4D) refers to 3D + time. That is, a model or a modelling workflow is considered to be 4d when the time is added to model objects to allow Construction Scheduling.

- **BIM Software tools:** The software applications which can author an object-based, data-rich, 3D model. These software applications often link to other Specialized Software Tools to generate a variety of Model-based Deliverables.

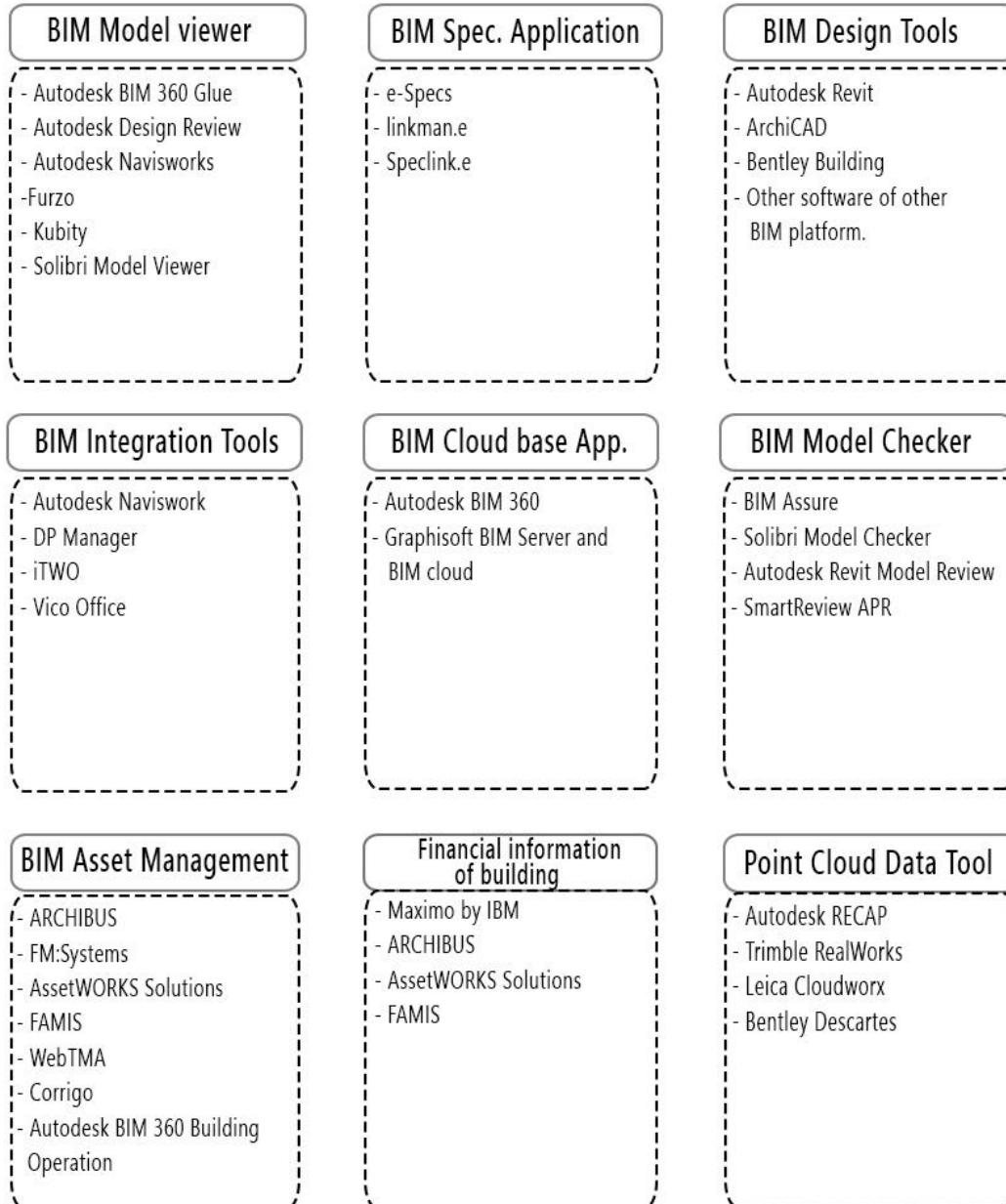


Figure 5.12. BIM Category and Tools 1

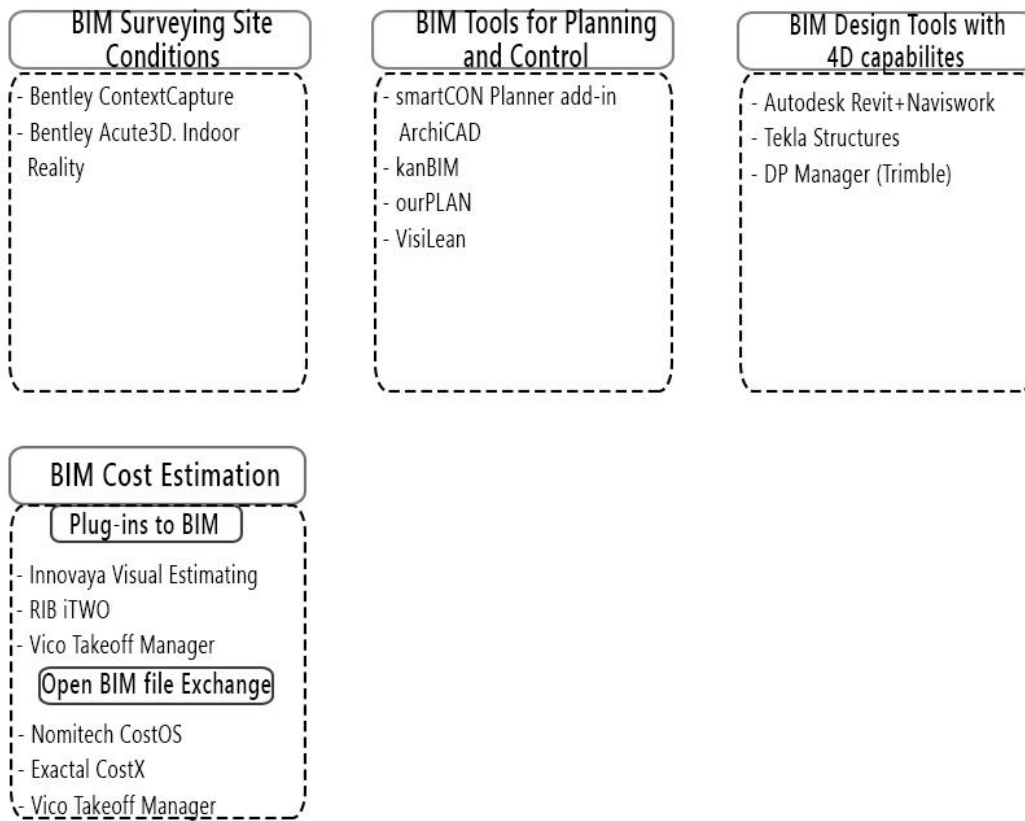


Figure 5.13. BIM Category and Tools 2

5.2.2. Result and Conclusion

A representation of a diagram below to understand the contents of the upcoming table for the identification of task.

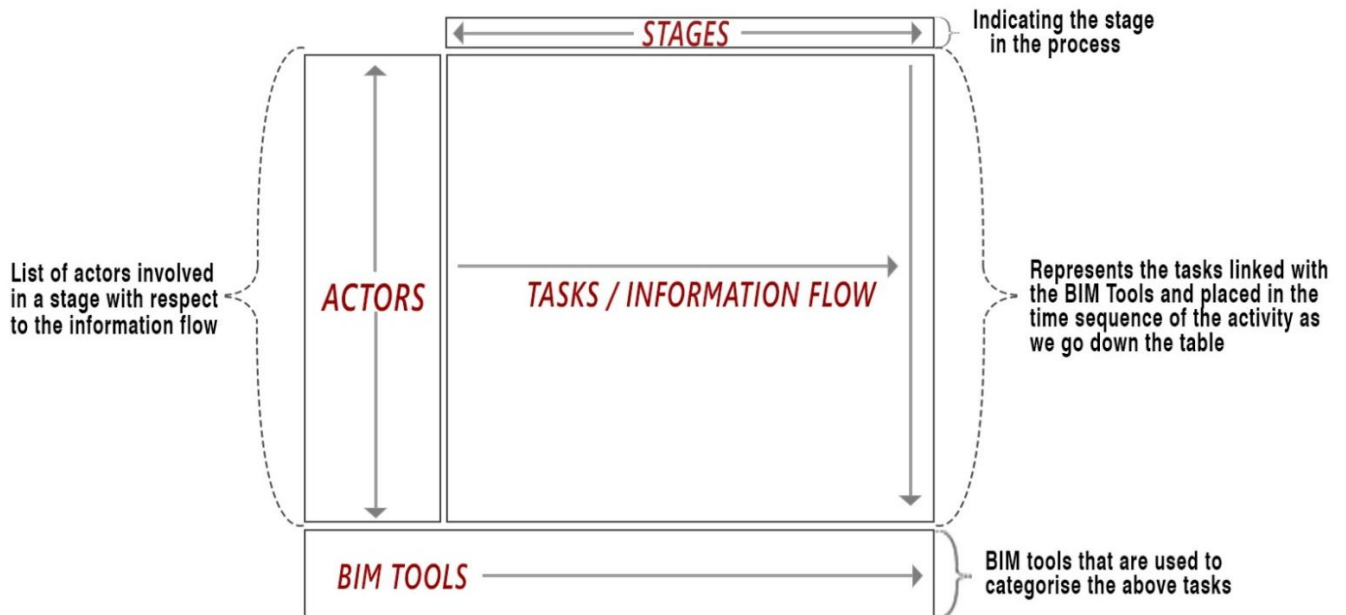


Figure 5.14. An example of a table showing the identification of task with respect to BIM tools

Actors: List of actors involved in a stage who's tasks and activities can be defined in the BIM management system.

Stages: Indicating the current stage of the project.

Tasks/information flow: Represents the tasks identified & assigned in accordance with the BIM Tool categories. Similar colour coding has been assigned to the actor and the respective tasks managed by the actor.

BIM Tools: The Tools which are used to assign and differentiate the tasks.

From the analysis of the BIM4EEB project the tables of identification of tasks is derived to comprehend the involved actors with their respective tasks to process the exchange of information among actors and are segregated accordingly to the BIM category tools for the tasks to be performed.

It is analysed & understood to include only the actors with the tasks which can be displayed and performed in the BIM Management system. The final output are the BIM category and tools which is assigned accordingly for the related tasks to be carried out.

The arrangement of tasks in the table is according to the time sequence for the task to be exercised in the BIM4EEB project as we go down the table, which gives an clear idea about the use of a particular BIM tool at a given point & time period in the project.

5.2.2.1. STAGE 1: INITIATIVE – PRIVATE & PUBLIC WORKS

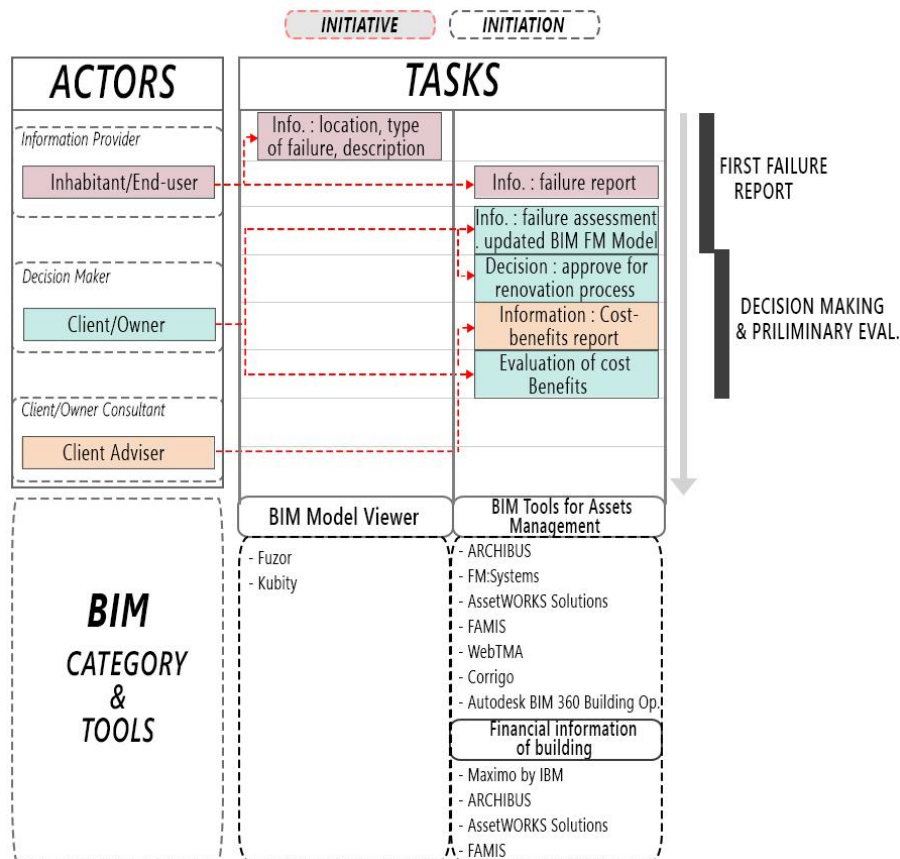


Figure 5.15. Identification of tasks for initiative stage – Private & Public works

The initiative stage consists of 3 actors with a total of 6 tasks to be directed in the BIM management system with the help of 2 BIM Tool Category which are BIM Model viewer and BIM Tools for Assets management. The stage mainly assists with following activities [Fig. 5.15]:

- First failure report (task 1-3)
- Decision making & Preliminary evaluation (task 4-6)

The process remains the same in case of public and private works as there is no modification in any of the actors and tasks.

5.2.2.2. STAGE 2: INITIATION – PRIVATE WORKS

The initiation stage in case of private works consists of 10 actors actively taking part: Financer (Bank or Third party), Decision Maker (Client/owner), Client/owner consultant (Client adviser, Information manager), Information Provider (Inhabitant/End-User), Project Management (Project leader), & Design team/Consultants (Cost consultant/ Quantity surveyor, site surveyor, lead designer, Health & safety adviser) with a total of 25 tasks to be directed in the BIM management system with the help of 7 BIM Tool Category which are BIM Model viewer, Point cloud data tool, BIM design tools, BIM integration tools, BIM cost estimation, BIM cloud/Server, BIM model checker [Fig. 5.16]:

The stage mainly assists with the following activities:

- Level 1 BIM model development stage (task 4-6)
- Data report (task 7-18)
- Level 2 BIM model development stage (task 19-24).

5.2.2.2.1. STAGE 2: INITIATION – PUBLIC WORKS

The initiation stage in case of public works consists of 10 actors actively taking part: Financer (Bank or Third party), Decision Maker (Client/owner), Client/owner consultant (Client adviser, Information manager), Information Provider (Inhabitant/End-User), Project Management (Project leader), & Design team/Consultants (Cost consultant/ Quantity surveyor, site surveyor, lead designer, Health & safety adviser) with a total of 28 tasks to be directed in the BIM management system with the help of 7 BIM Tool Category which are BIM Model viewer, Point cloud data tool, BIM design tools, BIM integration tools, BIM cost estimation, BIM cloud/Server, BIM model checker [Fig. 5.16.1]:

The stage mainly assists with the following activities:

- Level 1 BIM model development stage (task 5-7)
- Data report (task 8-19)
- Level 2 BIM model development stage (task 20-25).

The dissimilarity between the private and public works are highlighted in the public works. The additional tasks in public works are coming from the Project leader and End-user.

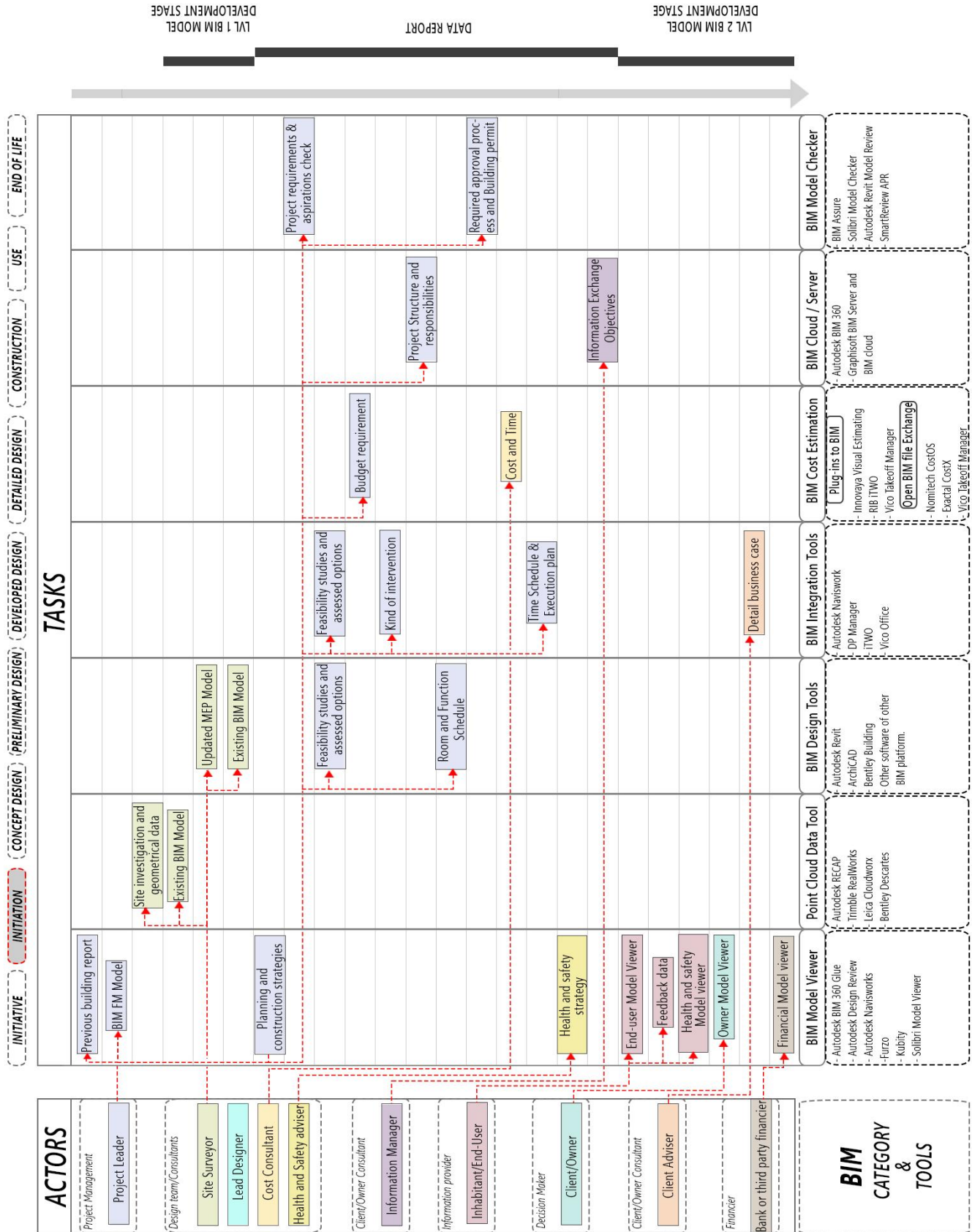


Figure 5.16. Identification of tasks for initiation stage – Private works

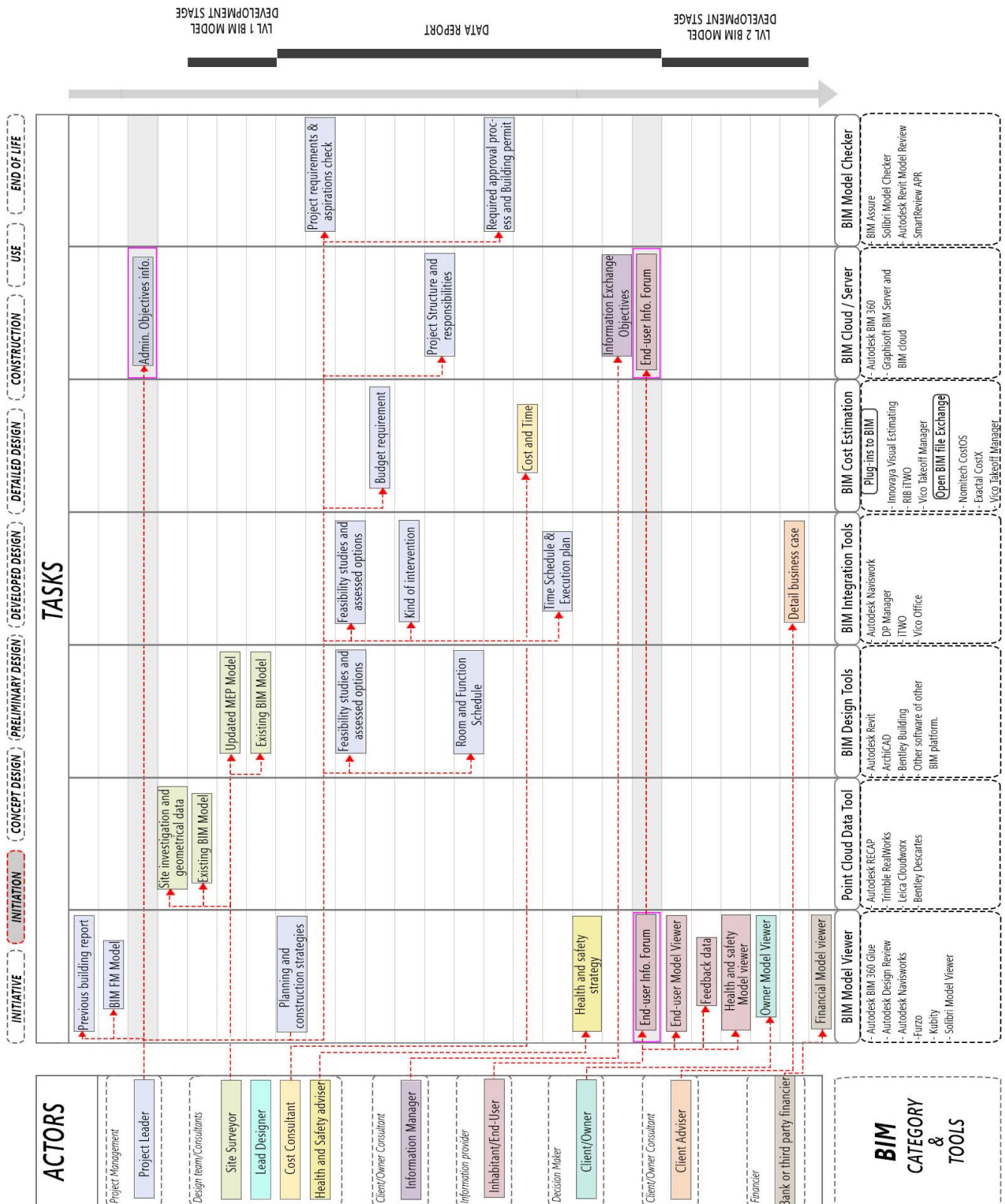


Figure 5.16.1. Identification of tasks for initiation stage – Public works

5.2.2.3. STAGE 3: CONCEPT – PUBLIC & PRIVATE WORKS

The Concept design stage consists of 6 actors which are: Decision Maker (Client/owner), Client/owner consultant (Information manager), Construction team (Tenderer), Project Management (Project leader), Design team/Consultants (lead designer, architectural designer) with a total of 17 tasks to be directed in the BIM management system with the help of 6 BIM Tool Category which are BIM Model viewer, BIM design tools, BIM integration tools, BIM cost estimation, BIM cloud/Server, BIM model checker [Fig. 5.17]:

The stage mainly assists with the following activities:

- 1) BIM architecture model and drawings (task 2-3)
- 2) Discussions and approvals (task 4-6)
- 3) 1st stage Tender procedures & contract approvals (task 7-9)
- 4) 1st stage Program and strategy (task 10-13)
- 5) 1st stage Information exchange (tasks 15-16)

The process remains the same in case of public and private works as there is no modification in any actions of the actors and their respective tasks. The concept stage is more in responsible with Architectural designer and project leader as these two actors perform the majority of the tasks.

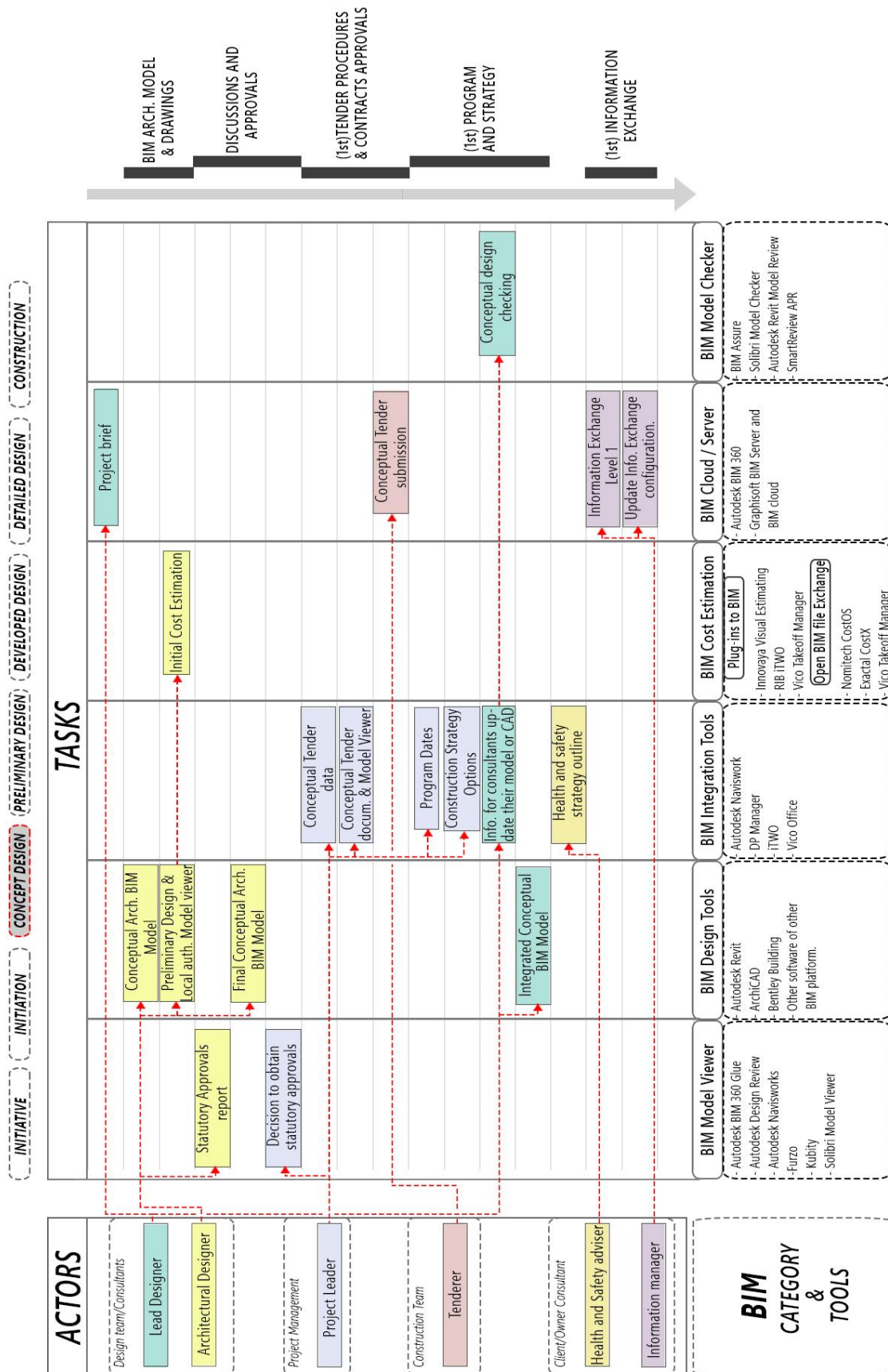


Figure 5.17. Identification of tasks for concept stage – Private & Public works

5.2.2.4. STAGE 4: PRELIMINARY DESIGN – PRIVAT & PUBLIC WORKS

The preliminary design stage consists of 7 actors in case of private works and 8 actors in case of public works which are: Project Management (Project leader), Design team/Consultants (lead designer, architectural designer), Government (local authority), Construction team (tenderer), Client/owner consultant (health and safety adviser & information manager), Decision maker (Client/Owner), with a total of 23 tasks to be directed in the BIM management system with the help of 6 BIM Tool Category which are BIM Model viewer, BIM specification application, BIM design tools, BIM integration tools, BIM cloud/Server, BIM model checker [Fig. 5.18]:

The stage mainly assists with the following activities:

- 1) Preliminary BIM architectural model (task 1-7)
- 2) Discussions and approvals (task 8-9)
- 3) 2st stage Tender procedures & contract approvals (task 10-12)
- 4) 2st stage Program and strategy (task 13-16)
- 5) 2st stage Information exchange (tasks 18)

The process remains the same in case of public and private works except in the public work at the end of the stage we have an additional actor which is the Client/Owner who is responsible for the approval of the information & data outputs in the stage. This action is followed in the further next 2 stages in the public works.

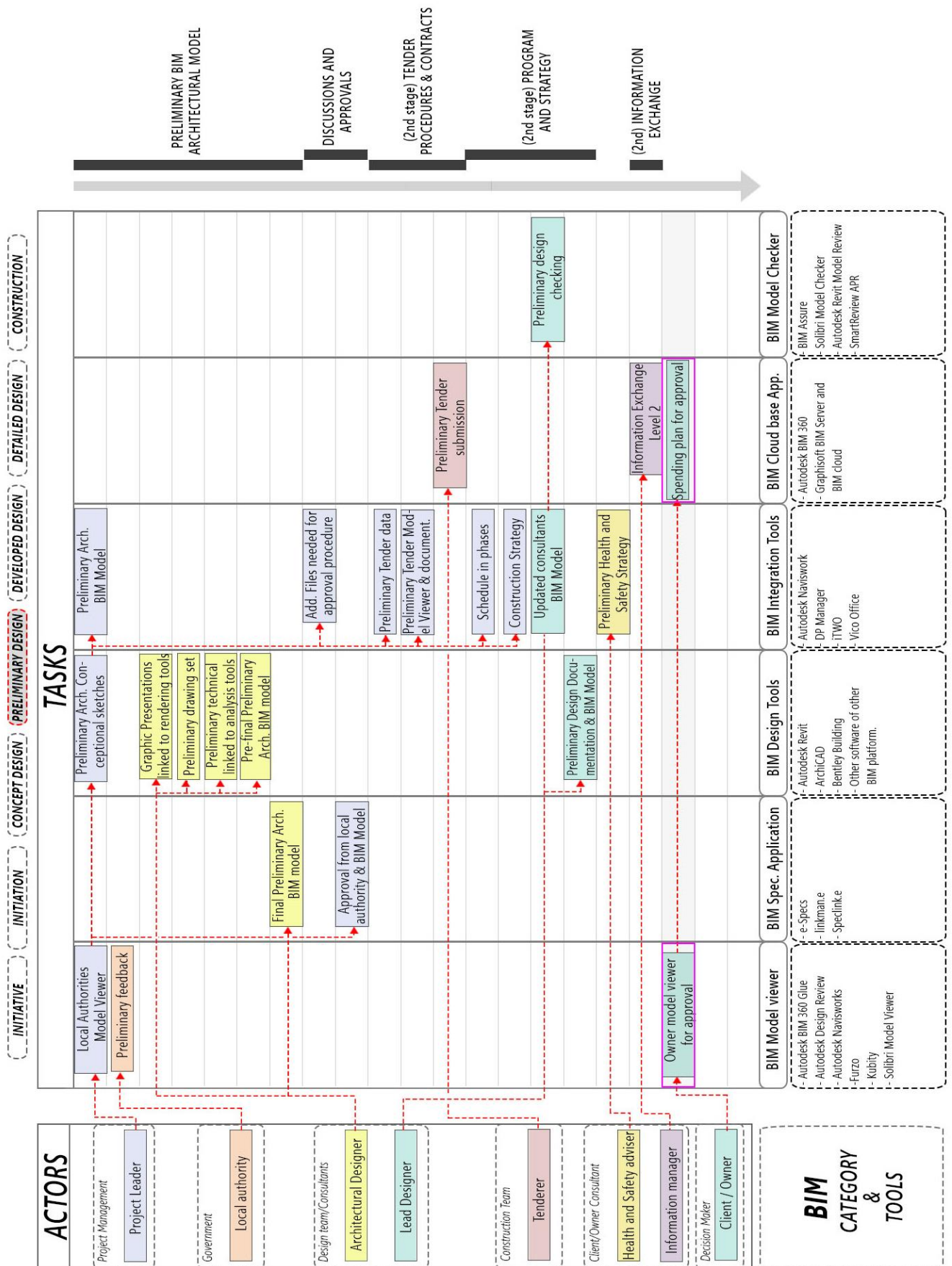


Figure 5.17. Identification of tasks for preliminary design stage – Private & Public works

5.2.2.5. STAGE 5: DEVELOPED DESIGN – PRIVATE & PUBLIC WORKS

The developed design stage consists of 6 actors in case of private works and 7 actors in case of public works which are: Project Management (Project leader), Design team/Consultants (lead designer, architectural designer, health & safety), Construction team (tenderer), Client/owner consultant (information manager) with a total of 17 tasks to be directed in the BIM management system with the help of 6 BIM Tool Category which are BIM Model viewer, BIM specification application, BIM design tools, BIM integration tools, BIM cloud/server, BIM model checker [Fig. 5.19]:

The stage mainly assists with the following activities:

- 1) Developed BIM architectural model & drawings (task 1-6)
- 2) Discussions and approvals (task 7-8)
- 3) 3rd stage Tender procedures & contract approvals (task 9-11)
- 4) 3rd stage Program and strategy (task 12-15)
- 5) 3rd stage Information exchange (tasks 17)

The process remains the same in case of public and private works except in the public work at the end of the stage we have an additional actor which is the Client/Owner who is responsible for the approval of the information & data outputs in the stage.

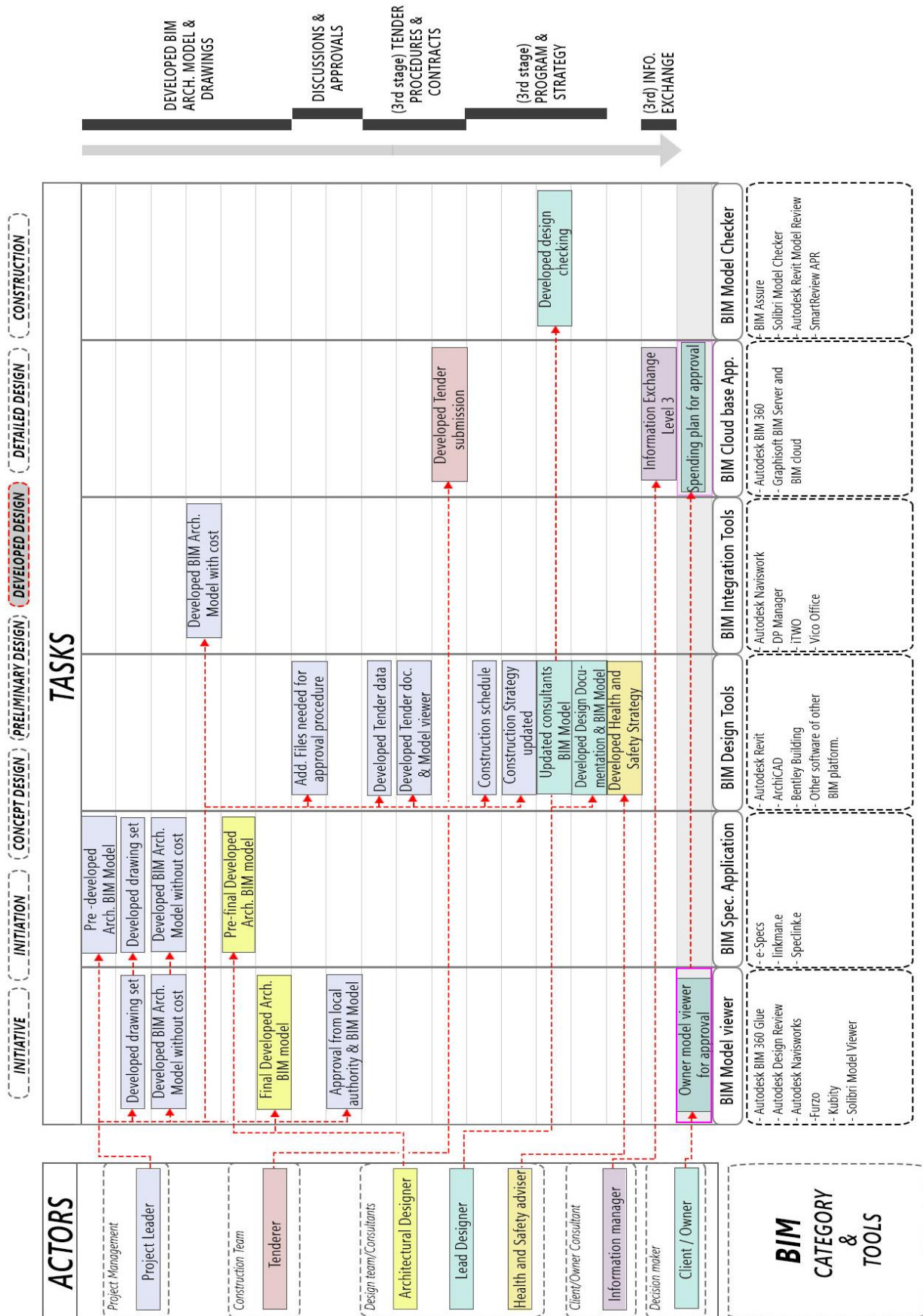


Figure 5.18. Identification of tasks for Developed design stage – Private & Public works

5.2.2.6. STAGE 6: DETAILED DESIGN – PRIVATE WORKS

The detailed design stage consists of 6 actors in case of private works which are: Project Management (Project leader), Design team/Consultants (lead designer, architectural designer, health & safety), Construction team (tenderer), Client/owner consultant (information manager) with a total of 17 tasks to be directed in the BIM management system with the help of 7 BIM Tool Category which are BIM asset management, BIM specification application, BIM design tools, BIM integration tools, BIM cost estimation, BIM cloud/server, BIM model checker [Fig. 5.20]:

The stage mainly assists with the following activities:

- 1) Developed BIM architectural model & drawings (task 1-6)
- 2) Discussions and approvals (task 7-8)
- 3) Developed BIM architectural model & drawings (task 9-10)
- 4) 4th stage Program and strategy (task 12-15)
- 5) 4th stage Information exchange (tasks 17)

5.2.2.6.1. STAGE 6: DETAILED DESIGN – PUBLIC WORKS

The detailed design stage in case of public works consists of 7 actors which are: Project Management (Project leader), Design team/Consultants (lead designer, architectural designer, health & safety), Construction team (tenderer), Client/owner consultant (information manager), decision maker (Client owner) with a total of 21 tasks to be directed in the BIM management system with the help of 7 BIM Tool Category which are BIM asset management, BIM specification application, BIM design tools, BIM integration tools, BIM cost estimation, BIM cloud/server, BIM model checker [Fig. 5.20.1]:

The stage mainly assists with the following activities:

- 1) Developed BIM architectural model & drawings (task 1-8)
- 2) Discussions and approvals (task 8-9)
- 3) Developed BIM architectural model & drawings (task 10-11)
- 4) 4th stage Program and strategy (task 13-18)
- 5) 4th stage Information exchange (tasks 19)

The process in case of public and private works are a little different in the public work, the project leader performs an additional task at the start of the project and at the end of the stage we have an additional actor which is the Client/Owner who is responsible for the approval of the information & data outputs in the stage.

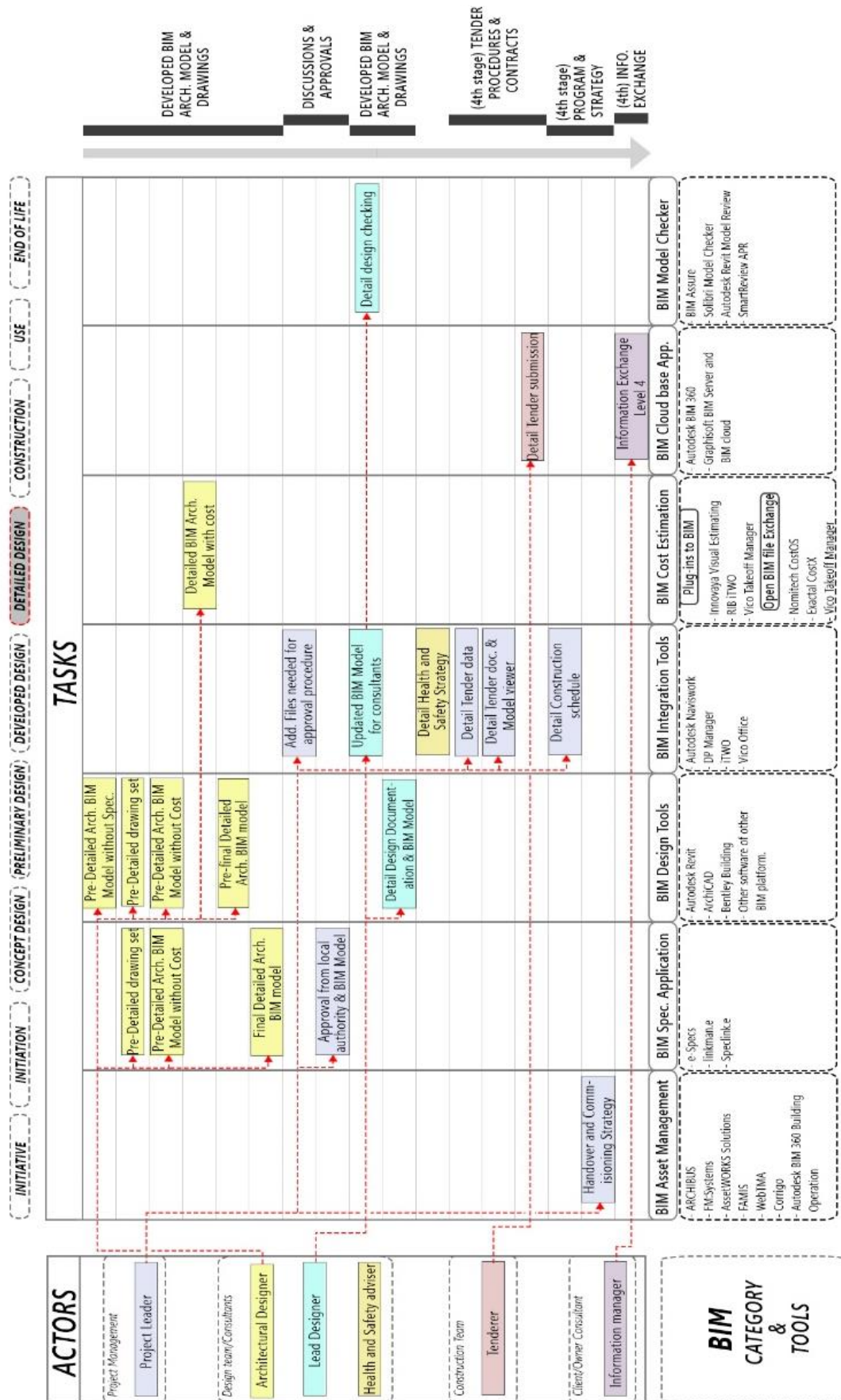


Figure 5.19. Identification of tasks for Detailed design stage – Private works

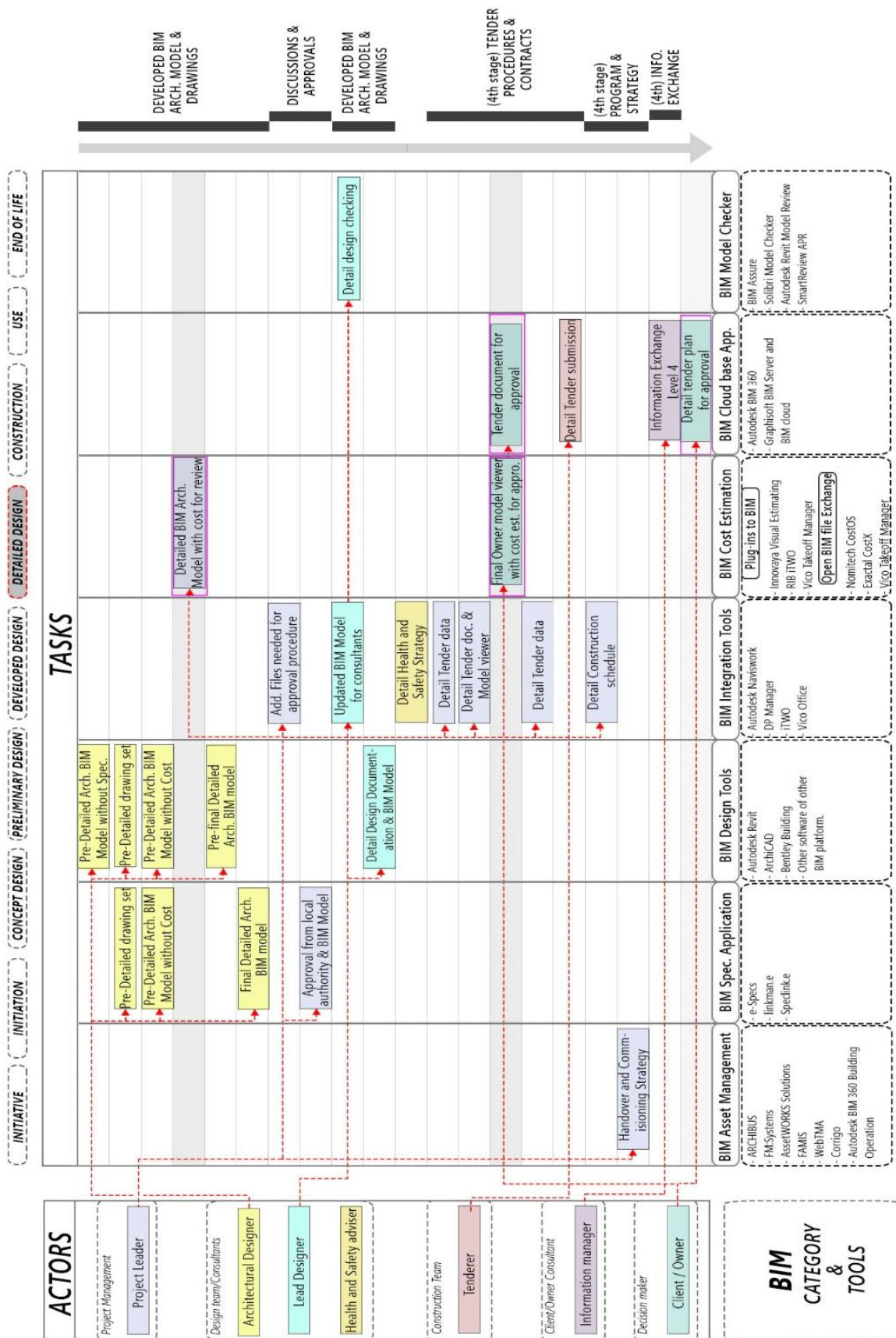


Figure 5.20.1. Identification of tasks for Detailed design stage – Public works

5.2.2.7. STAGE 7: CONSTRUCTION – PRIVATE WORKS

The construction stage consists of 7 actors which are: Project Management (Project leader), Design team/Consultants (structural engineer, HVAC engineer, electrical engineer, water & waste engineer), Construction team (contract administrator), information provider (inhabitant/End-user) with a total of 20 tasks to be directed in the BIM management system with the help of 7 BIM Tool Category which are BIM surveying site conditions, BIM tools for planning & control , BIM design tools, BIM integration tools, BIM specification application, BIM cloud/server, BIM model checker [Fig. 5.21]:

The stage mainly assists with the following activities:

- 1) Construction report (task 1-5)
- 2) BIM construction model (task 6-9)
- 3) As built document and model (task 14-15)
- 4) Discussions & approvals (task 16-18)
- 5) 5th stage Program & strategy (tasks 19-20)

5.2.2.7.1. STAGE 7: CONSTRUCTION – PUBLIC WORKS

The construction stage consists of 10 actors which are: Project Management (Project leader), Design team/Consultants (structural engineer, HVAC engineer, electrical engineer, water & waste engineer), Construction team (contract administrator), information provider (inhabitant/End-user), Decision maker (Client/owner), Project management (work supervisor), Client owner consultant (tester) with a total of 22 tasks to be directed in the BIM management system with the help of 7 BIM Tool Category which are BIM surveying site conditions, BIM tools for planning & control , BIM design tools, BIM integration tools, BIM specification application, BIM cloud/server, BIM model checker [Fig. 5.21.1]:

The stage mainly assists with the following activities:

- 1) Construction report (task 1-6)
- 2) BIM construction model (task 7-11)
- 3) As built document and model (task 16-17)
- 4) Discussions & approvals (task 18-19)
- 5) 5th stage Program & strategy (tasks 20-21)

The majority of the changes in private & public works are seen in the construction stage. Two new additional actors 1) Work supervisor 2) Tester are included in the stage, where the work supervisor manages most of the tasks conducted by the project leader in the private stage. And at the end of the stage the tester prepares a final report of Administration and technical report which is absent in the private works.

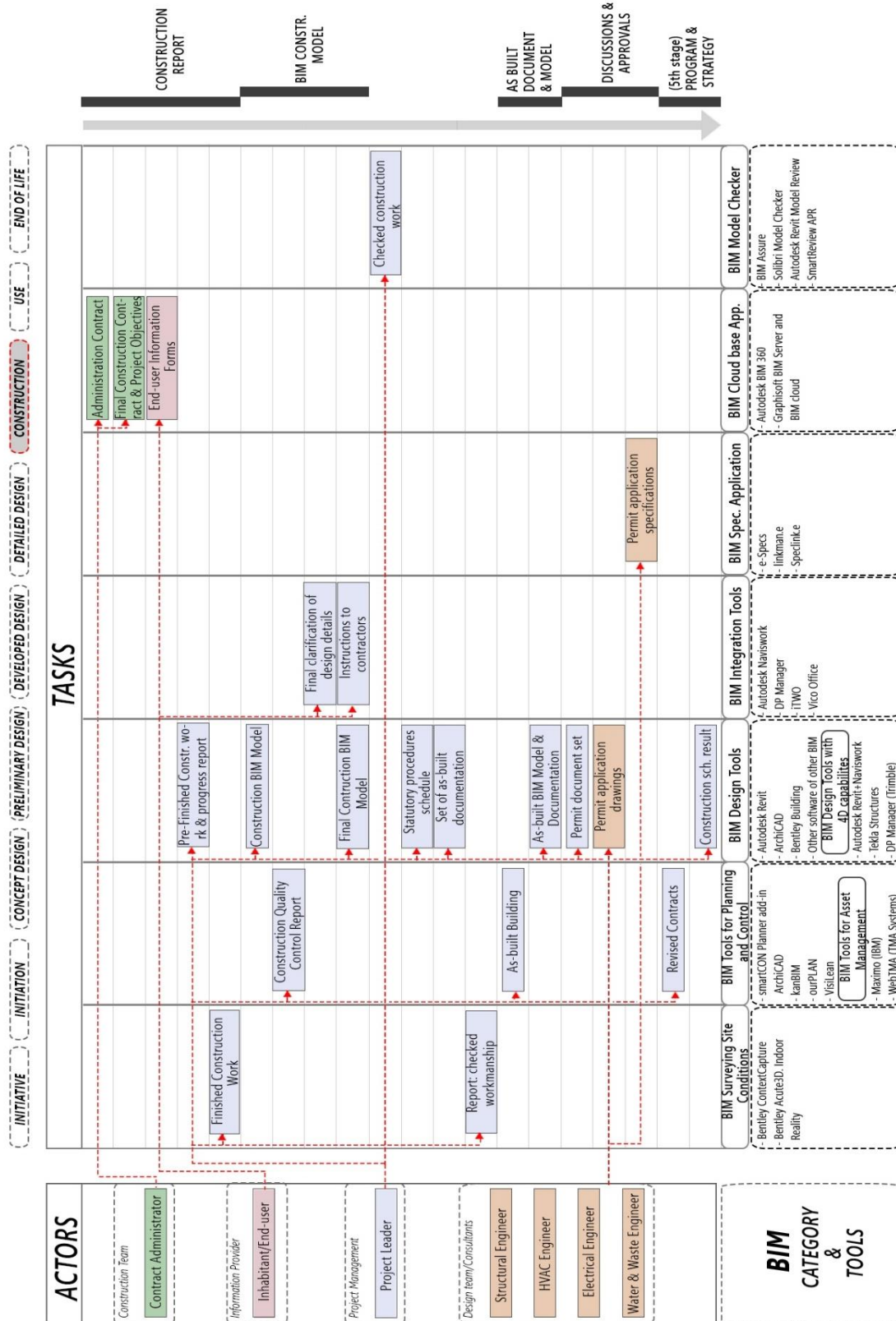


Figure 5.21. Identification of tasks for Construction stage – Private works

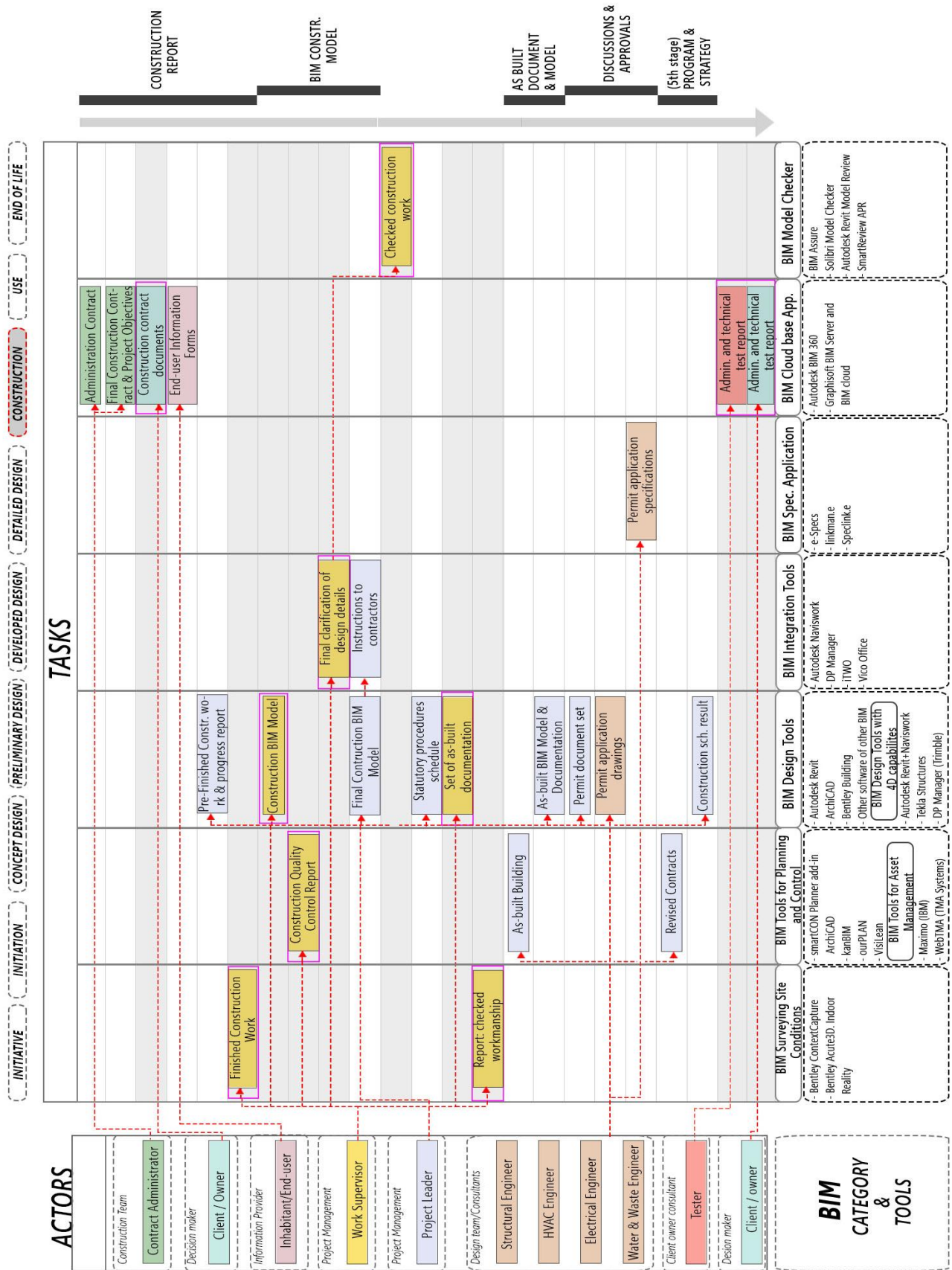


Figure 5.22.1. Identification of tasks for Construction stage – Public works

5.2.2.8. STAGE 8: USE – PRIVATE & PUBLIC WORKS

The Use stage consists of 5 actors in case of private works and 4 actors in case of public works (Technical adviser is absent) which are: Project Management (Project leader), Consultant team (facility management adviser, sustainability adviser, technical adviser), decision maker (client/owner) with a total of 11 tasks to be directed in the BIM management system with the help of 3 BIM Tool Category which are BIM asset management, BIM design tools, BIM integration tools [Fig. 5.22]:

The stage mainly assists with the following activities:

- 1) BIM FM model (task 1-5)
- 2) Maintenance & strategy (task 6-11)

The main difference in the Use stage between private and public works are the final two tasks which are End of life audit and Demolition & rehabilitation strategy which are performed by the project leader in the public works.

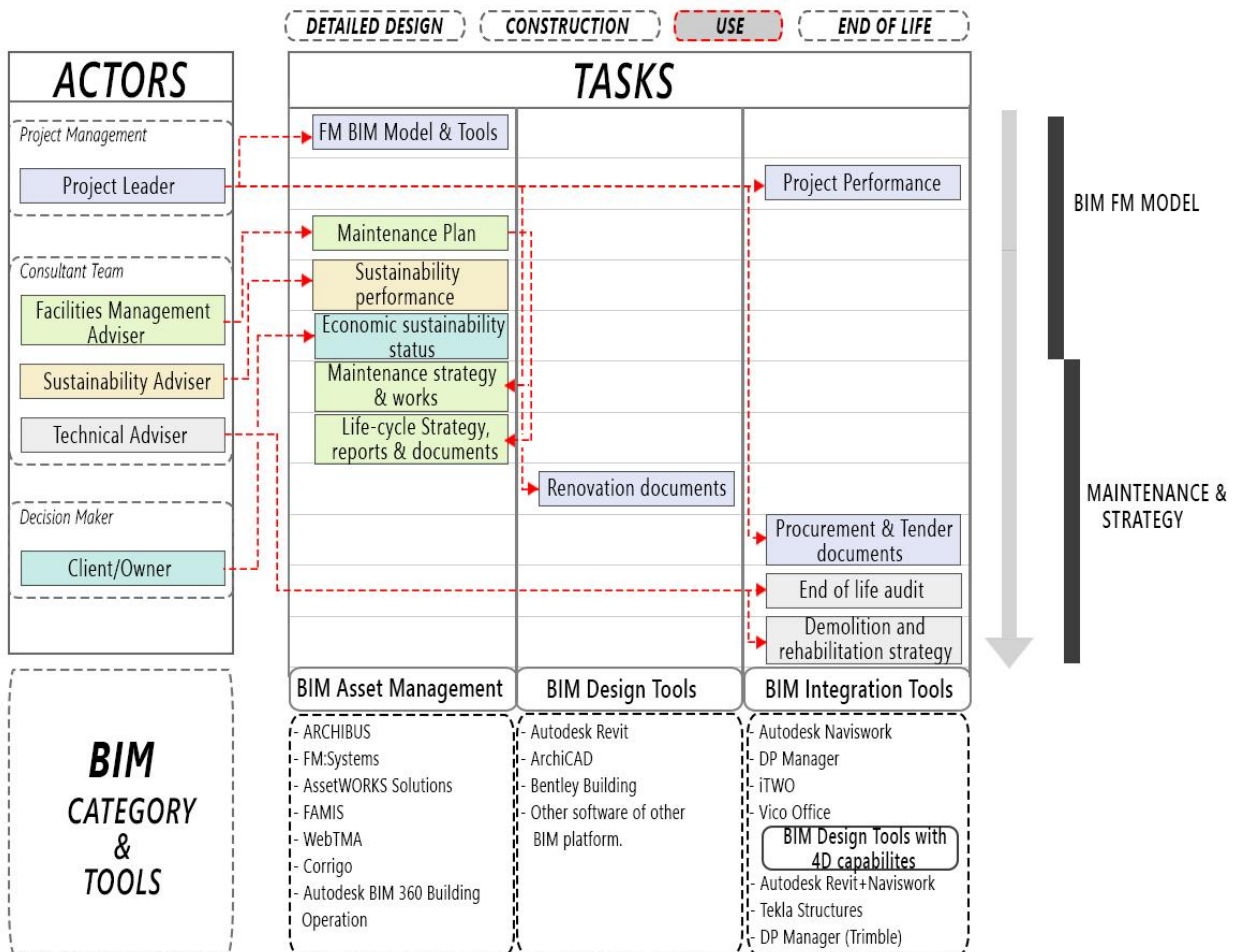


Figure 5.23. Identification of tasks for Use stage – Private and public works

5.2.2.9. STAGE 9: END OF LIFE – PRIVATE & PUBLIC WORKS

The End stage consists of 3 actors which are: Project Management (Project leader), Consultant team (health and safety adviser), demolition team (contractor) with a total of 11 tasks to be directed in the BIM management system with the help of 1 BIM Tool Category which is BIM integration tools[Fig. 5.23]:

The stage mainly assists with the following activities:

- 1) Revamping and scheduling (task 1-5)
- 2) Waste management & dismantling (task 6-11)

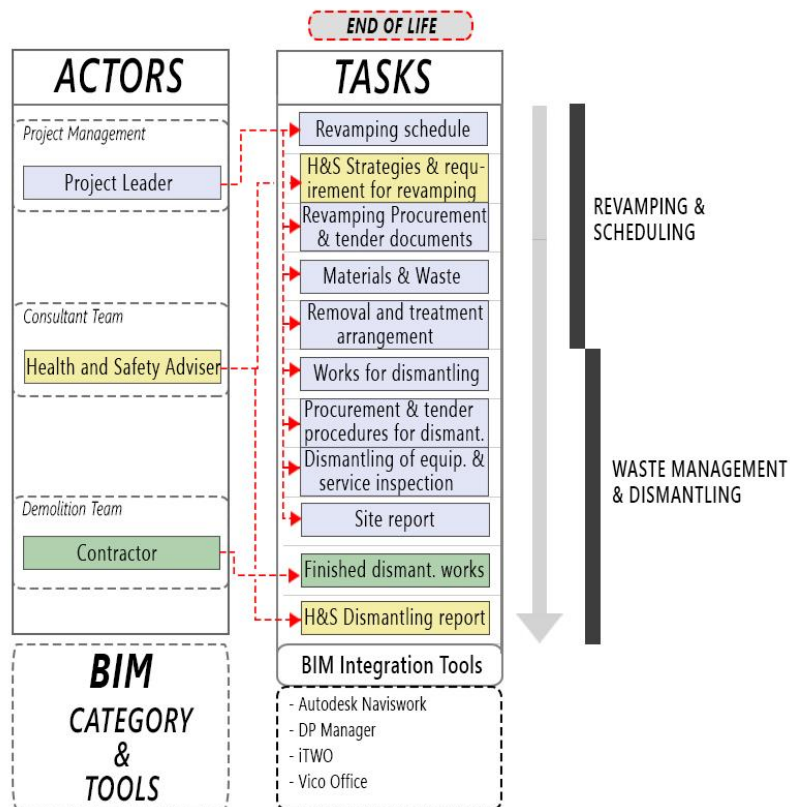


Figure 5.24. Identification of tasks for End of life

The process in the End of life stage remains the same in case of public and private works as there is no additional or modification in any of the actors and their respective tasks.

5.3. IDENTIFY USER PROFILES BASED ON INFORMATION WORKFLOW

In this chapter of the analysis, which is to identify the user profiles, the analysis was carried out by identifying all the Users/stakeholders listed in the BIM4EEB project in case of private works and private works as seen in Fig 5.24.

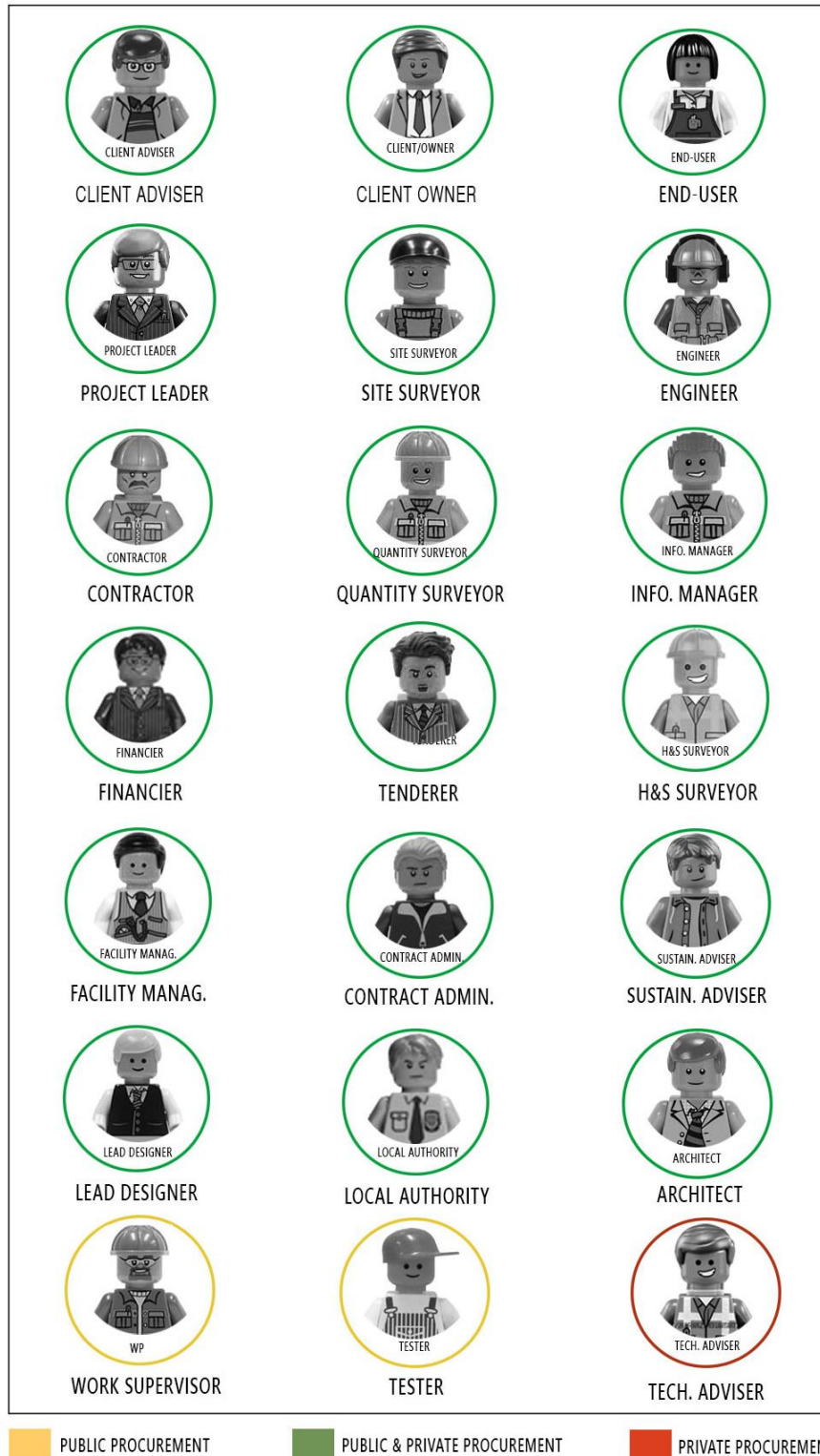


Figure 5.25. Identifying Users in public & private works,
 Character emoji source: Lego Building characters

The above listed 21 Actors are involved in the public and private works. The actors circled with green colour are those who are involved in both private and public works and the actors circled with yellow colour are involved only in public works whereas the actor circled with red colour is involved only in private works.

Followed by the previous step, to identify the User profiles model the information workflow is partitioned into two categories to understand the functional aspects and information exchange as seen in Fig 5.25.

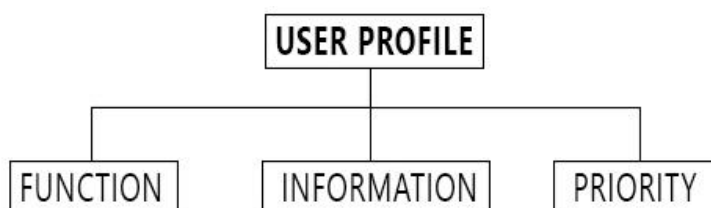


Figure 5.26. Identifying user profile

FUNCTION: The functional aspect represents the function workflow between the main User and interaction among other users in accordance with the BIM tool categories also indicating the nature of action between the users.

USER: The main user of the profile.

ACTORS: Actors involved in sharing information & work with the User.

BIM TOOLS: BIM tools are the means of partitioning the actors with respect to the actions.

ACTION: The nature of action between the User and the actors.

PRIORITIES: A kind tool included to validate and scale the way of interaction between the user and the BIM Tools in particular to understand the level of interaction with the BIM Tools.

By doing so it is clear for the kind of interaction that is carried out between different users with respect to the BIM tools which will direct the information flow in the project in a optimized and efficient way.

INFORMATION: The information section describes the information workflow for the User, where BIM Tool category is used as the main criteria displaying the Input Information and Output Information for the involved tasks in accordance with the stages.

- **Input info:** all data that the user process and need to access in the BIM management system

- **Output info:** all data that the user put back to the BIM system

PRIORITY: The priority feature used in the functional chart is to understand & validate the level of abilities and interaction of the user with respect to the BIM Tool categorized in the chart. The following are the three categories included in the priority ranking:

- **Category I:** Category I includes View, Feedback, Decision

View: It gives the ability for the user only to view the shared information in the BMS.

Feedback: Indicates if any suggestions, reaction or response to the particular action.

Decision: Where the user have the ability or tendency to make decisions quickly.

- **Category II:** Includes the actions of category I with review and changes.

Review: The user can report on or evaluate the result and change if necessary.

Changes: Gives user the ability to substitute, alter or modification in the BMS.

- **Category III:** Includes the actions of category I with category II in addition gives full access.

Full access: The user in this case can have full access to the BIM Tool to modify, addition or subtract, changes etc.

This helps in identifying the kind of information flow that is to be carried out with respect to the BIM tool category which will again direct the information flow in the project in a optimized and efficient manner.

Now both together Function and Information aspects will help in identifying the final User profile, resulting in sharing and flow of information within an organisation among many involved users to enhance the overall process and reduce the time and the cost of solving problems and a better coordination and develop interoperable business practice.

A representation of a diagram below to understand the contents of the upcoming table for the user's profile for accessing BIM management system.

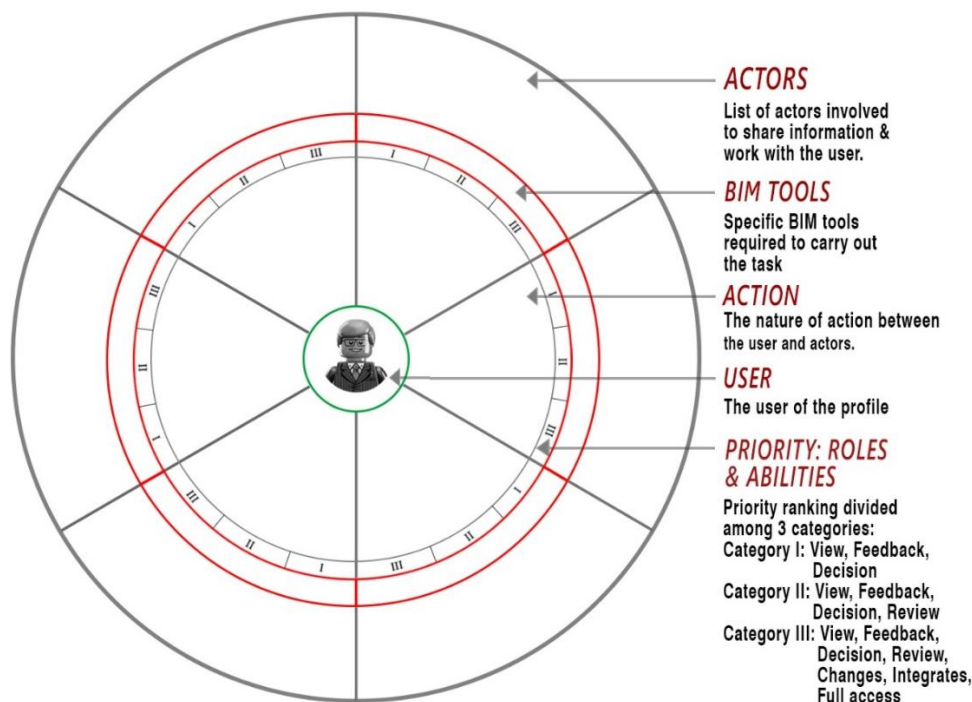


Figure 5.27. An example of a figure shows the function and priority in a user's profile

The following are the results and analysis of the above discussed subject:

5.3.1. CLIENT / OWNER – PRIVATE & PUBLIC WORKS

The figure below represents the user profile for Client/owner. The actor interacts with 4 different actors with the use of two different BIM Tool system. The category I priority is assigned for the use of BIM Tools depending on the scale of interaction.

The client/owner user profile is involved in both public & private works.

Function

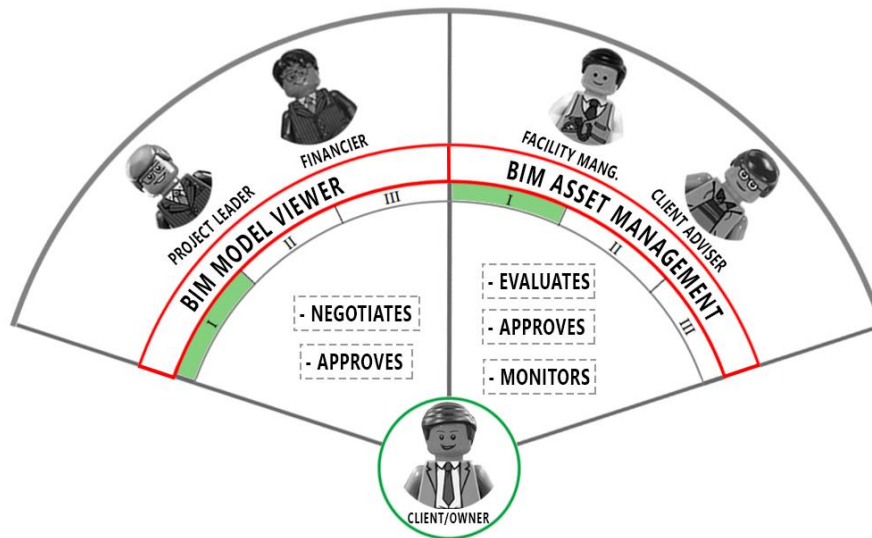


Figure 5.28. Function profile of Client/Owner

Information

Table 5.3. Information profile of Client/Owner

INFORMATION PROFILE: CLIENT/OWNER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Tools for Asset Management	INITIATIVE	Failure report resulted from End-user's information. Failure assessment from Owner itself or Facility Management Team depend on the capability of Owner itself or the scale of the building Cost-benefits report from Client Adviser	Failure assessment based on failure reports Decision about the approval of renovation process, the approval of cost-benefits for Client Adviser to prepare the preliminary business case

BIM Model Viewer	INITIATION	Model viewer of existing building BIM Model creating in initiation stage with related report	Information for negotiating financing contract with Financier.
Other	Other	Necessary information, model viewer and related report through the all other stages of the project from Project Leader, and other specialist.	Approval decision to proceed necessary activities in the project.

5.3.2. INHABITANT / END-USER - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for inhabitant/end-user. The actor interacts with 5 different actors with the use of three different BIM Tool system. The category I priority is assigned for the use of BIM Tools in all three cases.

The Inhabitant/End-user user profile is involved in both public & private works.

Function

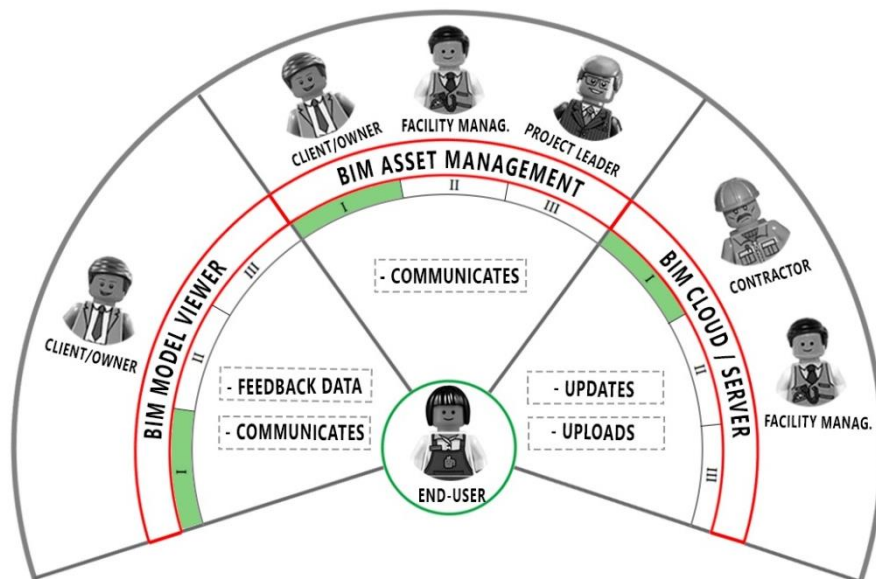


Figure 5.29. Function profile of Inhabitant/End-user

Information

Table 5.4. Information profile of Inhabitant/End-user

INFORMATION PROFILE: INHABITANT/END-USER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info



BIM Model Viewer	INITIATIVE	End-user's experiences about renovation needed	Picture and information of failure such as location, description of the failure to create a failure report for Owner or Facility Management Team
	INITIATION	A specific End-user's Model Viewer with following information: - work planning / schedules of pre / during renovation process - Optimal schedules of the renovation process - Security and safety recommendations about construction programming from Health and Safety Adviser.	Feedback data from End-user about this following information: - Work planning / schedules
BIM Tools for Asset Management	INITIATIVE	End-user's experiences about renovation needed	Communication to Owner or Facility Management Team.
	CONSTRUCTION	End-user's experiences and feeling about the comfort / discomfort during the renovation process	Feedback data from End-user about the comfort / discomfort of the renovation process caused by Contractor
	USE	End-user's experiences and feeling about the comfort / discomfort post renovation process	Feedback data from End-user about the comfort / discomfort post renovation process
BIM Server	CONSTRUCTION	End-user's information for the renovation process requested by Contractor	End-user's information form requested by Contractor

5.3.3. CLIENT / ADVISER - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for client/adviser. The actor interacts with one actor with the use of two different BIM Tool system. The category II priority is assigned for the use of BIM Tools in all both the cases.

The Client/Adviser user profile is involved in both public & private works.

Function

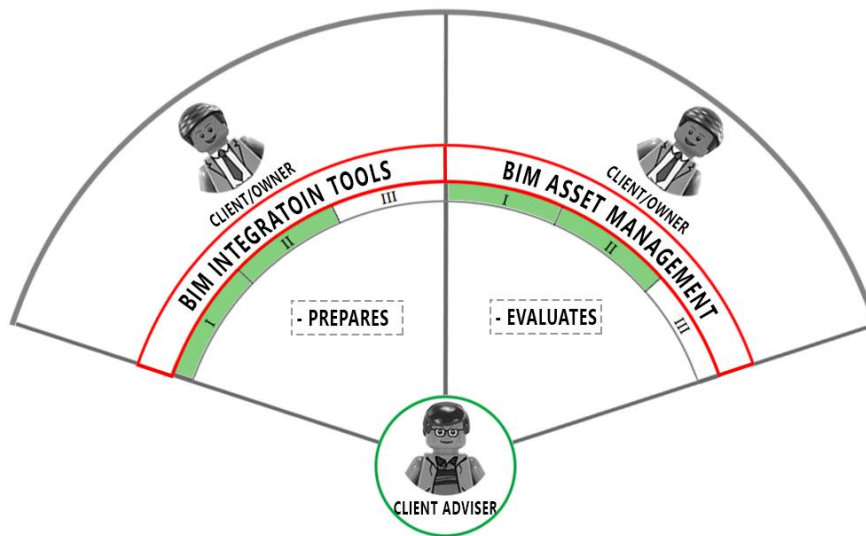


Figure 5.30. Function profile of Client/Adviser

Information

Table 5.5. Information profile of Client Adviser

INFORMATION PROFILE: CLIENT ADVISER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Tools for Asset Management	INITIATIVE	Failure assessment from Owner or Facility Management Team. BIM Facility Management model if available. Previous Facility Management documents if available.	Cost-benefits report
BIM Integration Tools	INITIATION	Existing building BIM model after site surveying. Preliminary business case	Detail business case

5.3.4. SITE SURVEYOR - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for site surveyor. The actor interacts with 2 different actors with the use of three different BIM Tool system. The priority category varies in use of BIM Tools in all the three cases.

The Site surveyor user profile is involved in both public & private works.

Function

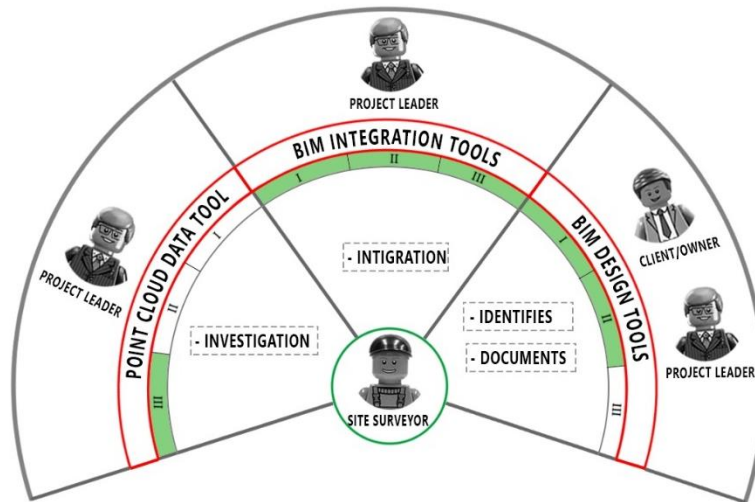


Figure 5.31. Function profile of Site Surveyor

Information

Table 5.6. Information profile of Site Surveyor

INFORMATION PROFILE: SITE SURVEYOR			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
Point Cloud Data Tools	INITIATION	Information after site surveying as geometrical data, condition data or point cloud data based on survey method.	BIM Model for existing building
BIM Design Tools	INITIATION	Information about causes and issues of deterioration; building services distribution, site; materials and classify of building components	Updated BIM model for existing building
BIM Integration Tools	INITIATION	Updated BIM model for existing building Previous data Point cloud data	Final existing building BIM Model

5.3.5. PROJECT LEADER - PRIVATE & PUBLIC WORKS

The figure below represents the 2-user profile for project leader. The actor interacts with 6 different actors with the use of 11 different BIM Tool system. The priority category varies in use of BIM Tools in both the profiles.

The Project leader user profile is involved in both public & private works.

Function

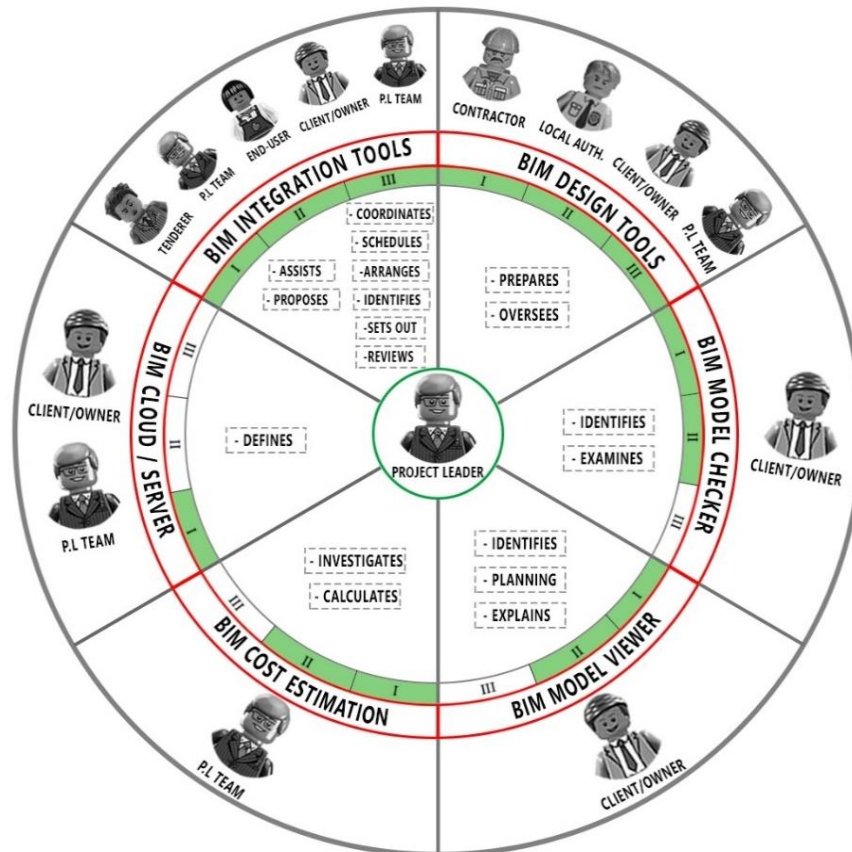


Figure 5.32. Function profile of Project Leader 1

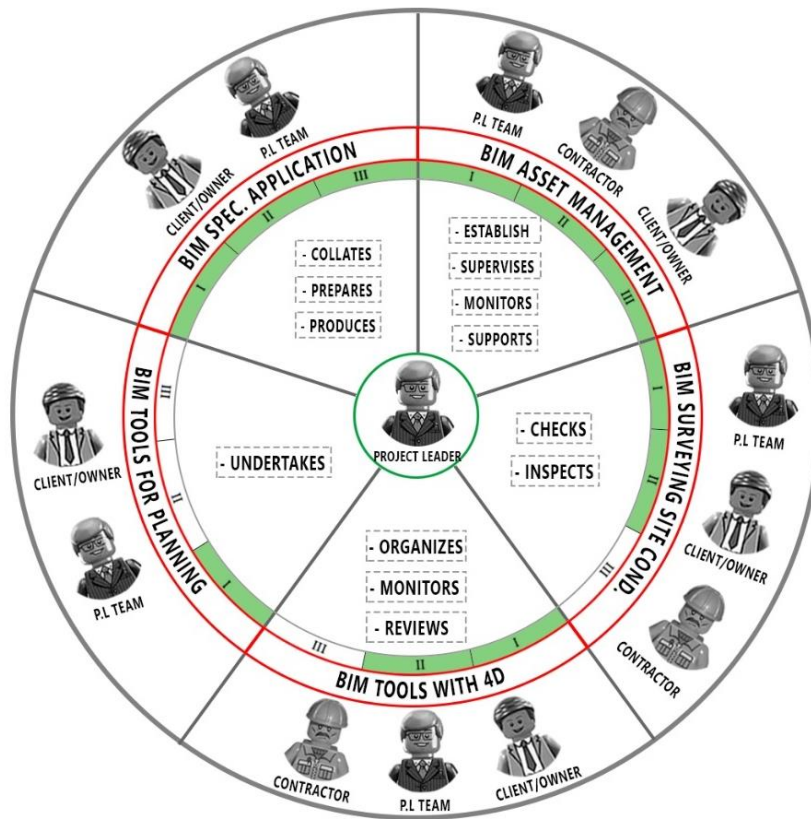


Figure 5.33. Function profile of Project Leader 2

Information

Table 5.7. Information profile of Project Leader

INFORMATION PROFILE: PROJECT LEADER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Model Viewer	INITIATION	- BIM FM Model - Information from previous tasks - Existing building BIM Model	- Site investigation location - Type of site investigation - Needed condition data - Model View Definitions - Report: planning principles and construction strategies
	CONCEPT DESIGN	- Report: Statutory Approvals - Conceptual Arch. BIM Model - Final Conceptual Arch. BIM Model	- Decision to obtain statutory approvals

BIM Model Checker	INITIATION	<ul style="list-style-type: none"> - Existing building BIM Model - Ruleset of requirements and aspirations 	<ul style="list-style-type: none"> - Report: requirements and aspirations that meet or not meet. - Report: required approval process and building permit
	CONSTRUCTION	<ul style="list-style-type: none"> - Final Construction BIM Model - Finished Construction Work 	<ul style="list-style-type: none"> - Report: checked construction work
BIM Design Tools	INITIATION	<ul style="list-style-type: none"> - Existing building BIM Model - Client needs 	<ul style="list-style-type: none"> - Report: feasibility studies and assessed options - Report: Room and function schedule
	PRELIMINARY DESIGN	<ul style="list-style-type: none"> - Final Conceptual Arch. BIM Model 	<ul style="list-style-type: none"> - Preliminary Arch. BIM Model
	DEVELOPED DESIGN	<ul style="list-style-type: none"> - Approved Preliminary Arch. BIM Model - Preliminary Project Execution Plan - Preliminary drawing set - Pre-Developed BIM Arch. Model 	<ul style="list-style-type: none"> - Pre-Developed BIM Arch. Model - Developed BIM Arch. Model without cost
	CONSTRUCTION	<ul style="list-style-type: none"> - Integrated Detail BIM Model - Contractor's drawings - Final Construction BIM Model - As-built Building - As-built BIM Model - As-built Documentation - Required documents 	<ul style="list-style-type: none"> - Construction BIM Model - Set of as-built documentation. - As-built BIM Model - As-built Documentation - Permit document set
	USE	<ul style="list-style-type: none"> - FM BIM Model - As-built BIM Model - As-built Documentation 	<ul style="list-style-type: none"> - Renovation documents
BIM Integration Tools	INITIATION	<ul style="list-style-type: none"> - Existing building BIM Model - Report: Cost and time 	<ul style="list-style-type: none"> - Data: kind of intervention and developed tasks. - Report: Time schedule - Project Execution Plan

	<p>CONCEPT DESIGN</p>	<ul style="list-style-type: none"> - Final Conceptual Arch. BIM Model - Conceptual Tender data - Report: Time schedule - Program Dates - Updated Project Execution Plan 	<ul style="list-style-type: none"> - Conceptual Tender data - Conceptual Tender documentation - Conceptual Tender Model Viewer - Program Dates - Report: Construction Strategy Options
	<p>PRELIMINARY DESIGN</p>	<ul style="list-style-type: none"> - Final Conceptual Arch. BIM Model - Building permit application documentation set. - Specific model viewer for building permit application. - Approved Preliminary Arch. BIM Model - Preliminary Tender data - Program Dates 	<ul style="list-style-type: none"> - Local Authorities Model Viewer - Additional files or certificates needed for approval procedure - Preliminary Tender data - Preliminary Tender documentation - Preliminary Tender Model Viewer - Schedule in phases
	<p>DEVELOPED DESIGN</p>	<ul style="list-style-type: none"> - Building permit application documentation set. - Specific model viewer for building permit application. - Approved Developed Arch. BIM Model - Developed Tender data - Schedule in phases - Report: Construction Strategy - Construction schedule - Developed Project Execution Plan 	<ul style="list-style-type: none"> - Additional files or certificates needed for approval procedure - Developed Tender data - Developed Tender documentation - Developed Tender Model Viewer - Construction schedule - Report: Construction Strategy updated
	<p>DETAIL DESIGN</p>	<ul style="list-style-type: none"> - Building permit application documentation set. - Specific model viewer for building permit application. - Integrated Detail BIM Model - Detail Tender data - Construction Schedule 	<ul style="list-style-type: none"> - Additional files or certificates needed for approval procedure - Detail Tender data - Detail Tender documentation - Detail Tender Model Viewer - Detail Construction schedule

	CONSTRUCTION	<ul style="list-style-type: none"> - Construction BIM Model - Integrated Detail BIM Model - Changes required by the client. - Finished Construction Work - Request for Payment 	<ul style="list-style-type: none"> - Final clarification of design details - Final Construction BIM Model - Instructions to contractors - Report: request for payment checked - Report: checked construction work
	USE	<ul style="list-style-type: none"> - As-built BIM Model - As-built Documentation - FM BIM Model - Renovation Documentation 	<ul style="list-style-type: none"> - Report: Project Performance - Procurement documents - Tender documents
	END OF LIFE	<ul style="list-style-type: none"> - As-built BIM Model - Built asset analysis - Partial dismantling works. - Revamping schedule - H&S Strategies and requirement for revamping - Dismantling schedule 	<ul style="list-style-type: none"> - Revamping schedule - Revamping Procurement documents - Revamping Tender documents - Report: Materials & Waste - Report: Removal and treatment arrangement. - Dismantling schedule - Dismantling Procurement documents - Dismantling Tender documents - Dismantling Inspection Report - Site report
BIM Cost Estimation	INITIATION	<ul style="list-style-type: none"> - Existing building BIM Model - Report: feasibility studies and assessed options 	<ul style="list-style-type: none"> - Report: budget requirements
	DEVELOPED DESIGN	<ul style="list-style-type: none"> - Developed BIM Arch. Model without cost - Customary prices 	<ul style="list-style-type: none"> - Developed BIM Arch. Model
	DETAIL DESIGN	<ul style="list-style-type: none"> - Pre-Detail Arch. BIM Model without updated cost - Customary prices 	<ul style="list-style-type: none"> - Detail Arch. BIM Model
BIM cloud-based application	INITIATION	<ul style="list-style-type: none"> - Data: kind of intervention and developed tasks. 	<ul style="list-style-type: none"> - Organisational structure - Type of users

BIM Specification Application	PRELIMINARY DESIGN	<ul style="list-style-type: none"> - Final Preliminary Arch. BIM model - Additional files or certificates needed for approval procedure 	<ul style="list-style-type: none"> - Approval from local authority - Approved Preliminary Arch. BIM Model
	DEVELOPED DESIGN	<ul style="list-style-type: none"> - Final Developed Arch. BIM model - Additional files or certificates needed for approval procedure 	<ul style="list-style-type: none"> - Approval from local authority - Approved Developed Arch. BIM Model
	DETAIL DESIGN	<ul style="list-style-type: none"> - Final Detail Arch. BIM model - Additional files or certificates needed for approval procedure 	<ul style="list-style-type: none"> - Approval from local authority - Approved Detail Arch. BIM Model
BIM Tools with 4D Capability	CONSTRUCTION	<ul style="list-style-type: none"> - Integrated Detail BIM Model - Detail Health and Safety Strategy. - Eventual Statutory Procedures - Construction Schedule - As-built BIM Model - Revised Contracts 	<ul style="list-style-type: none"> - Pre-Finished Construction Works. - Construction Progress report - Statutory procedures schedule - Construction schedule result
	USE	<ul style="list-style-type: none"> - As-built BIM Model - As-built Documentation 	<ul style="list-style-type: none"> - Report: Project Performance
BIM Surveying Site Condition	CONSTRUCTION	<ul style="list-style-type: none"> - Pre-Finished Construction Works. - Construction Progress report - Final Construction BIM Model - Finished Construction Work 	<ul style="list-style-type: none"> - Finished Construction Work - Construction Inspection Report - Report: checked construction work - Report: checked workmanship.
BIM Tools for Planning and Control	CONSTRUCTION	<ul style="list-style-type: none"> - Construction BIM Model 	<ul style="list-style-type: none"> - Construction Quality Control Report
BIM Tools for Asset Management	INITIATION	<ul style="list-style-type: none"> - BIM FM Model - Information: all of previous report and assessment 	<ul style="list-style-type: none"> - Data: Owner needs, User requirements.
	DETAIL DESIGN	<ul style="list-style-type: none"> - Detail Construction schedule - Integrated Detail BIM Model 	<ul style="list-style-type: none"> - Handover and Commissioning Strategy.



	CONSTRUCTION	<ul style="list-style-type: none"> - Final Construction BIM Model - Finished Construction Work - Handover and Commissioning Strategy - Final Construction Contract - Contract Project Objectives 	<ul style="list-style-type: none"> - As-built Building - Revised Contracts
	USE	<ul style="list-style-type: none"> - As-built BIM Model - As-built Documentation 	<ul style="list-style-type: none"> - FM BIM Model - FM BIM Tools

5.3.6. LEAD DESIGNER - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for lead designer. The actor interacts with 2 different actors with the use of 4 different BIM Tool system. The priority category varies in the use of BIM Tools.

The Lead designer user profile is involved in both public & private works.

Function

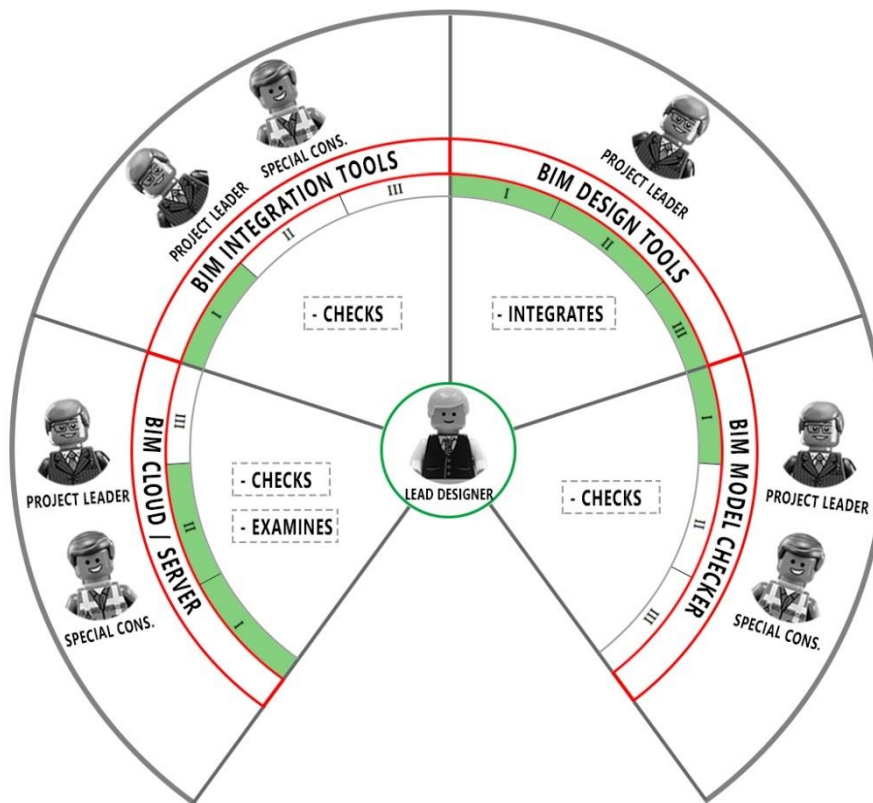


Figure 5.34. Function profile of Lead Designer

Information

Table 5.8. Information profile of Lead Designer

INFORMATION PROFILE: LEAD DESIGNER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Server	CONCEPT DESIGN	Project brief	Final project brief
	PRELIMINARY DESIGN	Data from project team	Review to project team's work
	DEVELOPED DESIGN	Data from project team	Review to project team's work
	DETAIL DESIGN	Data from project team	Review to project team's work

BIM Integration Tools	CONCEPT DESIGN	Final Conceptual Arch. BIM Model Final BIM model from project team	Conceptual design checking report
	PRELIMINARY DESIGN	Approved Preliminary Arch. BIM Model Approved Preliminary BIM model from project team	Feedback information for project team to update BIM model
	DEVELOPED DESIGN	Approved Developed Arch. BIM Model Approved Developed BIM model from project team	Feedback information for project team to update BIM model
	DETAIL DESIGN	Approved Detail Arch. BIM Model Approved Detail BIM model from project team	Feedback information for project team to update BIM model
BIM Model Checker	CONCEPT DESIGN	Final Conceptual Arch. BIM Model Final BIM model from project team 2D drawing from consultants	Conceptual design checking report
	PRELIMINARY DESIGN	Approved Preliminary Arch. BIM Model Approved Preliminary BIM model from project team	Preliminary design checking report
	DEVELOPED DESIGN	Approved Developed Arch. BIM Model Approved Developed BIM model from project team	Developed design checking report
	DETAIL DESIGN	Approved Detail Arch. BIM Model Approved Detail BIM model from project team	Detail design checking report
BIM Design Tools	CONCEPT DESIGN	Final Conceptual Arch. BIM Model Final BIM model from project team	Concept design documentation Integrated Conceptual BIM model
	PRELIMINARY DESIGN	Approved Preliminary Arch. BIM Model Approved Preliminary BIM model from project team	Preliminary design documentation Integrated Preliminary BIM model
	DEVELOPED DESIGN	Approved Developed Arch. BIM Model Approved Developed	Developed design documentation

		BIM model from project team	Integrated Developed BIM model
	DETAIL DESIGN	Approved Detail Arch. BIM Model Approved Detail BIM model from project team	Detail design documentation Integrated Detail BIM model

5.3.7. QUANTITY SURVEYOR - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for quantity surveyor. The actor interacts with 1 other actor with the use of 1 BIM Tool system. The category II priority is assigned in the use of BIM Tools.

The Quantity surveyor user profile is involved in both public & private works.

Function

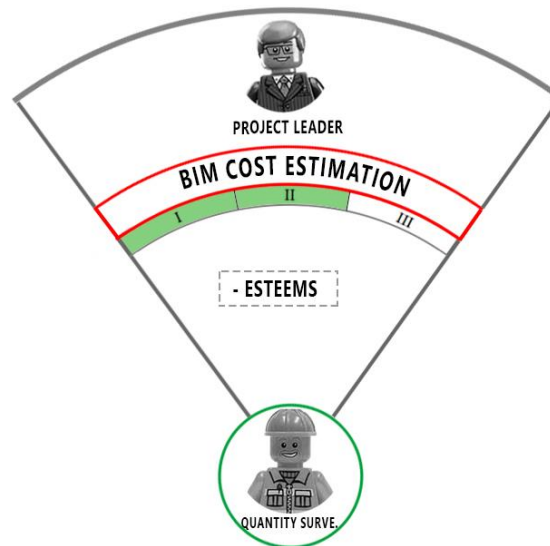


Figure 5.35. Function profile of Quantity Surveyor

Information

Table 5.9. Information profile of Quantity Surveyor

INFORMATION PROFILE: QUANTITY SURVEYOR			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Cost Estimation Tool	INITIATION	Existing building BIM Model Reports in initiation stage	Costs and time report

5.3.8. HEALTH & SAFETY ADVISER - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for health and safety adviser. The actor interacts with 3 other actors with the use of 2 BIM Tool system. The category II priority is assigned in the use of BIM Tools.

The Health & safety adviser user profile is involved in both public & private works.

Function

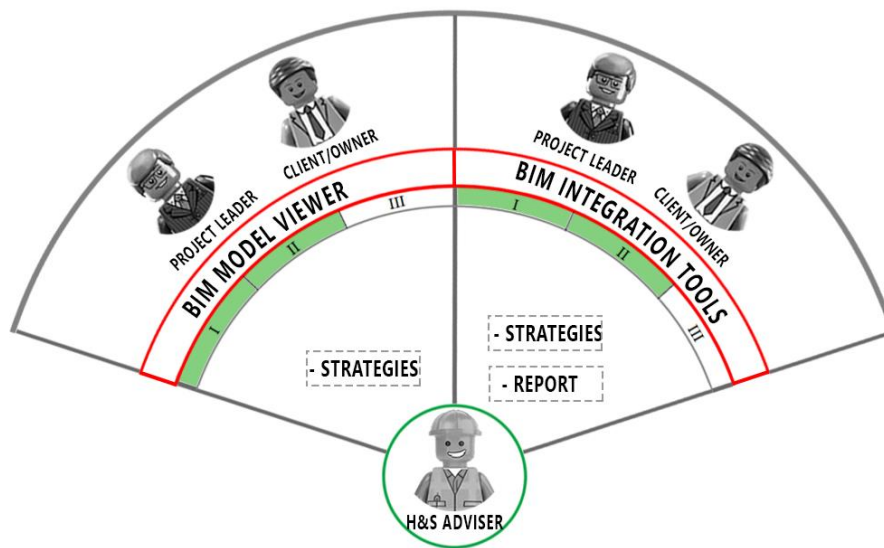


Figure 5.36. Function profile of Health & Safety Adviser

Information

Table 5.10. Information profile of Health & Safety Adviser

INFORMATION PROFILE: HEALTH & SAFETY ADVISER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Model Viewer	INITIATION	Existing building BIM model Kind of intervention and developed task	Health and safety strategy
BIM Integration Tools	CONCEPT DESIGN	Integrated Conceptual BIM Model Project Execution Plan Program Dates	Health and safety strategy outline
	PRELIMINARY DESIGN	Integrated Preliminary BIM Model Preliminary Project Execution Plan Schedule in phases Construction strategy	Preliminary health and safety strategy



	DEVELOPED DESIGN	Integrated Developed BIM Model Developed Project Execution Plan Construction schedule Construction strategy updated	Developed health and safety strategy
	DETAIL DESIGN	Integrated Detail BIM Model Project Execution Plan Construction schedule Construction strategy updated	Detail health and safety strategy
	END OF LIFE	As-built BIM model Partial dismantling works Revamping schedule	Health and safety strategies and requirements for revamping Health and safety dismantling report

5.3.9. INFORMATION MANAGER - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for information manager. The actor interacts with 2 other actors with the use of 1 BIM Tool system. The category III priority is assigned in the use of BIM Tool.

The information manager user profile is involved in both public & private works.

Function

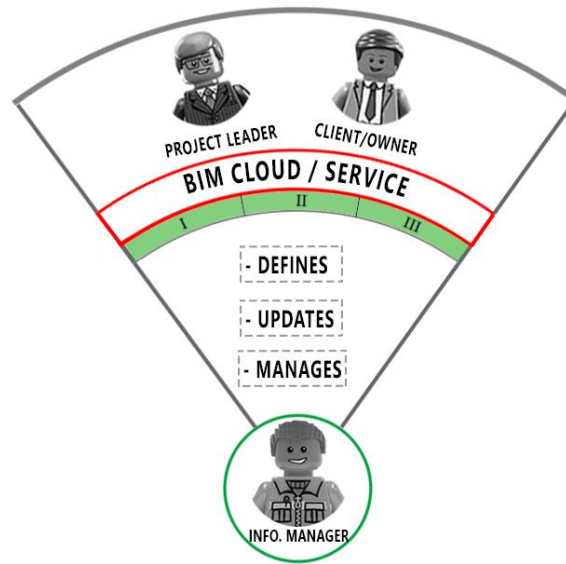


Figure 5.37. Function profile of Information Manager

Information

Table 5.11. Information profile of Information Manager

INFORMATION PROFILE: INFORMATION MANAGER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Server	INITIATION	Project Execution Plan Organisation Structure	Information Exchange Objectives
	CONCEPT DESIGN	Information Exchange Objectives Type of information exchange from all stakeholders Changes for Information Exchange after Owner approval	Information Exchange Level 1 Update Information exchange configuration
	PRELIMINARY DESIGN	Information Exchange Level 1	Information Exchange Level 2

DEVELOPED DESIGN	Information Exchange Level 2	Information Exchange Level 3
DETAIL DESIGN	Information Exchange Level 3	Information Exchange Level 4

5.3.10. ARCHITECTURAL DESIGNER - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for architectural designer. The actor interacts with 1 other actor with the use of 4 BIM Tool system. The category III priority is assigned in the use of BIM Tools.

The Architectural designer user profile is involved in both public & private works.

Function

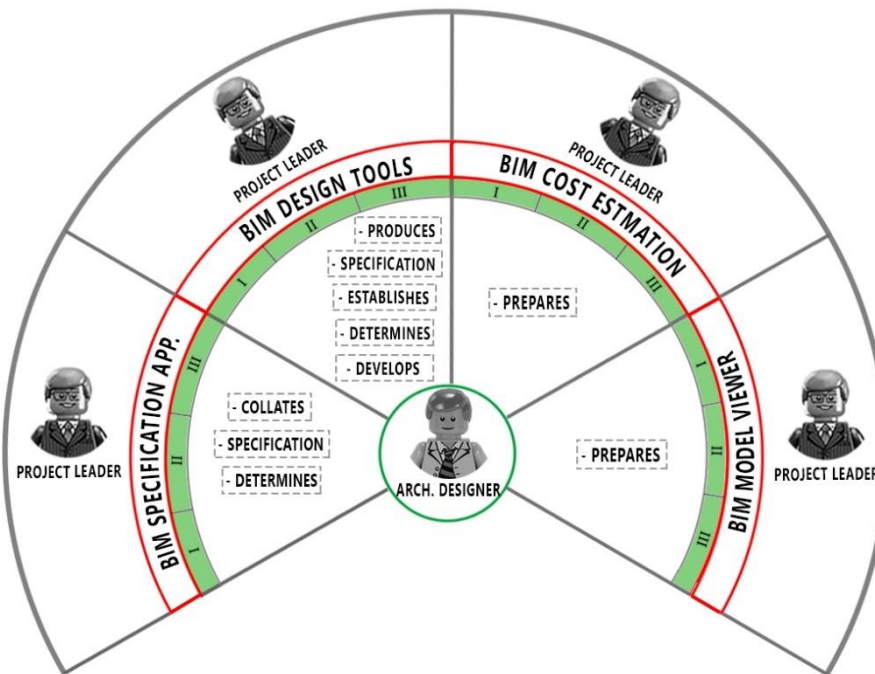


Figure 5.38. Function profile of Architectural Designer

Information

Table 5.12. Information profile of Architectural Designer

INFORMATION PROFILE: ARCHITECTURAL DESIGNER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info



BIM Design Tools	CONCEPT DESIGN	Existing building BIM Model Conceptual Arch. BIM Model Report: Statutory Approvals	Conceptual Arch. BIM Model Conceptual drawing set Report: Preliminary Design Final Conceptual Arch. BIM Model
	PRELIMINARY DESIGN	Preliminary Arch. BIM Model	Graphic presentations Preliminary drawing set Report: Preliminary technical Final Preliminary Arch. BIM Model
	DEVELOPED DESIGN	Developed BIM Arch. Model	Final Developed Arch. BIM model
	DETAIL DESIGN	Approved Developed Arch. BIM Model	Final Detail Arch. BIM model
BIM Model Viewer	CONCEPT DESIGN	Conceptual Arch. BIM Model	Local Authorities Model Viewer
BIM Cost Estimation	CONCEPT DESIGN	Conceptual Arch. BIM Model	Report: Initial Cost Estimation
BIM Specification Application	PRELIMINARY DESIGN	Pre-final Arch. BIM model Preliminary Technical Document	Final Preliminary Arch. BIM model
	DEVELOPED DESIGN	Pre-final Developed Arch. BIM model Developed Technical Document	Final Developed Arch. BIM model
	DETAIL DESIGN	Pre-final Detail Arch. BIM model Detail Technical Document Detail Cost Document	Final Detail Arch. BIM model

5.3.11. TENDERER - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for tenderer. The actor interacts with 2 other actors with the use of 1 BIM Tool system. The category I priority is assigned in the use of BIM Tools.

The Tenderer user profile is involved in both public & private works.

Function

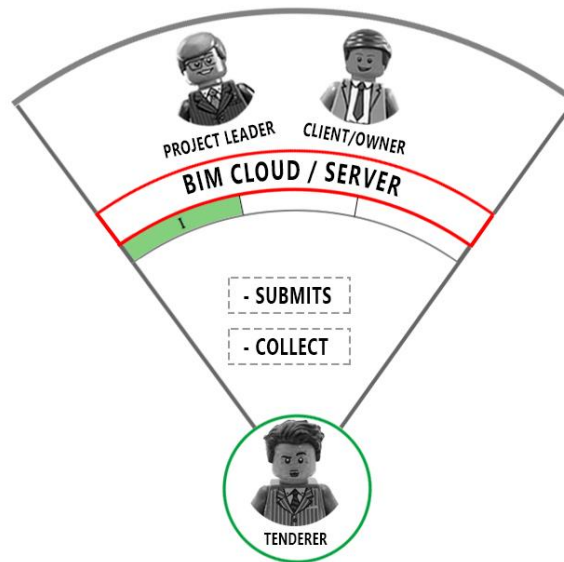


Figure 5.39. Function profile of Tenderer

Information

Table 5.13. Information profile of Tenderer

INFORMATION PROFILE: TENDERER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Server	CONCEPT DESIGN	- Conceptual Tender documentation - Conceptual Tender Model Viewer	- Conceptual Tender submission
	PRELIMINARY DESIGN	- Preliminary Tender documentation - Preliminary Tender Model Viewer	- Preliminary Tender submission
	DEVELOPED DESIGN	- Developed Tender documentation - Developed Tender Model Viewer	- Developed Tender submission

	DETAIL DESIGN	- Detail Tender documentation - Detail Tender Model Viewer	- Detail Tender submission
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5.3.12. CONTRACT ADMINISTRATOR - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for contract administrator. The actor interacts with 2 other actors with the use of 2 BIM Tool system. The category II & I priority is assigned in the use of BIM Tools.

The Contract administrator user profile is involved in both public & private works.

Function

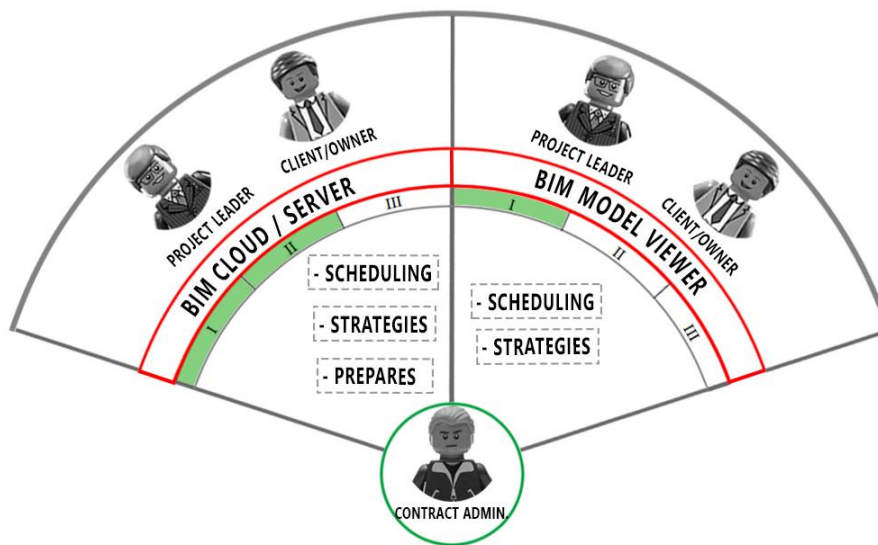


Figure 5.40. Function profile of Contract Administrator

Information

Table 5.14. Information profile of Contract Administrator

INFORMATION PROFILE: CONTRACT ADMINISTRATOR			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Server	CONSTRUCTION	- Detail Construction schedule - Construction Contracts - Integrated Detail BIM Model - Handover and Commissioning Strategy. - Report: Information	- Contract Administration

		Exchange Level 4 - Detail Health and Safety Strategy.	
BIM Model Viewer	CONSTRUCTION	- Contract Administration - Contractor BIM Model Viewer	- Final Construction Contract - Contract Project Objectives

5.3.13. ENGINEER - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for engineers. The actors interact with 1 other actor with the use of 2 BIM Tool system. The category III priority is assigned in the use of BIM Tools.

The Engineer user profile is involved in both public & private works.

Function

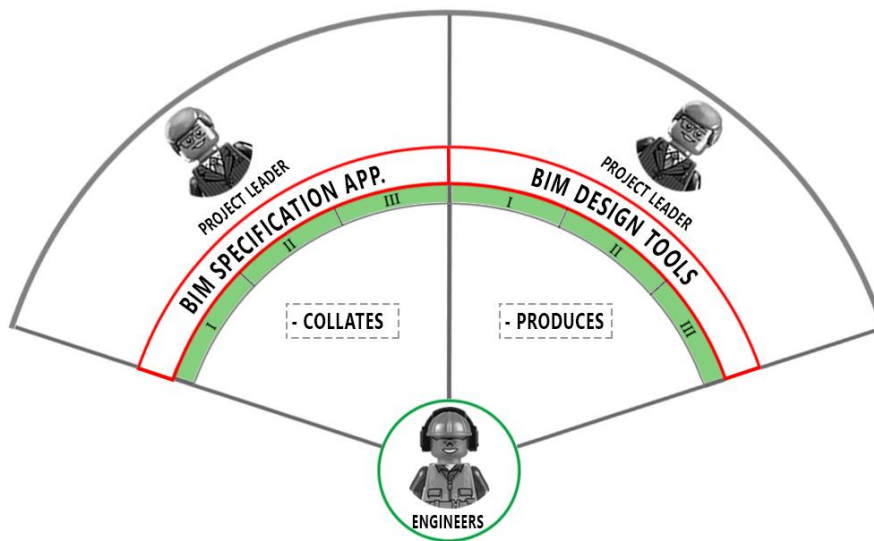


Figure 5.41. Function profile of Engineer

Information

Table 5.15. Information profile of Engineer

INFORMATION PROFILE: ENGINEER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info

BIM Design Tool	CONCEPT DESIGN	- Final Conceptual Arch. BIM Model	- Specific Conceptual BIM model from consultants
	PRELIMINARY DESIGN	- Final Preliminary Arch. BIM Model - Specific Conceptual BIM model from consultants	- Specific Preliminary BIM model from consultants
	DEVELOPED DESIGN	- Final Developed Arch. BIM Model - Specific Preliminary BIM model from consultants	- Specific Developed BIM model from consultants
	DETAIL DESIGN	- Final Detail Arch. BIM Model - Specific Developed BIM model from consultants	- Specific Detail BIM model from consultants
	CONSTRUCTION	- As-built BIM Model	- Permit application drawings
BIM Specification Application	CONSTRUCTION	- As-built BIM Model	- Permit application specifications
Other	Other	- Technical requirements or works in the project	- Technical documents, report - Specification in related discipline of the engineer

5.3.14. CONTRACTOR - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for contractor. The actor interacts with 1 other actor with the use of 5 BIM Tool system. The category priority varies in the use of BIM Tools.

The Contractor user profile is involved in both public & private works.

Function

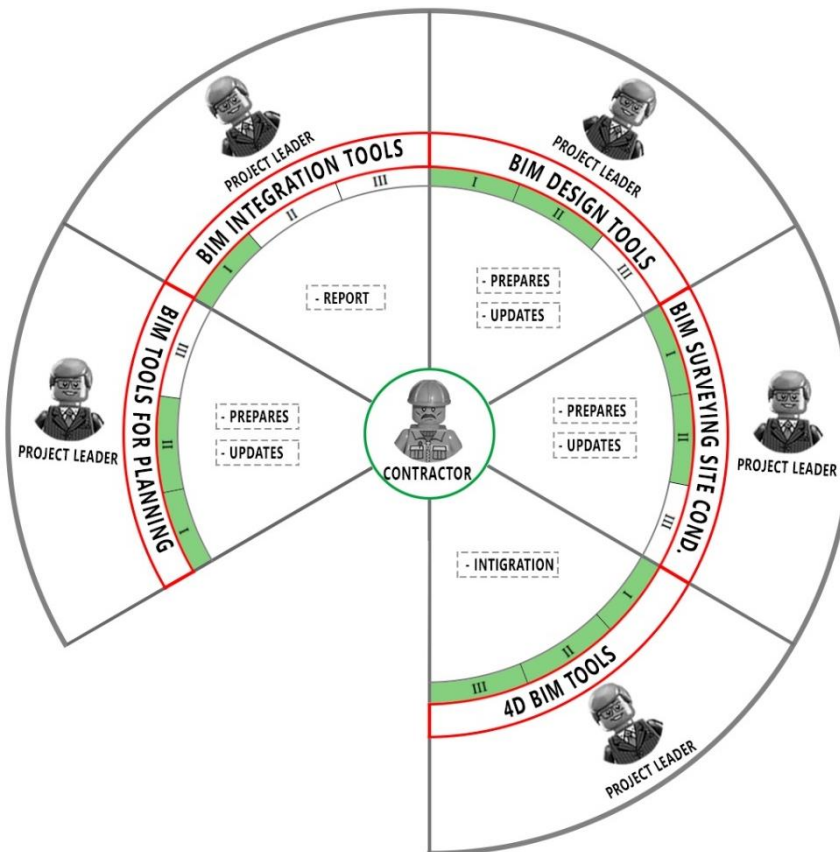


Figure 5.42. Function profile of Contractor

Information

Table 5.16. Information profile of Contractor

INFORMATION PROFILE: CONTRACTOR			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Tools with 4D Capability	CONSTRUCTION	- Integrated Detail BIM Model - Detail Health and Safety Strategy.	- Pre-Finished Construction Works. - Construction Progress report
BIM Surveying	CONSTRUCTION	- Pre-Finished Construction Works.	- Finished Construction Work

Site Condition		- Construction Progress report	- Construction Inspection Report
BIM Design Tools	CONSTRUCTION	- Integrated Detail BIM Model - Contractor's drawings - Construction BIM Model	- Construction BIM Model - Final Construction BIM Model
BIM Tools for Planning and Control	CONSTRUCTION	- Construction BIM Model	- Construction Quality Control Report
BIM Integration Tools	END OF LIFE	- As-built BIM Model - Report: Removal and treatment arrangement	- Finished dismantling works

5.3.15. SUSTAINABILITY ADVISER - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for sustainability adviser. The actor interacts with 2 other actors with the use of 1 BIM Tool system. The category I priority is assigned in the use of BIM Tools.

The Sustainability adviser user profile is involved in both public & private works.

Function

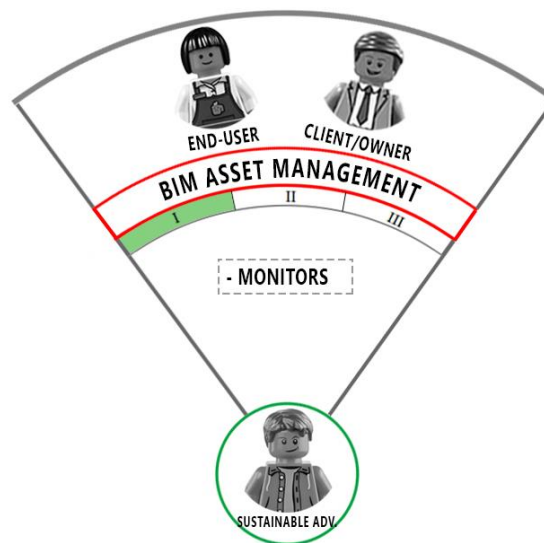


Figure 5.43. Function profile of Sustainability Adviser

Information

Table 5.17. Information profile of Sustainability Adviser

INFORMATION PROFILE: SUSTAINABILITY ADVISER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Asset Management Tool	USE	- Facility Management BIM Model	- Report: Sustainability performance

5.3.16. TECHNICAL ADVISER - PRIVATE WORKS

The figure below represents the user profile for technical adviser. The actor interacts with 2 other actors with the use of 1 BIM Tool system. The category I priority is assigned in the use of BIM Tools.

The Technical adviser user profile is only for the private works.

Function

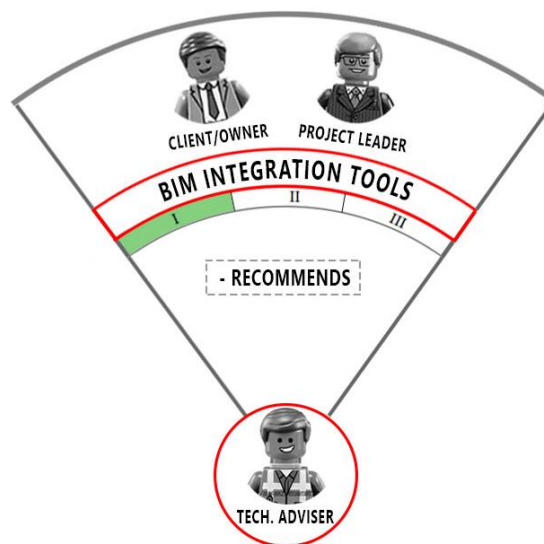


Figure 5.44. Function profile of Technical Adviser

Information

Table 5.18. Information profile of Technical Adviser

INFORMATION PROFILE: TECHNICAL ADVISER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Integration Tools	USE	- Facility Management BIM Model - As-built BIM model - Report: End of life audit	- Report: End of life audit - Report: Demolition and rehabilitation strategy.

5.3.17. FACILITY MANAGEMENT ADVISER - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for facility management adviser. The actor interacts with 2 other actors with the use of 1 BIM Tool system. The category II priority is assigned in the use of BIM Tools.

The Facility management adviser user profile is involved in both public & private works.

Function

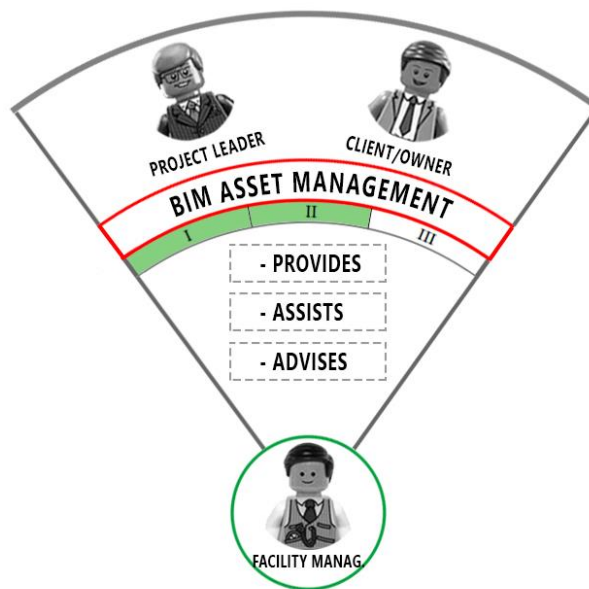


Figure 5.45. Function profile of Facility Management Adviser

Information

Table 5.19. Information profile of Facility Management Adviser

INFORMATION PROFILE: FACILITY MANAGEMENT ADVISER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Assets Management Tools	USE	- FM BIM Model - Maintenance Plan - Environmental, energy-waste water information.	- Maintenance plan - Maintenance strategy - Maintenance works - Report: Facility Management - Report: Environmental Monitoring - Life-cycle Strategy - Report: Energy wastewater management - Training documents

5.3.18. BANK or THIRD-PARTY FINANCIER ADVISER - PRIVATE & PUBLIC WORKS

The figure below represents the user profile for third-party financier adviser. The actor interacts with 1 other actor with the use of 1 BIM Tool system. The category I priority is assigned in the use of BIM Tools.

The Bank or Third-party financier adviser user profile is involved in both public & private works.

Function

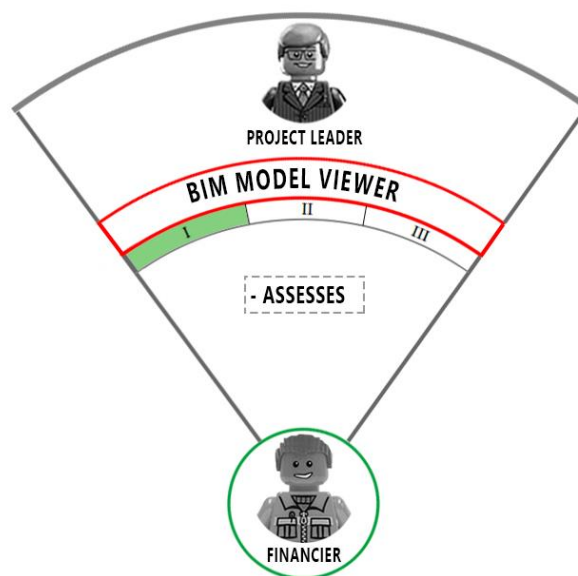


Figure 5.46. Function profile of Bank or Third-Party financier Adviser

Information

Table 5.20. Information profile of Bank or Third-Party Financier Adviser

INFORMATION PROFILE: BANK or THIRD-PARTY FINANCIER ADVISER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Model Viewer	INITIATION	- Financier Model Viewer	- Decision for financing the project

5.3.19. WORK SUPERVISOR – PUBLIC WORKS

The figure below represents the user profile for work supervisor. The actor interacts with 4 other actors with the use of 5 BIM Tool system.

The Work supervisor user profile is involved only in public works.

Function

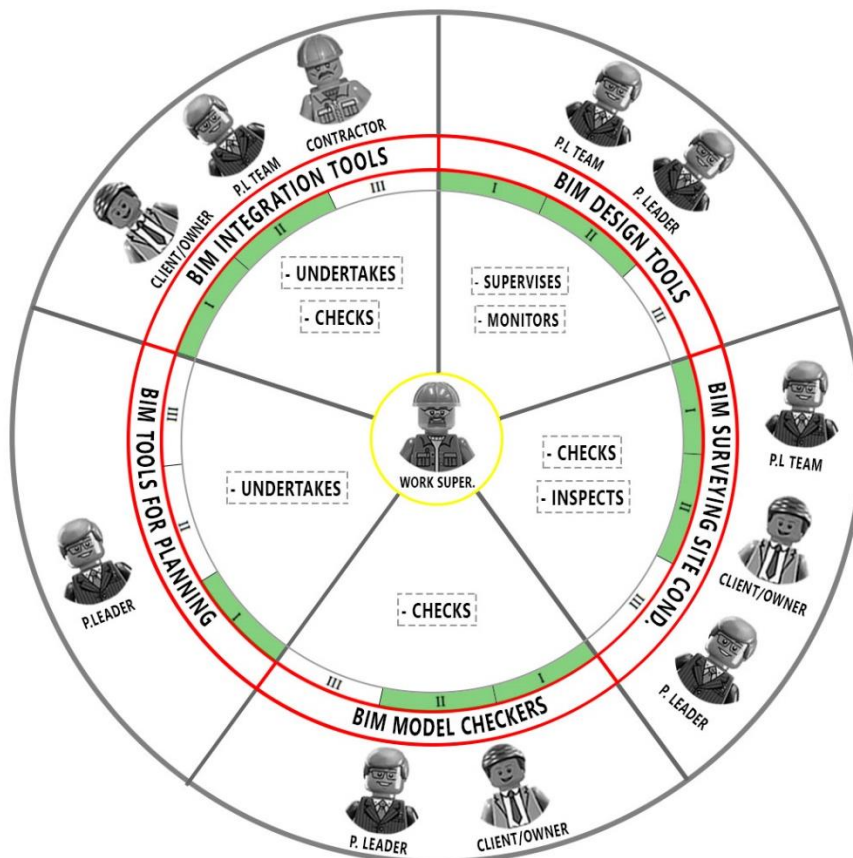


Figure 5.47. Function profile of Work Supervisor

Information

Table 5.21. Information profile of Work Supervisor

INFORMATION PROFILE: WORK SUPERVISOR			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Model checker	CONSTRUCTION	- Final Construction BIM Model - Finished Construction Work	- Report: checked construction work
BIM Surveying Site Condition	CONSTRUCTION	- Pre-Finished Construction Works. - Construction Progress report	- Finished Construction Work - Construction Inspection Report
BIM Design Tools	CONSTRUCTION	- Integrated Detail BIM Model - Contractor's drawings - Construction BIM Model	- Construction BIM Model - Final Construction BIM Model
BIM Tools for Planning and Control	CONSTRUCTION	- Construction BIM Model	- Construction Quality Control Report
BIM Integration Tools	CONSTRUCTION	- Changes required by the client. - Finished Construction Work	- Final clarification of design details - Report: checked construction work

5.3.20. TESTER – PUBLIC WORKS

The figure below represents the user profile for Tester. The actor interacts with 1 other actors with the use of 1 BIM Tool system.

The Tester user profile is involved only in public works.

Function

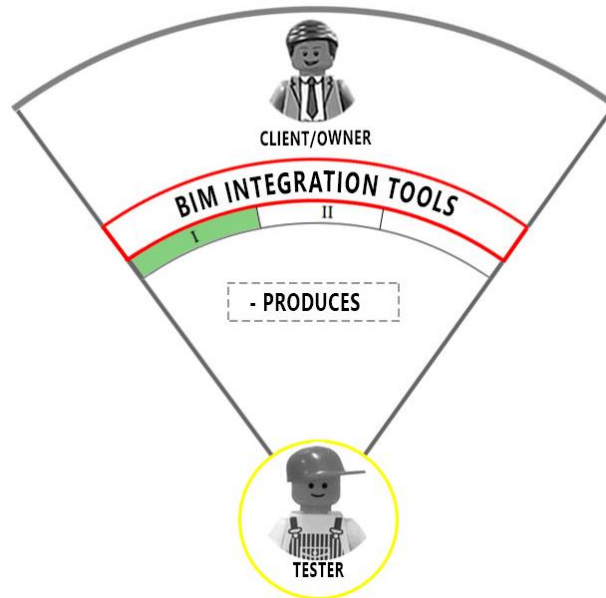


Figure 5.48. Function profile of Tester

Information

Table 5.22. Information profile of Tester

INFORMATION PROFILE: TESTER			
BIM Tool Category	Stage	Information workflow	
		Input Info	Output Info
BIM Integration Tools	CONSTRUCTION	- As-built BIM Model - Finished construction works	- Report: Administrative and technical test report



CHAPTER 6

USER PROFILE AND USE CASE DEVELOPMENT

6. USER PROFILE – USE CASES WORKFLOW

The goal of this chapter is to develop the Use case’s matrix for the BIM4EEB project to understand the line of activities/events which are performed by actors with the help of Tools/system to execute a particular action and for the further development of the project and the data necessary to develop a matured BMS (BIM Management system).

The figure below represents the methodology for analysing the User profile – Use case ‘s workflow which includes two main data adopted from the (i) Developed User profile from the previous chapter and (ii) Developed WP4 BMS Specification from the OneTeam company. The results which are 13 different User profile – Use case workflow diagram thus helping to arrive at the final table - Use Case’s Matrix.

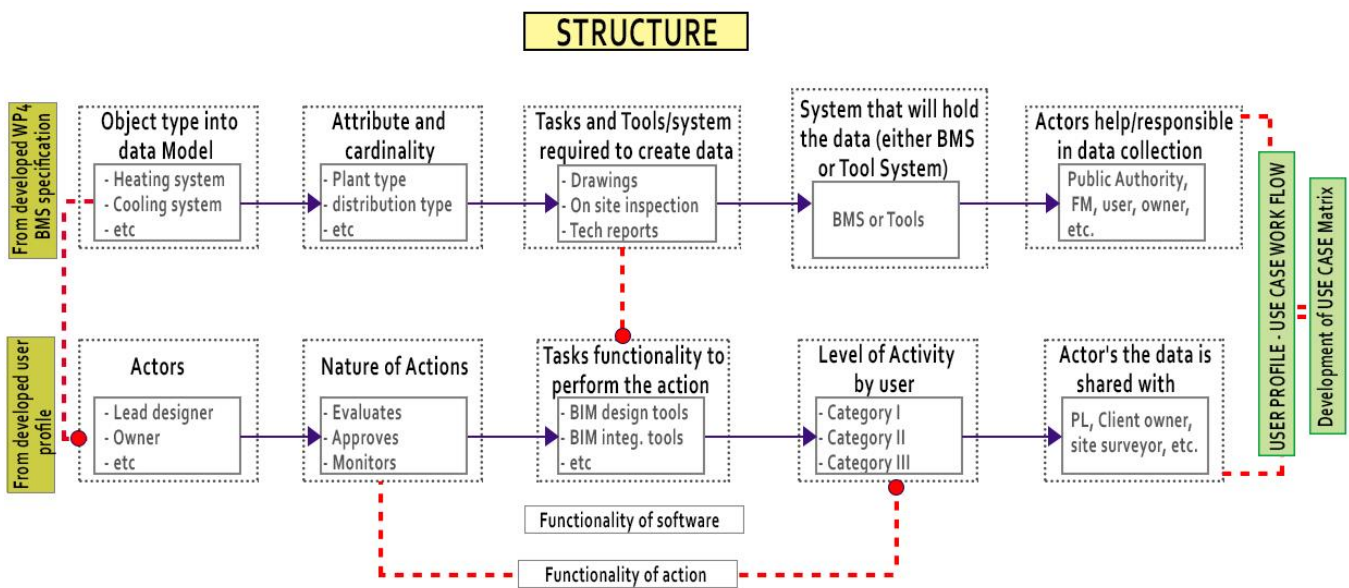


Figure 6.1. Methodology of Use case Matrix

6.1.METHODOLOGY

The methodology above explains the line the information’s adopted from two different sets of contexts. The developed WP4 BMS Specification helps us identify the “Object type into data model” whereas the developed user profile helps in Actor responsible to carry out the above actions. In such a way every attribute of WP4 BMS Specification is linked with User profile to arrive at the User profile – Use cases workflow which can be seen in the following sections.

Below explained are definitions of attribute in both the cases to have a better understanding on how to read the workflow diagrams.

6.1.1. From Developed WP4 BMS Specification

6.1.1.1. Object type into data model

As it is the starting point of the workflow diagram the Object type defines the nature & type of Object which must be registered into the data model. There are nearly 50 Object types that have been considered from the WP4 BMS Specification_polimi file. These object types after examining and studying well are linked with particular actors who are supposed to administer those object types.

6.1.1.2. Attribute and cardinality

In this section it is explained in a single sentence of the above Object type wherever it is necessary to understand better the nature of the Object type.

6.1.1.3. Task and Tools/system required to create data

Here it shows the list of Tasks and relative Tools/systems that are expected to create data. These data can be either in form of a document/report/plan/drawings/etc and also sometimes On-site inspection. It is also indicated in the workflow diagram the kind of format these data are shared among the actors which is necessary develop the BMS.

6.1.1.4. System that will hold the data (either BMS or Tools system)

It is necessary to understand where exactly the data is being stored advancing from the above section. Majority of the data are directed into the BMS to be shared and evaluated for other purposes while a few data is directed into the Tool system to further develop/simulate the required the results.

6.1.1.5. Actors help/responsible in data collection

To perform the above task, it is necessary to understand which actors is responsible to collect and share the data into the BMS or Tool system.

6.1.2. From Developed User profile

6.1.2.1. Actors

The actor responsible for carrying out the entire User profile – Use case workflow. In Some cases the workflow is performed by a single actor and in few cases it is supported by other actors who are involved in the workflow, this can be seen in the diagram next section.

6.1.2.2. Nature of Actions

The nature of actions helps in understanding the kind of developed data from all of the above collected information.

6.1.2.3. Task functionality to perform the action

To perform the developed above actions it is important to understand the BIM Tools which can be used to perform the actions. This section basically provides the information about the software tool.

6.1.2.4. Level of activity by the user

Indicated the functionality of the actor to what extent the information is going to be used:-

Category I : View, Feedback, Decision

Category II : View, Feedback, Decision, Feedback

Category III : View, Feedback, Decision, Review, Changes, Integrates, Full access

6.1.2.5. Actors the data is shared with

Under the section “Access and roles” in the workflow diagram it is indicated the “Actors the data is shared with” the shared information comes from the developed WP4 BMS Specification table. This information helps the actors to perform the next required tasks.

6.1.2.6. To perform Use cases

We have a list of Use cases in every workflow diagram which are assigned accordingly considering all of the above-mentioned sections. These User profile – Use cases workflow helps in developing the final Use case Matrix which is explained in more detail in the further section.

The below mentioned are the Use cases shared from the project team:

- **Use cases to specify better the information requirements**
 - Initiation: Renovation project initiation.
 - Concept Design: Quick calculation to find the design alternatives at conceptual level.
 - Preliminary Design: Preliminary energy simulations of the design alternatives.
 - Developed Design: More detailed energy simulation of the design alternatives.
 - Detailed Design: More detailed simulation of the design alternatives.
 - Construction: Implementation of the planned renovation measures.
 - Building Use: Operation and maintenance of the renovated building.
 - End of Life: Demolition and recycling of the renovated building.
- **Use cases from the building owners and inhabitant’s viewpoint**
 - Establishment of a comfort and IAQ preserving framework for inhabitants during the renovation period.
 - Establishment of a comfort and IAQ preserving framework for inhabitants during the renovation period post renovation phase.
 - A continuous interaction framework for comfort status monitoring and report for inhabitants.

- An alerts and notification framework during the renovation process for owners and inhabitants.
- Management and control of renovation interventions for owners.
- Control of working times and economic sustainability for owners - tracking tool for renovation.
- **Additional User cases**
 - Sensor monitoring of activity enablement and execution.
 - Workflow instantiation for an object (elements/spaces from BIM model, models and documents from design process models, contracts and procurement packages in procurement phase, shipments in transportation phase, objects identified in issues generated in inspection activities, and so on).
 - To acquire preliminary data from existing building.
 - To acquire detailed material and equipment data from existing building.
 - To define the kind of intervention, produce schedules, esteem cost.
 - To integrate work from specialist designers and publish the consolidated results.
 - To prepare preliminary design documentation.
 - Preparation of Developed Design Stage of BIM-Model.
 - Preparation of Detailed Design Stage of BIM-Model.
 - To oversee construction and commissioning processes.
 - To operate the building to the satisfaction of owner and tenants.
 - Preparation of End-of-Live BIM-Model.
 - Early identification of Indoor Air Quality model parameters.
 - Establishment of a health/IAQ environment during the renovation process - Renovation tasks/ processes to address IAQ standards.
 - Establishment of a IAQ preserving framework post renovation process.
 - Early identification of desired performance of acoustical properties for setting requirements (Concept design).
 - Early identification of acoustical parameters of structural/fluid model for planning, specifications and design of solutions (Preliminary/Developed/Detailed Design iterative process).
 - Implementation of solutions of importance for the acoustic performance during the construction phases.
 - Maintaining acceptable acoustical indoor conditions.
 - Documentation of User Comfort.
 - Documentation of System Usage.
 - Documentation Energy Consumption.
 - Documentation of occupation density.



- **Use cases related to occupants**
 - Establishment of a comfort preserving framework for building occupants.
 - Establishment of a modelling framework for building materials/ equipment.
 - Establishment of a modelling framework for energy systems in building premises.
 - Establishment of a modelling framework for indoor air quality conditions.
 - Establishment of a modelling framework for building acoustics.

6.2. USER PROFILE – USE CASE WORKFLOW

The User profile – Use case workflow represents a lists of use cases that actors can perform and is directly related to the requirements of the project process. Use cases are a recognition of the requirements that the project must achieve. To achieve this goal using all of the above described section we start from identifying all the key users of the system and their roles by matching the user requirements to develop the Use cases. For every workflow diagram a Code name is assigned to read the final Use Cases Matrix.

The following are the 13 listed User profile – Use case workflow diagram:

6.2.1. CONTRACTOR – INHABITANT/END-USER (CODE: CONTR. – E.U)

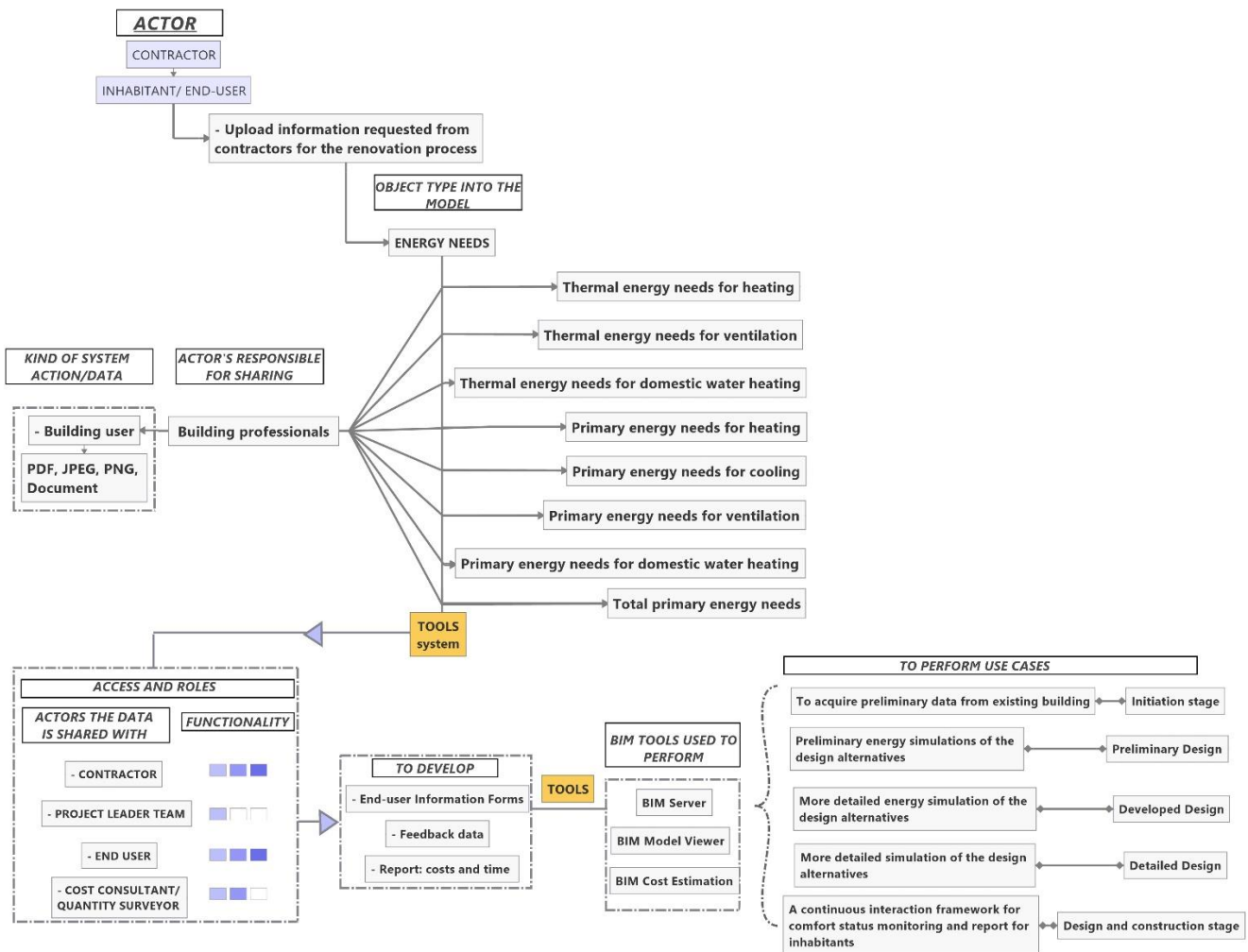


Figure 6.2. Contractor-End user workflow

The above workflow diagram is between the Contractor-End user, the main goal of the workflow is for the End-users to upload information requested from contractors for the renovation process for which the Object type is “Energy Needs” and listed under it are the attributes related to the energy needs. In the “Access and Roles” section below denotes with whom the information is shared with and the level of their actions.



In this case the Actors the data is shared with are: Contractor, Project leader team, End-user, Cost consultant/Quantity surveyor. The functionality bar shows that the contractor and end-user are given the highest priority involvement in the task then followed by the project leader team and quantity surveyor. The following products can be developed from the acquired data: End-user information forms, Feedback data, Report: cost & time and the required BIM Tools to perform this action are: BIM Server, BIM Model viewer, BIM cost estimation. Finally, the Use cases that can be developed out of this workflow diagram are:

- To acquire preliminary data from existing building
- Preliminary energy simulations of the design alternatives
- More detailed energy simulation of the design alternatives
- More detailed simulation of the design alternatives
- A continuous interaction framework for comfort status monitoring and report for inhabitants

6.2.2. CLIENT/OWNER – CLIENT ADVISER (CODE: C.O – C.A)

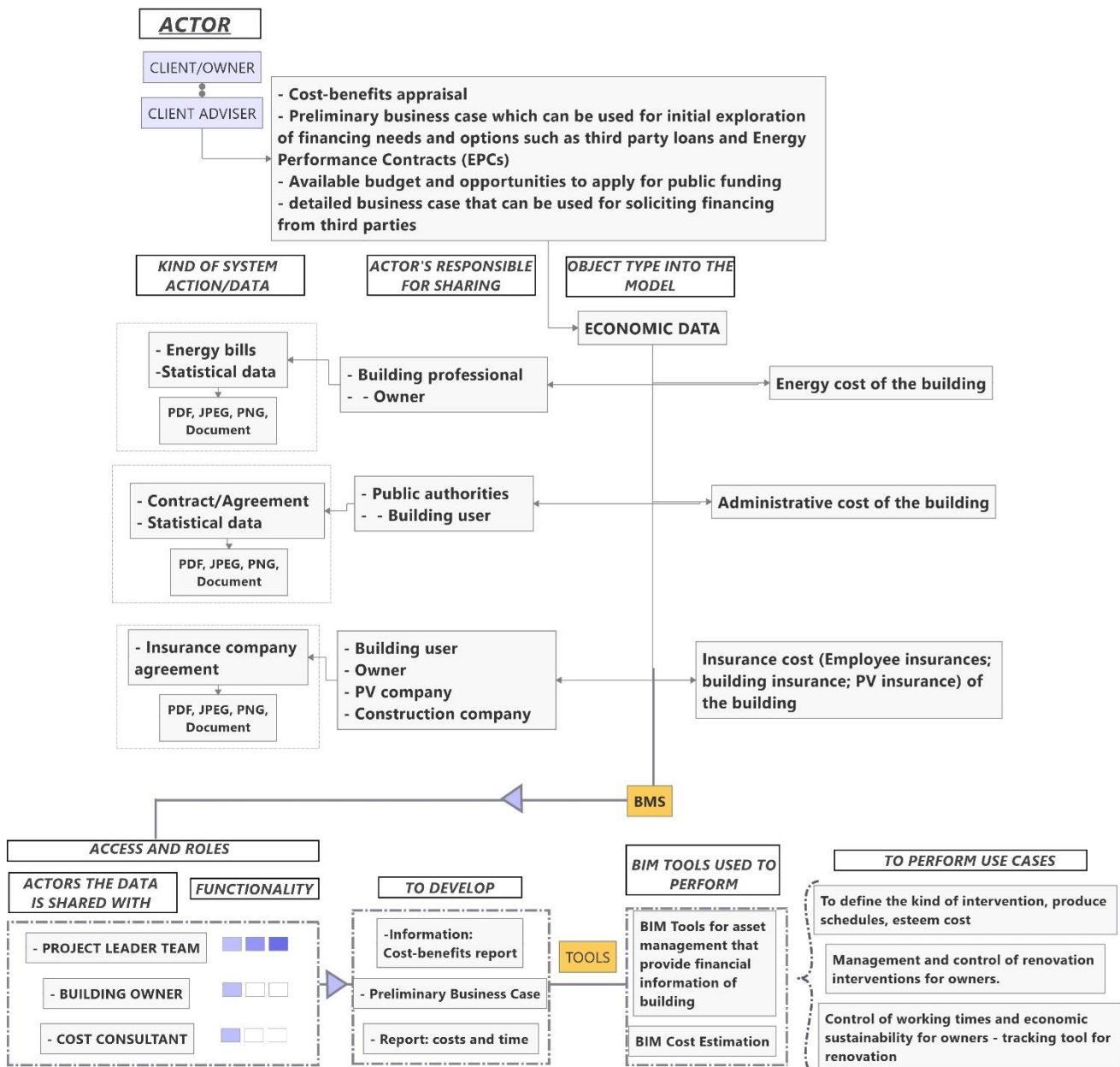


Figure 6.3. Client/owner-Client adviser workflow

The above workflow diagram is between the Client/owner-Client adviser, the main goal of the workflow is to develop (i) cost-benefits appraisal (ii) preliminary business case which can be used for initial exploration of financing needs and options such as third party loans and Energy Performance Contracts (EPCs) (iii) available budget and opportunities to apply for public funding (iv) detailed business case that can be used for soliciting financing from third parties. For which the Object types are (i) Energy cost of the building (ii) Administrative cost of the building (iii) Insurance cost of the building. In the “Access and Roles” section below denotes with whom the information is shared with and the level of their actions.



In this case the Actors the data is shared with are: Building owner, Project leader team, Cost consultant. The functionality bar shows that the project leader is given the highest priority involvement in the task then followed by the Building owner and Cost consultant. The following products can be developed from the acquired data: Cost benefit report, preliminary business case, Report: cost & time, and the required BIM Tools to perform this action are: BIM tools for asset management, BIM cost estimation. Finally, the Use cases that can be developed out of this workflow diagram are:

- To define the kind of intervention, produce schedules, esteem cost Preliminary energy simulations of the design alternatives
- Management and control of renovation interventions for owners
- Control of working times and economic sustainability for owners - tracking tool for renovation

6.2.3. BANK OR THIRD PARTY FINANCE (CODE: BANK/FINANCE)

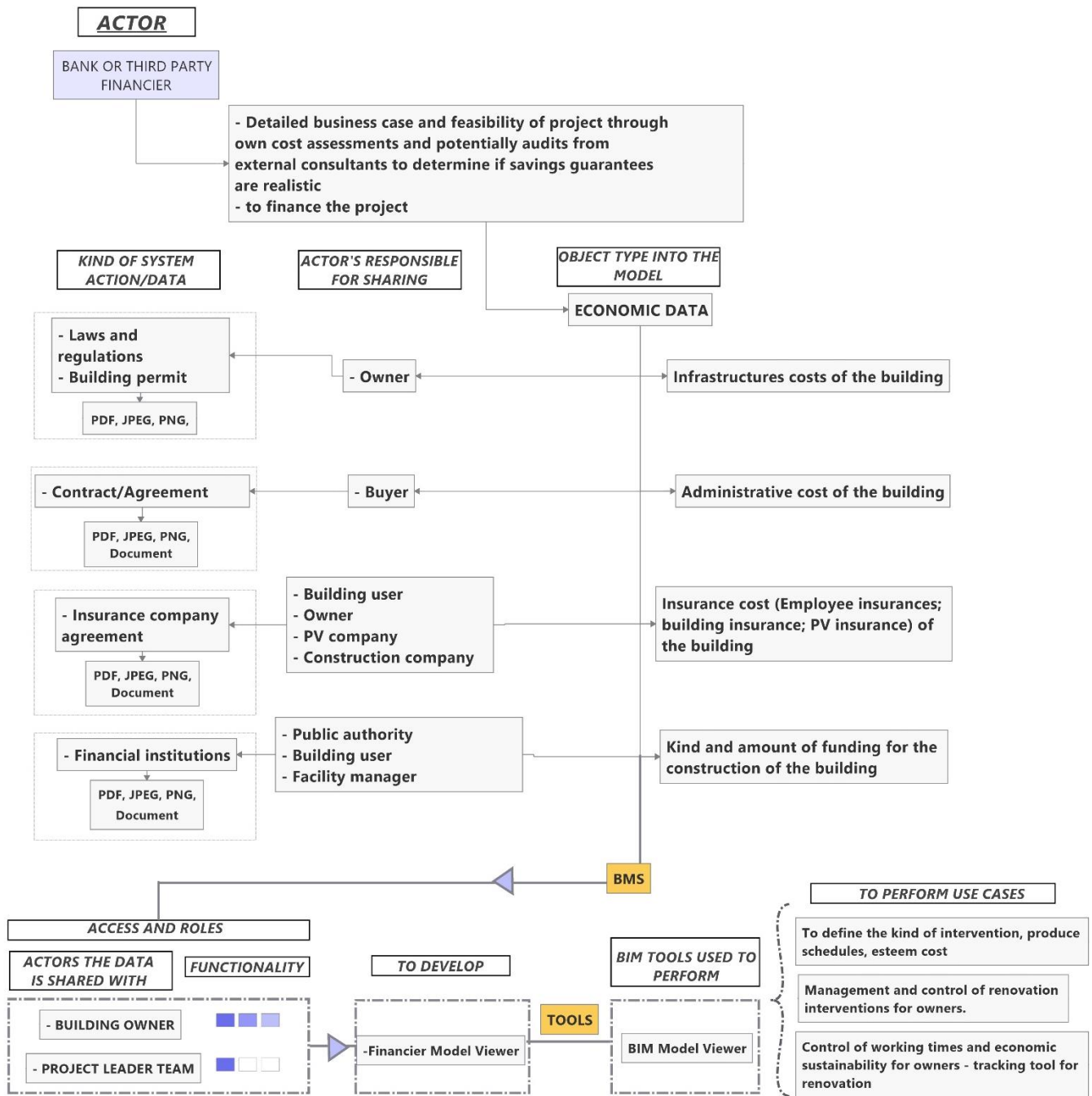


Figure 6.4. Bank/Third party finance workflow

The above workflow diagram is for Bank/Third party finance, the main goal of the workflow is to develop (i) detailed business case and feasibility of project through own cost assessments and potentially audits from external consultants to determine if savings guarantees are realistic (ii) to finance the project. For which the Object types are (i) Infrastructure cost of the building (ii) Administrative cost of the building (iii) Insurance cost of the building (iv) Kind and amount of funding for the construction of the building. In the “Access and Roles” section below denotes with whom the information is shared with and the level of their actions.



In this case the Actors the data is shared with are: Building owner & Project leader team. The functionality bar shows that the Building owner is given the highest priority involvement in the task then followed by the project leader team. The following products can be developed from the acquired data: Financier model viewer and the required BIM Tools to perform this action is: BIM Model viewer. Finally, the Use cases that can be developed out of this workflow diagram are:

- To define the kind of intervention, produce schedules, esteem cost Preliminary energy simulations of the design alternatives
- Management and control of renovation interventions for owners
- Control of working times and economic sustainability for owners - tracking tool for renovation

6.2.4. FACILITY MANAGEMENT – DESIGN TEAM – ENERGY AUDITORS (CODE: F.M – D.T- E.A)

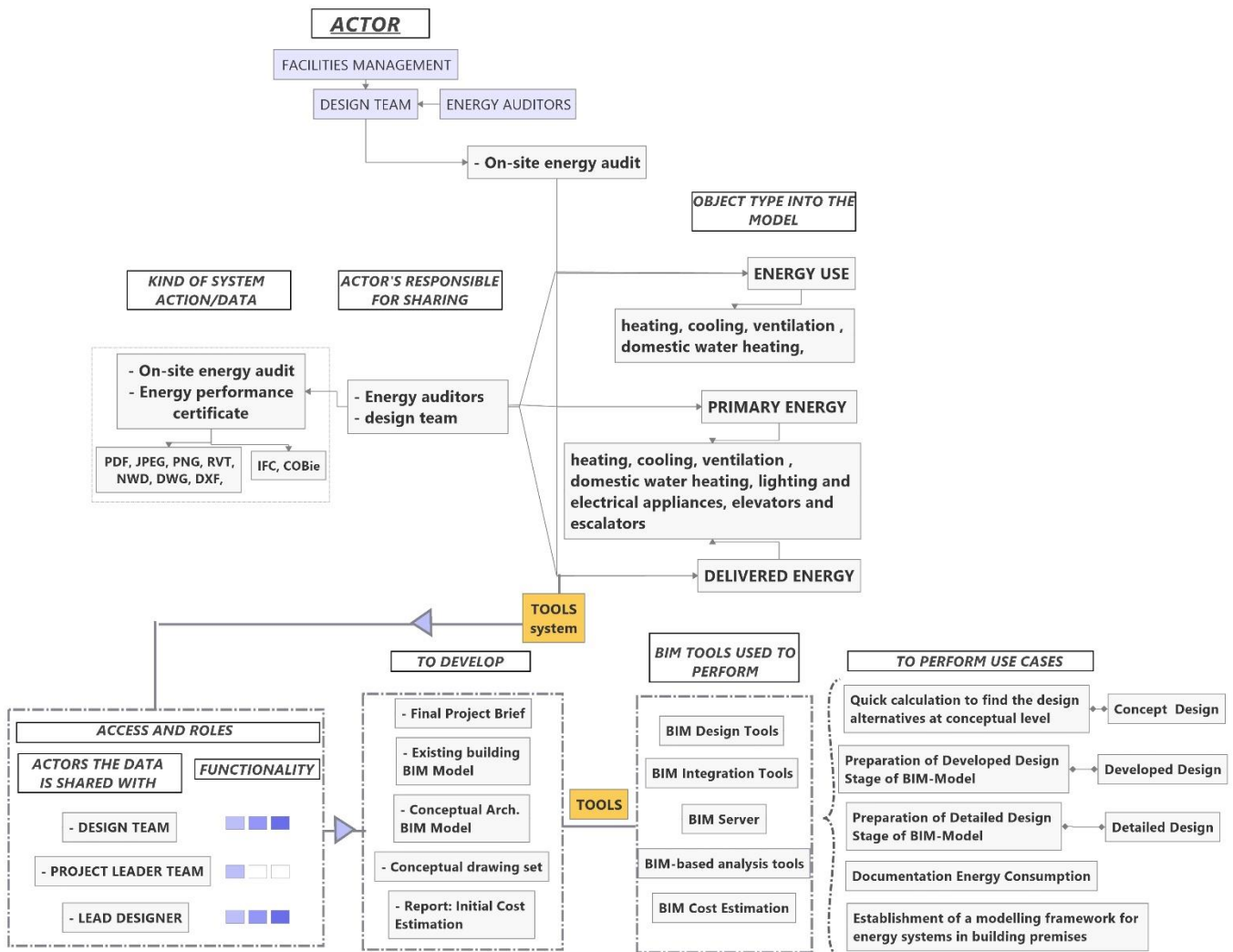


Figure 6.5. Facility management-Design team-Energy auditors workflow

The above workflow diagram is between the Facility management-Design team-Energy auditors, the main goal of the workflow is to develop (i) On site energy audit. For which the Object types are (i) Energy use - heating, cooling, ventilation, domestic water heating (ii) Primary energy - heating, cooling, ventilation, domestic water heating, lighting and electrical appliances, elevators and escalators. In the “Access and Roles” section below denotes with whom the information is shared with and the level of their actions.

In this case the Actors the data is shared with are: Design team, project leader team, lead designer. The functionality bar shows that the design team & lead designer is given the highest priority involvement in the task then followed by the project leader team. The following products can be developed from the acquired data: Final project brief, Existing building BIM Model, Conceptual Arch. BIM Model, Conceptual drawing set & Report: Initial cost estimation and the required BIM Tools to perform this action is: BIM design tools, BIM Integration tools,



BIM server, BIM based analysis tools, BIM cost estimation. Finally, the Use cases that can be developed out of this workflow diagram are:

- Quick calculation to find the design alternatives at conceptual level
- Preparation of Developed Design Stage of BIM-Model
- Preparation of Detailed Design Stage of BIM-Model
- Documentation Energy Consumption
- Establishment of a modelling framework for energy systems in building premises

6.2.5. FACILITY MANAGEMENT (CODE: FACILITY MANAG.)

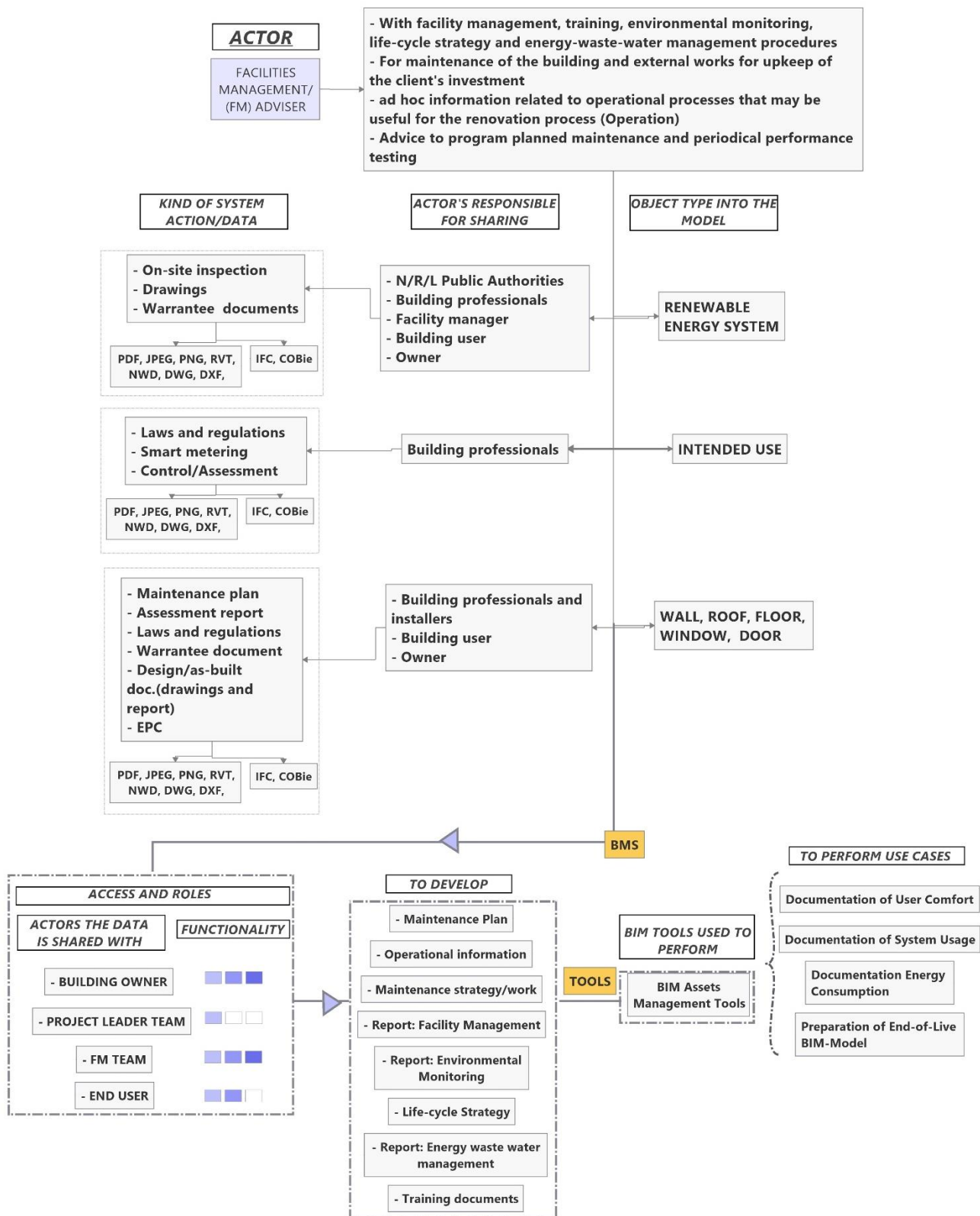


Figure 6.6. Facility management workflow

The above workflow diagram is for the Facility Management, the main goal of the workflow is to develop (i) With facility management, training, environmental monitoring, life-cycle strategy and energy-waste-water management procedures (ii) For maintenance of the building and external works for upkeep of the client's investment (iii) Ad hoc information related to operational processes that may be useful for the renovation process (Operation) (iv) Advice to program planned maintenance and periodical performance testing. For which the Object types are (i) Renewable energy system (ii) Intended use (iii) Wall, roof, floor, window, door. In the “Access and Roles” section below denotes with whom the information is shared with and the level of their actions.

In this case the Actors the data is shared with are: Building owner, project leader team, FM Team, End user. The functionality bar shows that the building owner & FM team is given the highest priority involvement in the task then followed by the end user & project leader team.

The following products can be developed from the acquired data: Maintenance plan, Operational information, Maintenance strategy/work, Report: Facility management, Report: Environmental monitoring, Life cycle strategy, Report: Energy waste water management, Training documents and the required BIM Tools to perform this action is: BIM asset management Tools. Finally, the Use cases that can be developed out of this workflow diagram are:

- Documentation of User Comfort
- Documentation of System Usage
- Documentation Energy Consumption
- Preparation of End-of-Live BIM-Model

6.2.6. LEAD DESIGNER – ENGINEERS - 1 (CODE: L.D - ENG.)

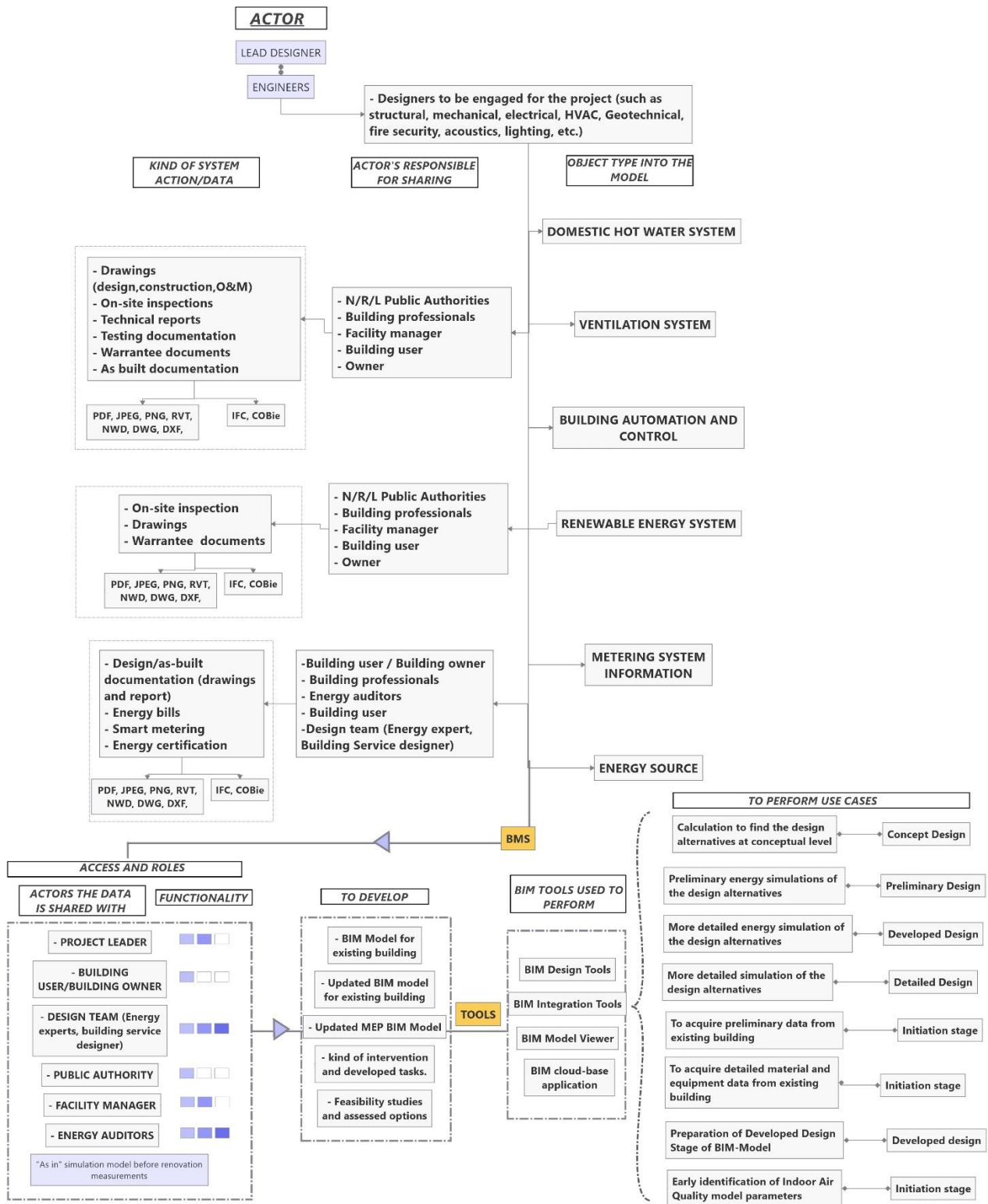


Figure 6.7. Facility management workflow

The above workflow diagram is for the Lead designer – Engineers - 1, the main goal of the workflow is to develop (i) Designers to be engaged for the project (such as structural, mechanical, electrical, HVAC, geotechnical, fire security, acoustics, lighting, etc.) For which the Object types are (i) Domestic hot water system (ii) Ventilation system (iii) Building Automation and control (iv) Renewable Energy system (v) Metering system information (vi) Energy resource. In the “Access and Roles” section below denotes with whom the information is shared with and the level of their actions.

In this case the Actors the data is shared with are: (i) Project leader, (ii) Building user/Building owner, (iii) Design team (energy experts, building services designers) (iv) Public authority (v) Facility manager (vi) Energy auditors. The functionality bar shows that the Design team & Energy auditors are given the highest priority involvement in the task then followed by Project leader and Facility manager, Building user/Building owner and Public authority.

The following products can be developed from the acquired data: BIM model for existing building, Updated BIM model for existing building, Updated MEP BIM model, Kind of intervention and developed tasks, Feasibility studies and assessed options and the required BIM Tools to perform this action is: BIM design tools, BIM integration tools, BIM model viewer and BIM cloud-base application. Finally, the Use cases that can be developed out of this workflow diagram are:

- Calculation to find the design alternatives at conceptual level
- Preliminary energy simulation of the design alternatives
- More detailed energy simulations of the design alternatives
- More detailed simulations of the design alternatives
- To acquire preliminary data from the existing building
- To acquire detailed materials and equipment data from existing building
- Preparation of developed design stage of BIM-model
- Early identification of indoor air quality model parameters

6.2.7. LEAD DESIGNER – ENGINEERS - 2 (CODE: L.D - ENG.)

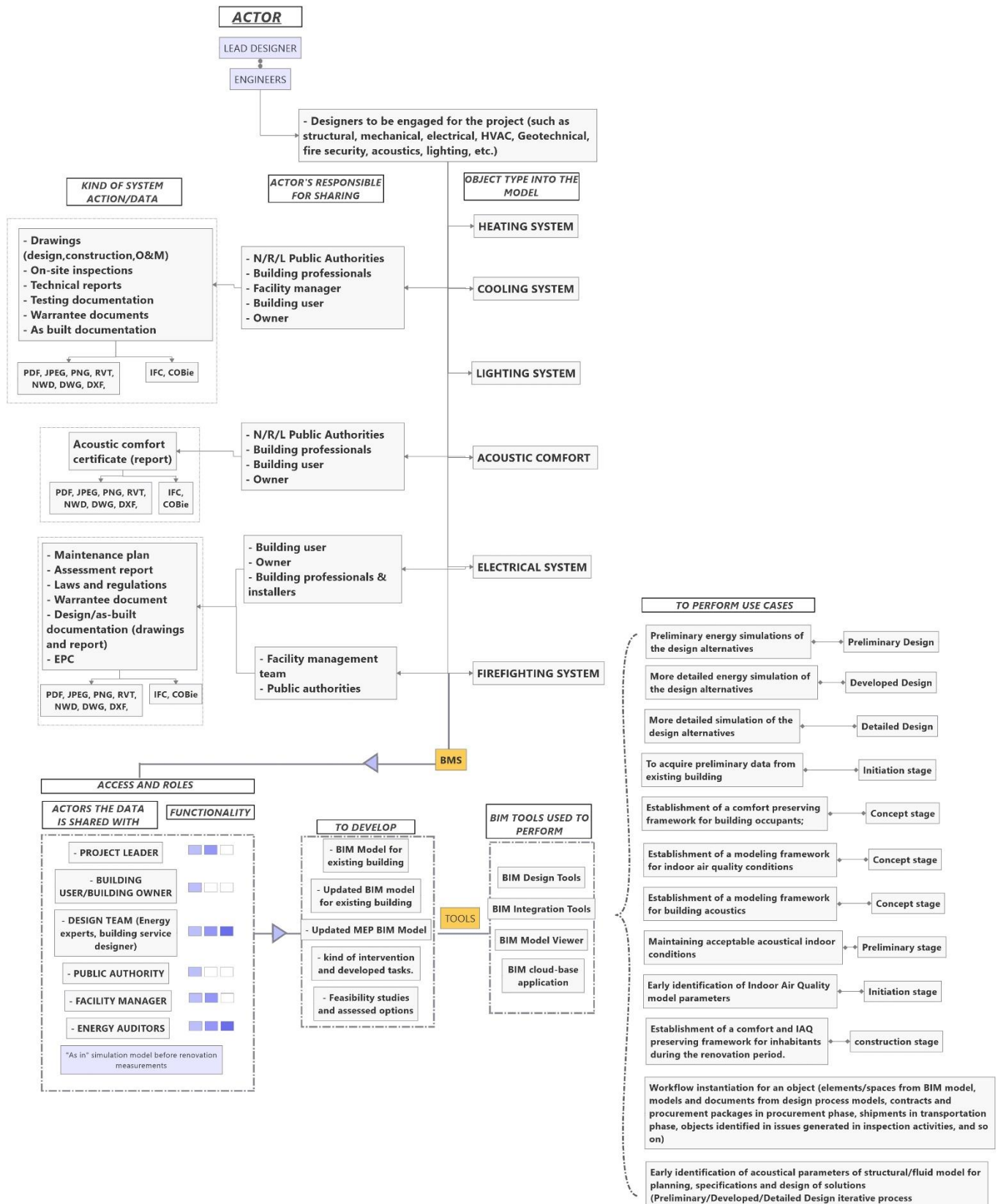


Figure 6.8. Facility management workflow

The above workflow diagram is for the Lead designer – Engineers – 2, the main goal of the workflow is to develop (i) Designers to be engaged for the project (such as structural, mechanical, electrical, HVAC, geotechnical, fire security, acoustics, lighting, etc.) For which the Object types are (i) Heating system (ii) Cooling system (iii) Lighting system (iv) Acoustic comfort (v) Electrical system (vi) Firefighting system. In the “Access and Roles” section below denotes with whom the information is shared with and the level of their actions.

In this case the Actors the data is shared with are: (i) Project leader, (ii) Building user/Building owner, (iii) Design team (energy experts, building services designers) (iv) Public authority (v) Facility manager (vi) Energy auditors. The functionality bar shows that the Design team & Energy auditors are given the highest priority involvement in the task then followed by Project leader and Facility manager, Building user/Building owner and Public authority.

The following products can be developed from the acquired data: BIM model for existing building, Updated BIM model for existing building, Updated MEP BIM model, Kind of intervention and developed tasks, Feasibility studies and assessed options and the required BIM Tools to perform this action are: BIM design tools, BIM integration tools, BIM model viewer and BIM cloud-base application. Finally, the Use cases that can be developed out of this workflow diagram are:

- Preliminary energy simulations of the design alternatives
- More detailed energy simulations of the design alternatives
- More detailed simulation of the design alternatives
- To acquire preliminary data from existing building
- Establishment of a comfort preserving framework for building occupants
- Establishment of a modelling framework for indoor air quality conditions
- Establishment of a modelling framework for building acoustics
- Maintaining acceptable acoustical indoor conditions
- Early identification of indoor air quality model parameters
- Establishment of a comfort and IAQ preserving framework for inhabitants during the renovation period.
- Workflow instantiation for an object (elements/spaces from BIM model, models and documents from design process models, contracts and procurement packages in procurement phase, shipments in transportation phase, objects identified in issues generated in inspection activities, and so on)



- Early identification of acoustical parameters of structural/fluid model for planning, specifications and design of solutions (preliminary/Developed/Detailed design iterative process)

6.2.8. PROJECT LEADER – END USER (CODE: P.L – END USER)

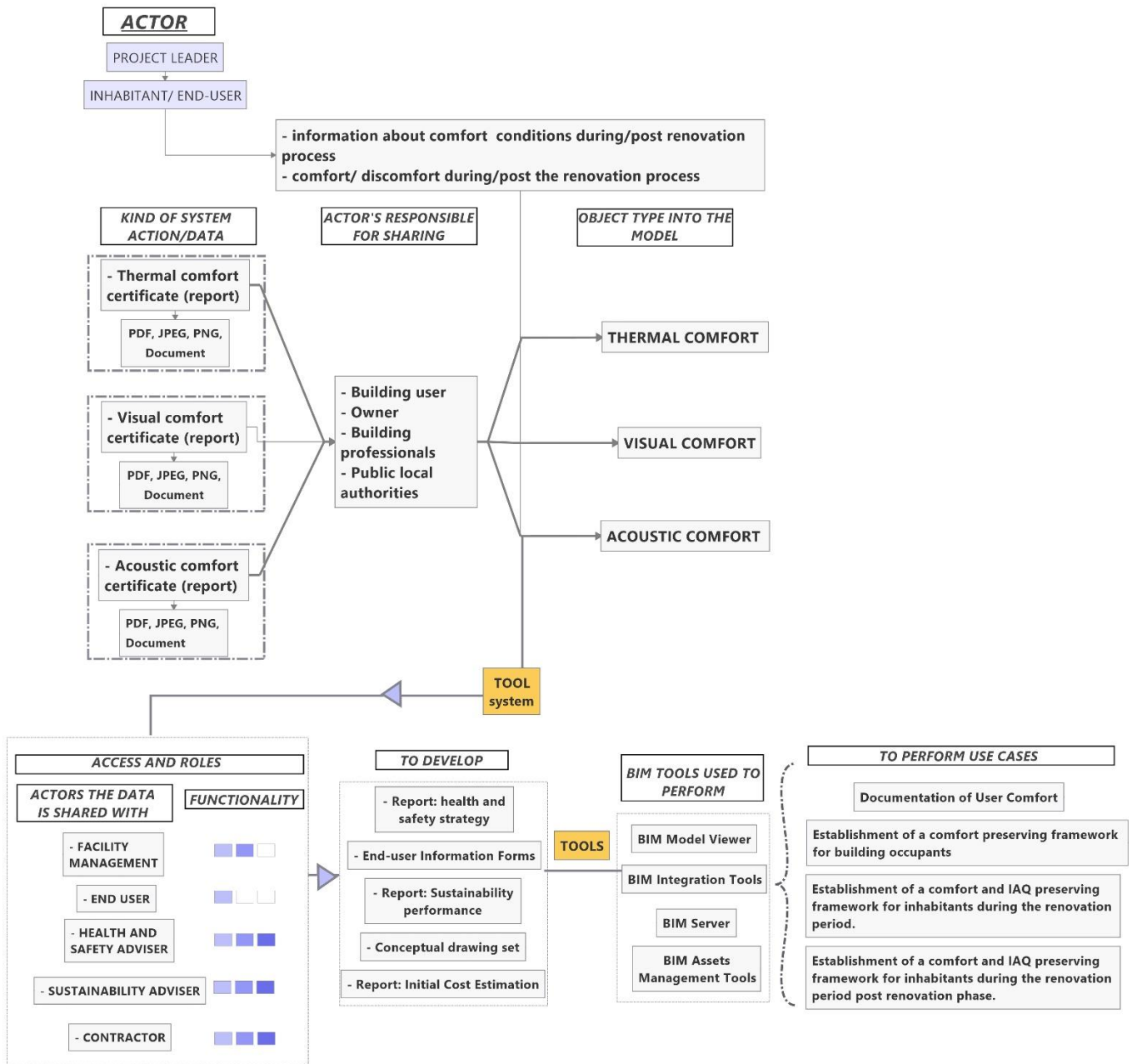


Figure 6.9. Facility management workflow

The above workflow diagram is for the Project leader – End user, the main goal of the workflow is to develop (i) Information about comfort conditions during/post renovation process. (ii) Comfort/ discomfort during/post the renovation process. For which the Object types are (i) Thermal comfort (ii) Visual comfort (iii) Acoustical comfort. In the “Access and Roles” section below denotes with whom the information is shared with and the level of their actions.



In this case the Actors the data is shared with are: (i) Facility management (ii) End user (iii) Health and safety adviser (iv) Sustainability adviser (v) contractor. The functionality bar shows that the Sustainability adviser, Contractor and Health and safety adviser are given the highest priority involvement in the task then followed by the Facility management and End user.

The following products can be developed from the acquired data: Health and safety strategy, End-user information form, Report: Sustainability performance, Conceptual drawing set Report: Initial cost estimation and the required BIM Tools to perform this action are: BIM model viewer, BIM integration tools, BIM server, BIM assets management tools diagram. Finally, the Use cases that can be developed out of this workflow diagram are:

- Documentation of User Comfort
- Establishment of a comfort preserving framework for building occupants
- Establishment of a comfort and IAQ preserving framework for inhabitants during the renovation period
- Establishment of a comfort and IAQ preserving framework for inhabitants during the renovation period post renovation phase

6.2.9. PROJECT LEADER - 1 (CODE: PROJECT LEADER)

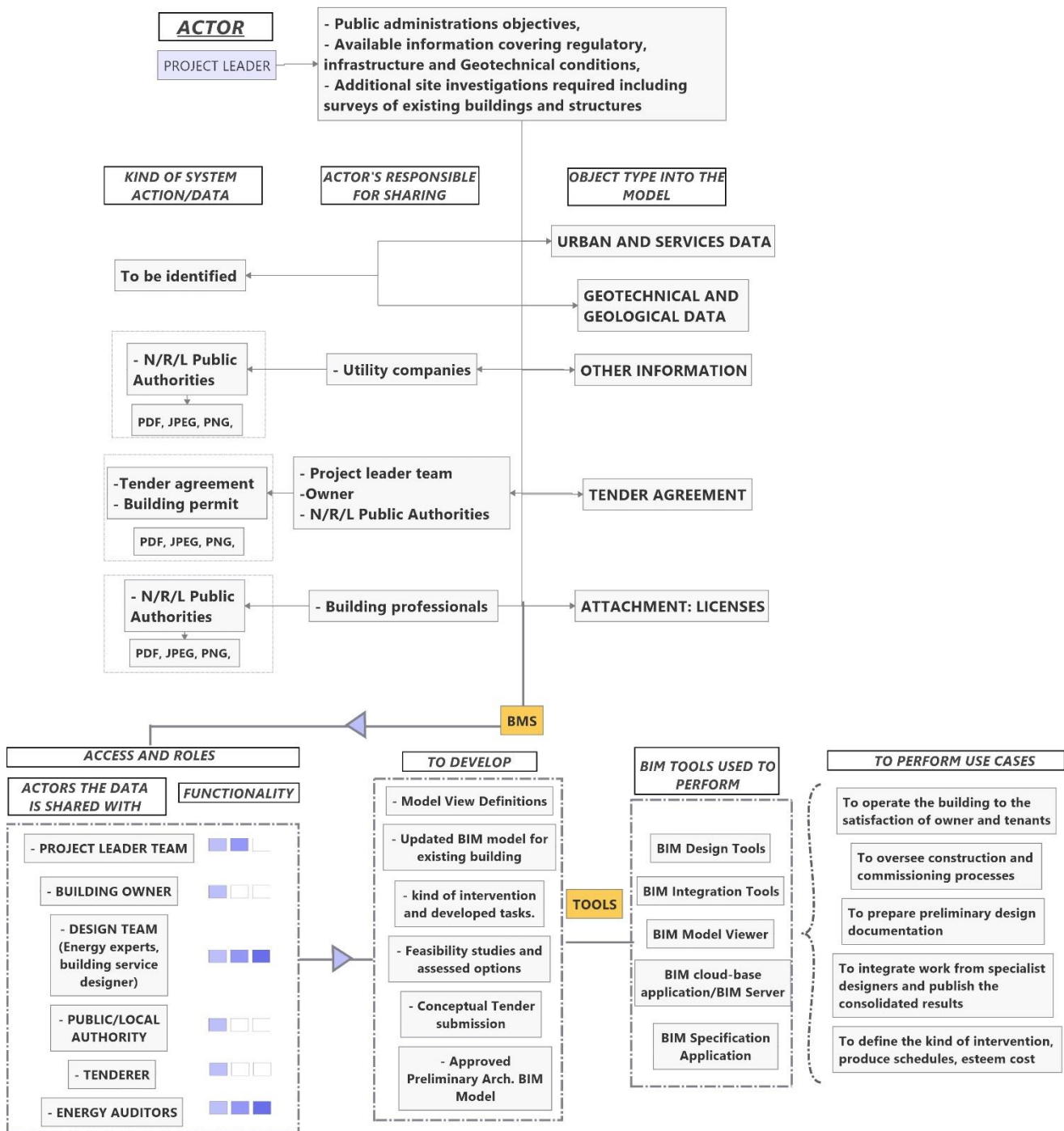


Figure 6.10. Facility management workflow

The above workflow diagram is for the Project leader – 1, the main goal of the workflow is to develop (i) Public administration objectives (ii) Available information covering regulatory, infrastructure and geotechnical conditions (iii) Additional site investigations required including surveys of existing building and structures. For which the Object types are (i) Urban and services data (ii) Geotechnical and geological data (iii) Other information (iv)



Tender agreement (v) attachment: licenses. In the “Access and Roles” section below denotes with whom the information is shared with and the level of their actions.

In this case the Actors the data is shared with are: (i) Project leader team (ii) Building owner (iii) Design team (energy experts, building services designers) (iv) Public/local authority (v) Tenderer (vi) Energy auditors. The functionality bar shows that the Design team & Energy auditors are given the highest priority involvement in the task then followed by the Project leader team, Building owner, Public/local authority & Tenderer.

The following products can be developed from the acquired data: Model View definitions, Updated BIM model for existing building, kind of intervention and developed tasks, Feasibility studies and assessed options, conceptual tender submission and approved preliminary Arch. BIM model and the required BIM Tools to perform this action is: BIM design tools, BIM integration tools, BIM model viewer, BIM cloud-base application/BIM server, BIM specification application. Finally, the Use cases that can be developed out of this workflow diagram are:

- To operate the building to the satisfaction of owner and tenants
- To oversee construction and commissioning processes
- To prepare preliminary design documentation
- To integrate work from specialist designers and publish the consolidated result
- To define the kind of intervention, produce schedules, esteem cost

6.2.10. PROJECT LEADER - 2 (CODE: PROJECT LEADER)

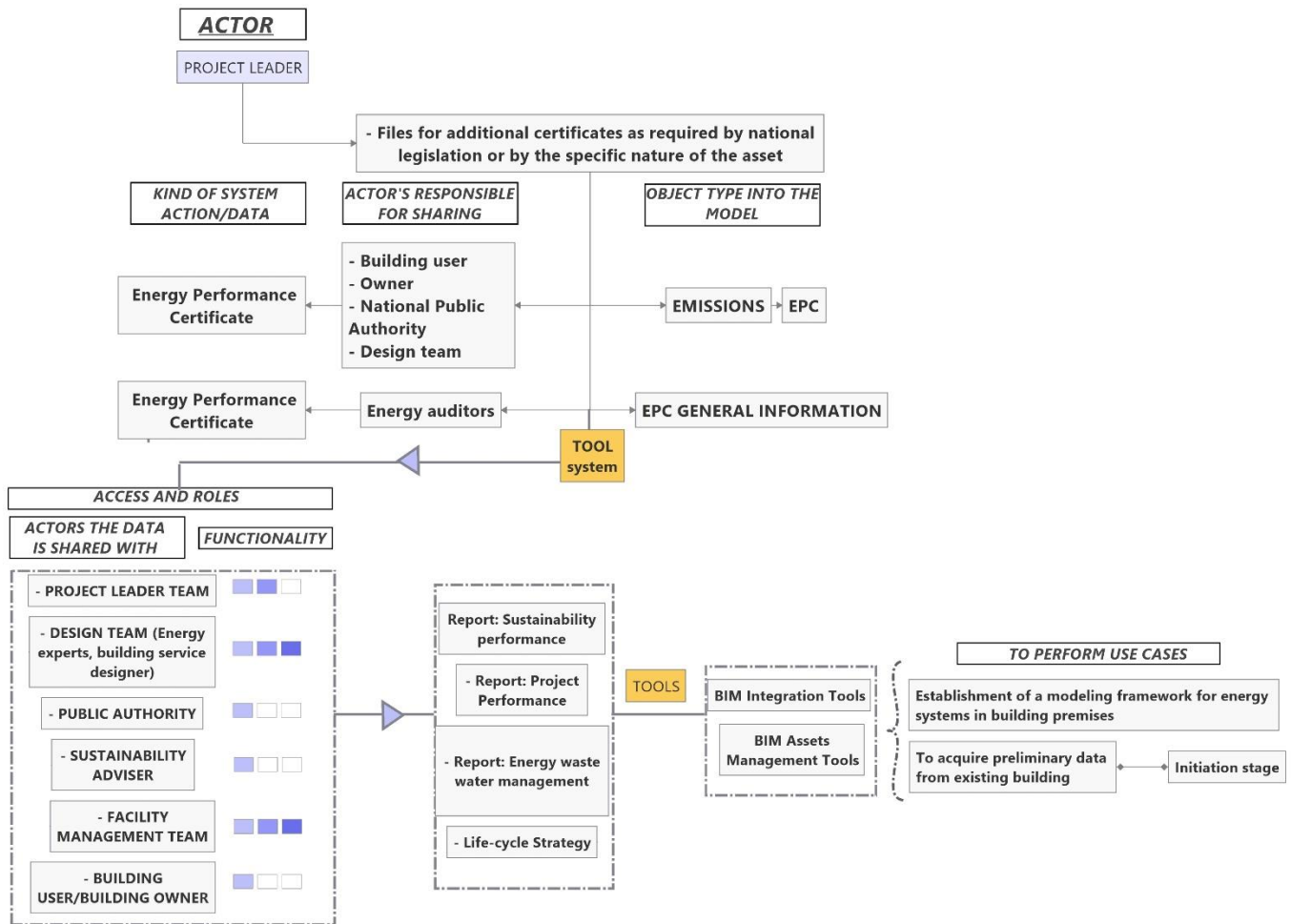


Figure 6.11. Facility management workflow

The above workflow diagram is for the Project leader – 2 , the main goal of the workflow is to develop (i) Files for additional certificates are required by national legislation or by the specific nature of the asset. For which the Object types are (i) Emissions (ii) EPC General information. In the “Access and Roles” section below denotes with whom the information is shared with and the level of their actions.

In this case the Actors the data is shared with are: (i) Project leader team (ii) Design team (energy experts, building services designers) (iii) Public authority (iv) Sustainability adviser (v) Facility management team (vi) Building user/Building owner. The functionality bar shows that the Facility management team & Design team is given the highest priority involvement in the task then followed by the project leader team, Public authority, Sustainability adviser & Building user/Building owner.

The following products can be developed from the acquired data: Report: Sustainability performance, Report: Project performance, Report: Energy waste water management, Lifecycle strategy and the required BIM Tools to perform this action is: BIM Integration tools,



BIM assets Management tools. Finally, the Use cases that can be developed out of this workflow diagram are:

- Establishment of a modelling framework for energy systems in building premises
- To acquire preliminary data from existing building

6.2.11. SITE SURVEYOR – DESIGN TEAM – FACILITY MANAGEMENT (CODE: S.S - D.T – F.M)

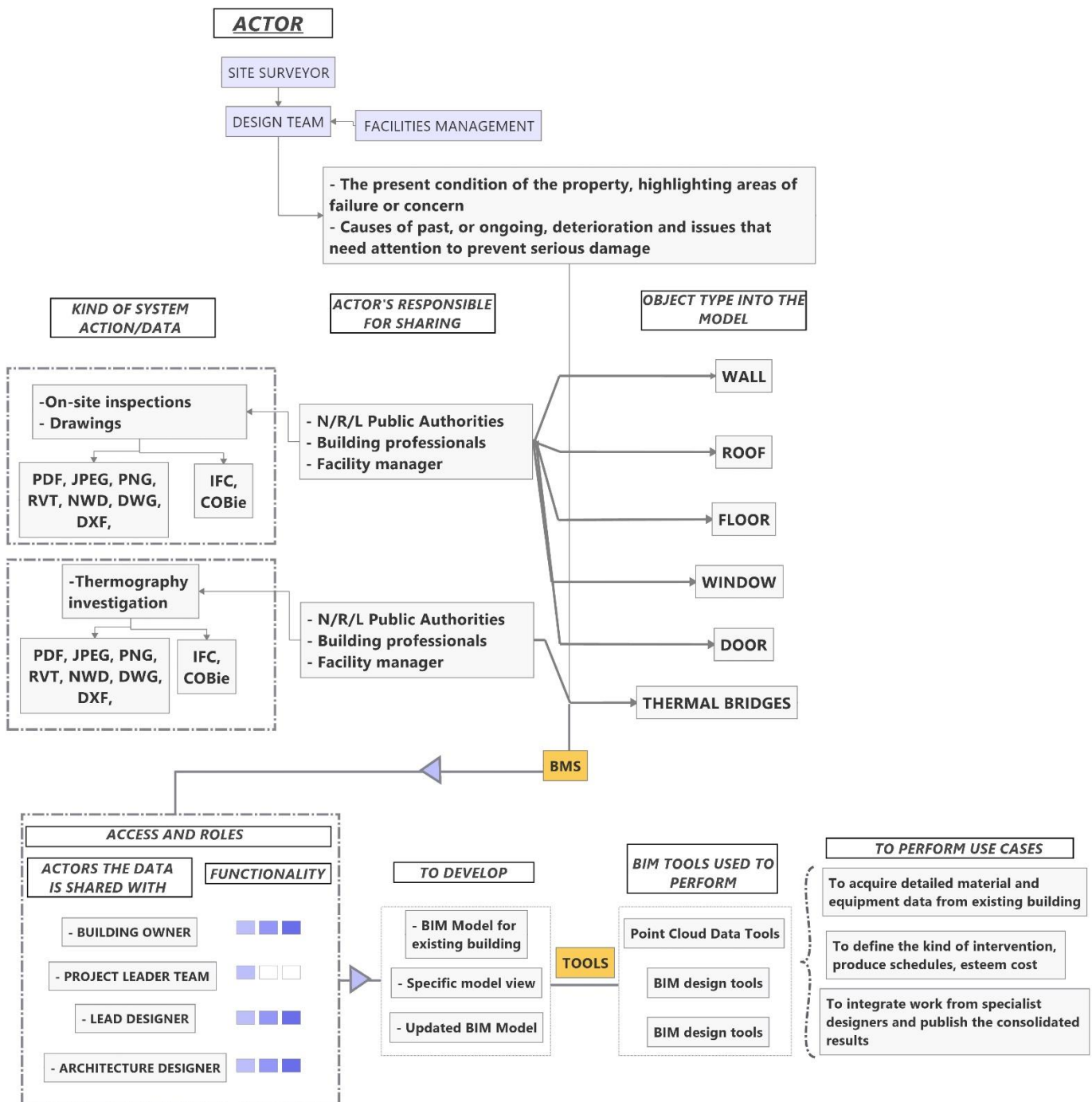


Figure 6.12. Facility management workflow

The above workflow diagram is for the Site surveyor – design team – facility management, the main goal of the workflow is to develop (i) The present condition of the property, highlighting areas of failure or concern (ii) Causes of past, or ongoing, deterioration and issues that need attention to prevent serious damage. For which the Object types are (i) Wall (ii) Roof (iii) Floor (iv) Window (v) Door (vi) Thermal bridges. In the “Access and Roles” section below denotes with whom the information is shared with and the level of their actions.



In this case the Actors the data is shared with are: (i) Building owner, (ii) Project leader team, (iii) Lead designer (iv) Architecture designer. The functionality bar shows that the building owner, Architecture designer & Lead designer are given the highest priority involvement in the task then followed by the Project leader team.

The following products can be developed from the acquired data: BIM model for existing building, Specific model view, Updated BIM model and the required BIM Tools to perform this action are: Point cloud data tools, BIM design tools. Finally, the Use cases that can be developed out of this workflow diagram are:

- To acquire detailed material and equipment data from existing building
- To define the kind of intervention, produce schedules, esteem cost
- To integrate work from specialist designers and publish the consolidated results

6.2.12. SITE SURVEYOR (CODE: SITE SURVEYOR)

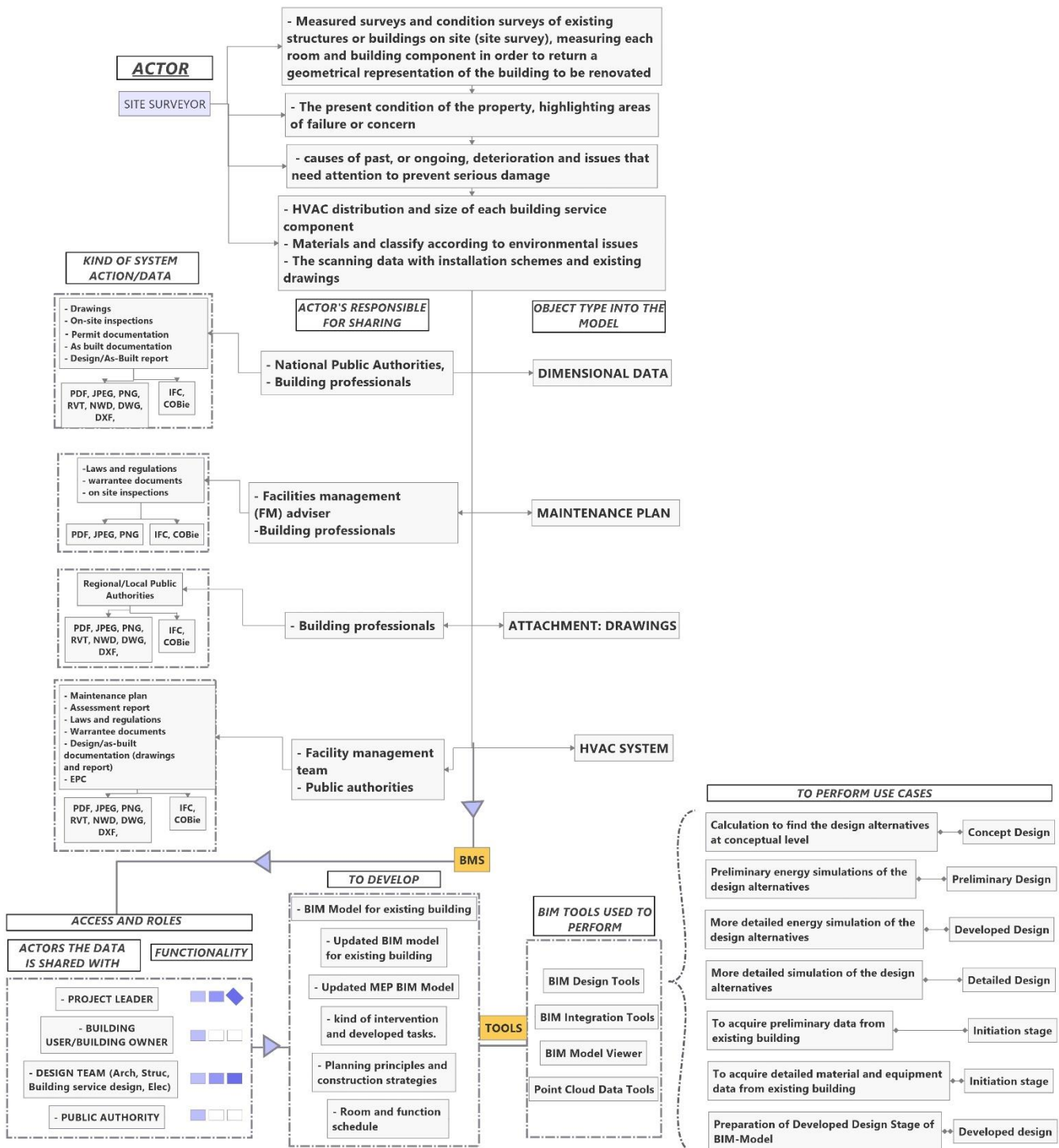


Figure 6.13. Facility management workflow

The above workflow diagram is for the Site surveyor, the main goal of the workflow is to develop (i) Measured surveys and condition surveys of existing structures or building on site (site survey), measuring each room and building component in order to return a geometrical representation of the building to be renovated (ii) The present condition of the property, highlighting areas of failure or concern (iii) Causes of past, or ongoing, deterioration and issues that need attention to prevent serious



damage (iv) HVAC distribution and size of each building service component (v) Materials and classify according to environmental issue (vi) The scanning data with installation scheme and existing drawings. For which the Object types are (i) Dimensional data (ii) Maintenance plan (iii) Attachment: drawing (iv) HVAC system. In the “Access and Roles” section below denotes with whom the information is shared with and the level of their actions.

In this case the Actors the data is shared with are: (i) Project Leader (ii) Building user/Building owner (iii) Design team (Arch, struc, Building service design, Elec) (iv) Public authority. The functionality bar shows that the Project leader & Design team are given the highest priority involvement in the task then followed by the Building user/Building owner & Public authority.

The following products can be developed from the acquired data: Updated BIM model for existing building, Updated MEP BIM model, Kind of intervention and developed task, Planning principles and construction strategies, Room and function schedule and the required BIM Tools to perform this action are: BIM Design tools, BIM integration tools, BIM model viewer and Point cloud data tools. Finally, the Use cases that can be developed out of this workflow diagram are:

- Calculation to find the design alternatives at conceptual level
- Preliminary energy simulations of the design alternatives
- More detailed energy simulations of the design alternatives
- More detailed simulation of the design alternatives
- To acquire preliminary data from existing building
- To acquire detailed material and equipment data from existing building
- Preparations of developed design stage of BIM-model

6.2.13. SUSTAINABILITY ADVISER (CODE: SUST. ADVISER)

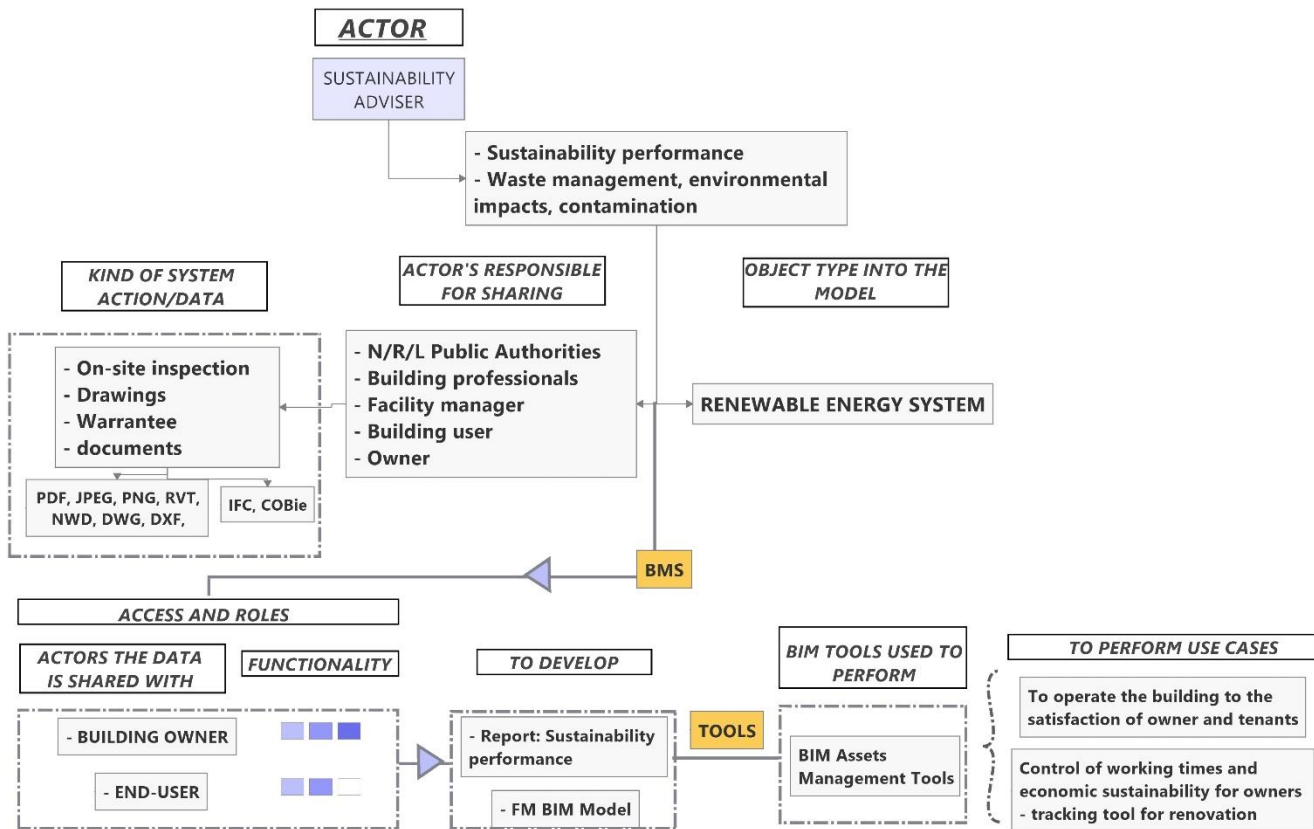


Figure 6.14. Facility management workflow

The above workflow diagram is for the Sustainability adviser, the main goal of the workflow is to develop (i) Sustainability performance (ii) Waste management, environmental impacts, contamination. For which the Object types are (i) Renewable energy system. In the “Access and Roles” section below denotes with whom the information is shared with and the level of their actions.

In this case the Actors the data is shared with are: (i) Building owner (ii) End user. The functionality bar shows that the building owner is given the highest priority involvement in the task then followed by the end user.

The following products can be developed from the acquired data: Report: Sustainability performance, FM BIM model and the required BIM Tools to perform this action is: BIM asset management Tools. Finally, the Use cases that can be developed out of this workflow diagram are:

- To operate the building to the satisfaction of owner and tenants
- Control of working times and economic sustainability for owners
- Tracking tool for renovation

6.2.14. TENDERER (CODE: TENDERER)

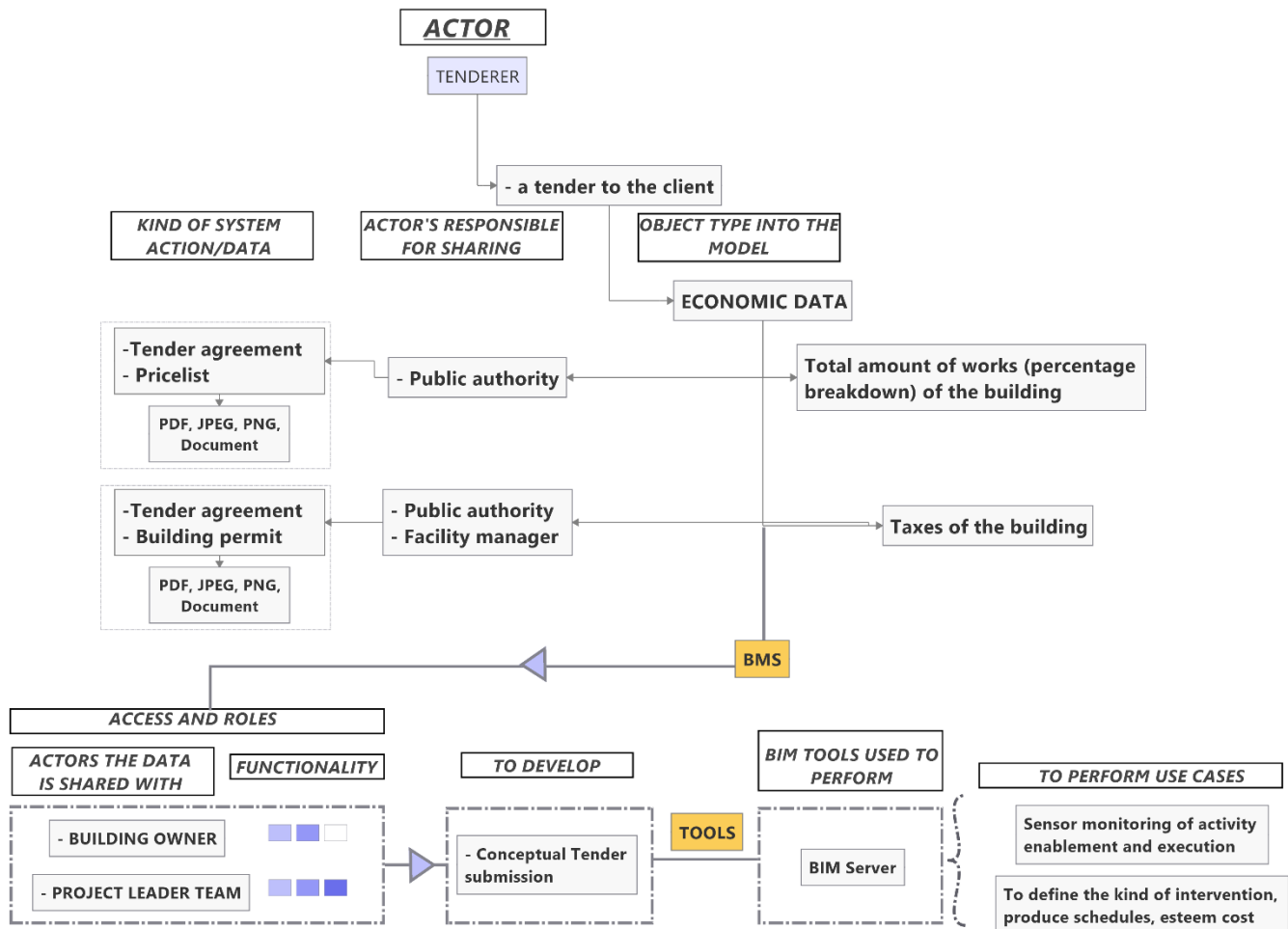


Figure 6.15. Facility management workflow

The above workflow diagram is for the Tenderer, the main goal of the workflow is to develop (i) A tender to the client. For which the Object types are (i) Economic data (ii) Total amount of works (percentage breakdown) of the building (iii) Taxes of the building. In the “Access and Roles” section below denotes with whom the information is shared with and the level of their actions.

In this case the Actors the data is shared with are: (i) Building owner (ii) project leader. The functionality bar shows that the Project leader is given the highest priority involvement in the task then followed by the Building owner.

The following products can be developed from the acquired data: Conceptual tender submission and the required BIM Tools to perform this action is: BIM server. Finally, the Use cases that can be developed out of this workflow diagram are:

- Sensor monitoring of activity enablement and execution
- To define the kind of intervention, produce schedules, esteem cost

6.3. USE-CASE MATRIX TABLE

The Use-case matrix is the final table with the list of Use-cases which gives an idea about the how to perform the Use-cases with the above developed Use Profile-Use case workflow diagrams. These Use-Cases are listed from the BIM4EEB project time and has been analysed further. From the Use-case matrix table, the related workflow has to be combined for the particular case to arrive at the final Use-case matrix which can be considered as the future scope of work which is explained in more detail in the next section.

The following are the 4 developed table for the Use-case matrix:

6.3.1. Use cases to specify better the information requirements

No.	USE CASES	USER PROFILE	SITE SURVEYOR	TENDERER	SUST. ADVISER	FACILITY MANAG.	L.D - ENG.	S.S - D.T - F.M	F.M - D.T - E.A	PROJECT LEADER	C.O - C.A	BANK/FI-NANCE	P.L - END USER	CONTR. - E.U
	Use cases to specify better the information requirements													
1	Initiation: Renovation project initiation													
2	Concept Design: Quick calculation to find the design alternatives at conceptual level		X				X		X					
3	Preliminary Design: Preliminary energy simulations of the design alternatives		X				X							X
4	Developed Design: More detailed energy simulation of the design alternatives		X				X							X
5	Detailed Design: More detailed simulation of the design alternatives		X				X							X
6	Construction: Implementation of the planned renovation measures													
7	Building Use: Operation and maintenance of the renovated building													
8	End of Life: Demolition and recycling of the renovated building													

Table 6.1. Use cases to specify better the information requirements

The above listed Use-case matrix must is for a better information requirement about the project in generic. The Workflow achieved in the above section helps in developing 4 Use cases from the above table, which are:

Use-cases	Workflow
1) Concept Design: Quick calculation to find the design alternatives at conceptual level	1) Site Surveyor 2) Lead designer – Engineer 3) Facility management - Design team – Energy Auditors
2) Preliminary Design: Preliminary energy simulations of the design alternatives	1) Site Surveyor 2) Lead designer – Engineer 3) Contractor – End-User
3) Developed Design: More detailed energy simulation of the design alternatives	1) Site Surveyor 2) Lead designer – Engineer 3) Contractor – End-User

4) Detailed Design: More detailed simulation of the design alternatives	1) Site Surveyor 2) Lead designer – Engineer 3) Contractor – End-User
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6.3.2. Use cases from the building owners and inhabitant’s point of view

No.	USE CASES	USER PROFILE	SITE SURVEYOR	TENDERER	SUST. ADVISER	FACILITIES MANAG.	L.D - ENG.	S.S - D.T - F.M	F.M - D.T - E.A	PROJECT LEADER	C.O - C.A	BANK/FI-NANCE	P.L - END USER	CONTR. - E.U
No.	Use cases from the building owners and inhabitant’s viewpoint													
1	Establishment of a comfort and IAQ preserving framework for inhabitants during the renovation period						X						X	
2	Establishment of a comfort and IAQ preserving framework for inhabitants during the renovation period post renovation phase												X	
3	A continuous interaction framework for comfort status monitoring and report for inhabitants													X
4	An alerts and notification framework during the renovation process for owners and inhabitants													
5	Management and control of renovation interventions for owners										X	X		
6	Control of working times and economic sustainability for owners - tracking tool for renovation				X						X	X		

Table 6.2. Use cases from the building owners and inhabitant’s point of view

The above listed Use-case matrix is for building owners and inhabitant’s point of view. From the Workflow achieved in the above section helps in developing 5 Use cases from the above table, which are:

Use-cases	Workflow
1) Establishment of a comfort and IAQ preserving framework for inhabitants during the renovation period	1) Lead designer – Engineer 2) Project leader – End -User
2) Establishment of a comfort and IAQ preserving framework for inhabitants during the renovation period post renovation phase	1) Project leader – End -User
3) A continuous interaction framework for comfort status monitoring and report for inhabitants	1) Contractor – End-User
4) Management and control of renovation interventions for owners	1) Client owner – Client adviser 2) Bank/Third party finance

<p>5) Control of working times and economic sustainability for owners - tracking tool for renovation</p>	<p>1) Sustainability adviser 2) Client owner – Client adviser 3) Bank/Third party finance</p>
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6.3.3. Additional Use cases

No.	USER PROFILE USE CASES	SITE SURVEYOR	TENDERER	SUST. ADVISER	FACILITY MANAG.	L.D - ENG.	S.S - D.T - F.M	F.M - D.T - E.A	PROJECT LEADER	C.O - C.A	BANK/FI-NANCE	P.L - END USER	CONTR. - E.U
Additional User cases													
1	Sensor monitoring of activity enablement and execution		X										
2	Workflow instantiation for an object (elements/spaces from BIM model, models and documents from design process models, contracts and procurement packages in procurement phase, shipments in transportation phase, objects identified in issues generated in inspection activities, and so on)					X							
3	To acquire preliminary data from existing building	X				X			X				X
4	To acquire detailed material and equipment data from existing building	X				X	X						
5	To define the kind of intervention, produce schedules, estimate cost		X				X		X	X	X		
6	To integrate work from specialist designers and publish the consolidated results						X		X				
7	To prepare preliminary design documentation								X				
8	Preparation of Developed Design Stage of BIM-Model	X				X		X					
9	Preparation of Detailed Design Stage of BIM-Model							X	X				
10	To oversee construction and commissioning processes								X				
11	To operate the building to the satisfaction of owner and tenants			X									
12	Preparation of End-of-Live BIM-Model				X								
13	Early identification of Indoor Air Quality model parameters					X							
14	Establishment of a health/IAQ environment during the renovation process - Renovation tasks/ processes to address IAQ standards												
15	Establishment of a IAQ preserving framework post renovation process												
16	Early identification of desired performance of acoustical properties for setting requirements (Concept design)												
17	Early identification of acoustical parameters of structural/fluid model for planning, specifications and design of solutions (Preliminary/Developed/Detailed Design iterative process)					X							
18	Implementation of solutions of importance for the acoustic performance during the construction phases												
19	Maintaining acceptable acoustical indoor conditions					X							
20	Documentation of User Comfort				X							X	
21	Documentation of System Usage				X								
22	Documentation Energy Consumption				X			X					
23	Documentation of occupation density												

Table 6.3. Additional use cases

The above listed Use-case matrix are additional use-cases for the better information requirement about the project in generic. The Workflow achieved in the above section helps in developing 18 Use cases from the above table, which are:

Use-cases	Workflow
1) Sensor monitoring of activity enablement and execution	1) Tenderer
2) Workflow instantiation for an object (elements/spaces from BIM model, models and documents from design process models, contracts and procurement packages in procurement phase, shipments in transportation phase, objects identified in issues generated in inspection activities, and so on)	1) Lead designer - Engineer
3) To acquire preliminary data from existing building	1) Site Surveyor 2) Lead designer - Engineer 3) Project leader 4) Contractor – End-User
4) To acquire detailed material and equipment data from existing building	1) Site Surveyor 2) Lead designer - Engineer 3) Site Surveyor - Design team – Facility management
5) To define the kind of intervention, produce schedules, esteem cost	1) Tenderer 2) Site Surveyor - Design team – Facility management 3) Project leader 4) Client owner – Client adviser 5) Bank/Third party finance
6) To integrate work from specialist designers and publish the consolidated results	1) Site Surveyor - Design team Facility management 2) Project leader
7) To prepare preliminary design documentation	1) Project leader



8) Preparation of Developed Design Stage of BIM-Model	<ul style="list-style-type: none"> 1) Site Surveyor 2) Lead designer – Engineer 3) Facility management – Design team – Energy audit
9) Preparation of Detailed Design Stage of BIM-Model	<ul style="list-style-type: none"> 1) Facility management – Design team – Energy audit 2) Project leader
10) To oversee construction and commissioning processes	<ul style="list-style-type: none"> 1) Project leader
11) To operate the building to the satisfaction of owner and tenants	<ul style="list-style-type: none"> 1) Sustainability adviser
12) Preparation of End-of-Live BIM-Model	<ul style="list-style-type: none"> 1) Facility management
13) Early identification of Indoor Air Quality model parameters	<ul style="list-style-type: none"> 1) Lead designer – Engineer
14) Early identification of acoustical parameters of structural/fluid model for planning, specifications and design of solutions (Preliminary/Developed/Detailed Design iterative process	<ul style="list-style-type: none"> 1) Lead designer – Engineer
15) Maintaining acceptable acoustical indoor conditions	<ul style="list-style-type: none"> 1) Lead designer – Engineer
16) Documentation of User Comfort	<ul style="list-style-type: none"> 1) Facility management 2) Project leader – End User
17) Documentation of System Usage	<ul style="list-style-type: none"> 1) Facility management
18) Documentation Energy Consumption	<ul style="list-style-type: none"> 1) Facility management 2) Facility management – Design team – Energy audit

6.3.4. Use cases related to occupants

No.	USE CASES	USER PROFILE												
		SITE SURVEYOR	TENDERER	SUST. ADVISER	FACILITIES MANAG.	L.D - ENG.	S.S - D.T - F.M	F.M - D.T - E.A	PROJECT LEADER	C.O - C.A	BANK/FI-NANCE	P.L - END USER	CONTR. - E.U	
	Use cases related to occupants													
1	Establishment of a comfort preserving framework for building occupants					X							X	
2	Establishment of a modeling framework for building materials/ equipment													
3	Establishment of a modeling framework for energy systems in building premises							X						
4	Establishment of a modeling framework for indoor air quality conditions					X								
5	Establishment of a modeling framework for building acoustics					X								

Table 6.4. Additional use cases

The above listed Use-case matrix is related to occupants. From the Workflow achieved in the above section helps in developing 4 Use cases from the above table, which are:

Use-cases	Workflow
1) Establishment of a comfort preserving framework for building occupants	1) Lead designer – Engineer 2) Project leader – End -User
2) Establishment of a modelling framework for energy systems in building premises	1) Facility management - Design team – Energy Auditors
3) Establishment of a modelling framework for indoor air quality conditions	1) Lead designer – Engineer
4) Establishment of a modelling framework for building acoustics	1) Lead designer – Engineer



CHAPTER 7

DISCUSSION & CONCLUSION

7. DISCUSSION & CONCLUSION

7.1. FINAL DISCUSSION

7.1.1. Group of stakeholders and their priority for accessing BMS

After analysis all activities of renovation in building in case of private works, the actors related with respect to works are segregated into 7 main groups, which are strongly related to each other and have different priority for accessing the BMS of the project, discussed and rated as below:

Decision maker

Client / Owner is the prime actor in the whole process. The actor can be a person or a company. They appear in all stages of the work, from very first one – initiative to the end-of-life stage. The actor is responsible for important decisions relating to the implementation of the project, the business plan for renovation, approval for all design as well as organising the communication between participants in the project before appointing a Project Leader. However, their involvement and accessing into BIM management system is slender, the actor receives the information from other groups by a simple model viewer and examines & takes decision accordingly with the support of Project Management Team and another Client/Owner Consultant Team.

Priority for accessing the BMS: 1/3

Client / Owner Consultant Team

Client/Owner Consultant Team is a group of specialists, consultant who advises directly to the Decision Maker group. In fact, Client/Owner in private sector business plan works very well, which can be profitable or non-profitable. Hence, they need a distinctive consultant about financing, and communication, which is Client Adviser and Information Manager for the analysis. Usually, the information is directly from the Client/Owner, and Project Management Team through a simple model viewer, thereafter it is analysed and a feedback as a report is handed over to the Client/Owner.

Priority for accessing the BMS: 1/3

Project Management Team

Project Leader is another key actor in the whole renovation process, which can be an individual or a team according to the scale of renovation project. Hence, the project management team is in charge of managing and ensuring the projects wellness under the decision of Client/Owner. For managing the work, Project Management Team needs to embody with all other participants including Design Team/Consultant Team and Construction Team. In summary, the PM team avails the highest priority and full access for the BMS to get the information, distribution of the information and changes directly into the system.

Priority for accessing the BMS: 3/3

Information Provider

Information Provider here is the Inhabitant/End-user, is the one who lives in the renovated building. In the initial stages of the project, this group provides all the relevant and fundamental

information to the Client/Owner to take decision about initiating the renovation process. In the later stage during construction, this group provides with the feedback data for the contractor and other consultant to examine their works. The Inhabitant/End-user is essential to take their feedback as the renovation process affects directly to their living conditions. And, they need to be involved into the BMS for feedback data, information providing; but not of a much priority for accessing the system

Priority for accessing the BMS: 1/3

Design Team / Consultant

Design Team / Consultant is an important group in the renovation workflow. It consists of many specialist and consultant under the leading of Lead Designer such as Architectural Designer and other Specialist Consultant. They are the key players in design stages from concept design, preliminary design, developed design till detail design. They have to be assigned with higher priority for accessing the BMS from initial stage of the project starting from creating, editing, managing and updating their work, also in collaborating with other participants. The Project Management Team with the Design Team / Consultant needs a detailed organisation chart and BIM execution plan from the beginning of the project.

Priority for accessing the BMS: 2/3

Construction Team

In the later stage of design process, the Construction Team joins the workflow under the direction of Project Management Team. As a key player in the construction stage, the team manages and coordinates most of the works on site as well as developing the BIM Construction Model, which is the preliminary model for the final As-built BIM model and Facility Management BIM model for later stages of renovation process. However, the team consist of Contractor, Construction Administrator, Health and Safety Adviser and other Engineers as well. They have to be assigned a high priority to access the BMS system from their stage of works.

Priority for accessing the BMS: 2/3

Consultant Team

Consultant Team perform in the later stage of the project, when the construction work is done. They are mostly Facility Management Adviser, Technical Adviser, Sustainability Adviser and Health & Safety Adviser. Their main responsibility is to check the performance of the building after renovation and ensure the operation and maintenance work as well. Their decision is very important for later stage of the project such as Use and End-of-Life; hence, they need to guarantee a high priority for accessing into the BMS, especially in later stages of the project.

Priority for accessing the BMS: 2/3

Government

Government group here is the Local Authority, who approves the design for the renovation project to meet the ongoing building regulation and building performance. They work directly with the Client/Owner and Project Management Team with a simple BIM model viewer to review the project and later with feedbacks to changes and updates to be in cooperated in the project work. Hence, they only need the data from the BIM model, and not to access the BMS system.

Priority for accessing the BMS: 0/3

Conclusion

It is necessary to build a user's profile for each stakeholder, based on the information they need and the information they generate into the BMS. This user's profile should define the priority as well as function of the stakeholder as general in any renovation project for its scalability to all kind of renovation intervention.

7.1.2. Information workflow and the BIM involvement into activities of the renovation works

From step 2 of the analysis for renovation in building in case of private works, there are in total 13 BIM Tool category related to all the activities. The use of these BIM Tool category depends on the stage accordingly, the stakeholder and tasks in each of the stage. The conclusion about the BIM tools involvement to each stage of renovation work is as following:

Stage 1: Initiative (INVE)

In this stage, the existing building is analysed based on the feedback and information provided by the Inhabitant/End-user. Most of the buildings nowadays in Europe has been built a long time ago, and there was no computer-aided management system during that point of time. Hence, the documentation for operating and maintenance of the building itself is incomplete or outdated due to several renovation work before.

There are 2 types of operational work available now. The first one is the traditional method with drawing in paper, traditional communication through email, phone calls as well. For this case, there is a need of BMS system or BIM-based toolkit to collect the information from Inhabitant/End-user to be developed, sending this information to the Client/Owner, and providing support for Owner itself to make renovation intervention.

The second one is updated method. The building itself may have a facility management team, which can be individual or a group of people, managing, operating and do the maintenance work through an application. This facility management tool can be BIM-based or not. For this case, there is a need of implementing a BIM-based tool as a BMS providing the accessing for Inhabitant/End-user to submit the information about building failure through a user-friendly model viewer of the building.

Based on the analysis for the BIM involvement, the BIM-based FM tools needs a specific user interface for new user, who never uses BIM model viewer before to submit their information, and another user interface for the Owner or Facility Management Team to control, manage and summary the information from the Inhabitant to help themselves make decision to start the renovation works. There are 2 type of BIM tool category need for this stage, which are BIM model viewer and BIM Facility Management Tools.

Stage 2: Initiation (INON)

In this stage, after the decision of the Owner for implementing renovation intervention, the most important thing is quick capturing the existing building to prepare documents for early cost estimation, a financial plan for project funding, and necessary feasibility analysis to early determine

the renovation method for the building. In this stage, the most important role is the Site Surveyor for quick capturing the building, and the Project Leader for managing and collating all information.

Hence, there are many BIM Category Tools needed in this stage:

Point Cloud Data Tool for site investigation and geometrical data, which generate first point-cloud data of existing BIM model.

BIM Design Tools for updating the existing BIM model and combining with the MEP BIM model of the building after site surveying. In addition, the feasibility study, room and function schedule can be implemented in this BIM Tool Category with some necessary add-on.

- BIM Integration Tools for doing the feasibility study as well, and to analyse the kind of intervention for the renovation process.
- BIM Cost Estimation Tools for early estimate the budget requirement with the cost and time report.
- BIM Model Viewer to show the result for Consultants, Client/Owner and Client Adviser to make decision and prepare necessary advice
- BIM Cloud / Server to maintain the collaboration and sharing between stakeholders.
- BIM Model Checker to guarantee that all BIM model is under aspirations check as well as to get approved for the early building permit and regulation.

Otherwise, in some case, the renovation is small intervention, or the building is simple and small, the site surveying work can be done by traditional way with measurement tools and creating BIM modelling directly on BIM design tools.

Stage 3: Concept Design (CD)

In the concept design stage, the design team is getting involved into the project through the BIM Design Tools, BIM Integration Tools and BIM Cost Estimation. The BIM Model Viewer is used to submit the work to the Client/Owner to make important decision on implementing the project, to transfer the data to the Local Authority for the building permit assessment.

The most important goals in this stage is developing a Conceptual BIM modelling of the building from the existing BIM model from previous stage, which have enough information to get the initial cost estimation, tender data and early defines the program dates as well as the construction strategy options, health and safety strategy.

Otherwise, the BIM Cloud/Server need to be revised by the Information Manager to expand the sharing and collaboration ability.

Stage 4: Preliminary Design (PD)

In this stage, like the Concept Design, the BIM model is developed into Preliminary BIM model, which can generate the graphic presentation, drawing sets and define technical documentation. After that, it is submitted to the Local Authority for approval to implement the following procedures such as developing Tender document, have a construction schedule in phases, and providing necessary information in detail for building documentation.

The BIM Cloud/Sever also needs to be revised and updated to maintain the collaboration and sharing ability among participated stakeholders.

There are 6 BIM Category related to this stage, they are: BIM Model Viewer, BIM Design Tools, BIM Integration Tools, BIM Cloud Base Application, BIM Model Checker and BIM Specification Application.

Stage 5: Develop Design (DPD)

Then, from the Preliminary Design, with the feedback from Local Authority, the BIM model is updated to the Developed BIM Model, which now provide most of the information for the tendering, health and safety, construction schedule, construction strategy process.

The BIM Cloud/Server is again updated to maintain the collaboration, since there are many stakeholders involved from this stage. The BIM Tools Category is the same as preliminary design.

Stage 6: Detail Design (DD)

After the building permit is issued, the project team developing the model into Detail BIM Model, which have all information required for construction process, and handover and commissioning strategy. The most important goals of this stage is producing a good detail documentation about the building, checking carefully all of the BIM model to ensure there is no error in the construction process, preparing all specification document, technical document for the Contractor as well as added required documents for approval from Local Authority.

The BIM Cloud/Server is revised and updated for the last time to maintain the collaboration and sharing.

Stage 7: Construction (CON)

The construction team get involved mainly in this stage, from Detail BIM model, Construction BIM model is developed, which update all information in the construction site based on the construction schedule. After that, Project Leader collates the necessary information, collaborate with Contractor to generate the As-built BIM model, which contains all data, objects in the building after renovation.

In addition to 6 main BIM Tools category in the design stage, there are some special BIM Tools are used in this stage, which are BIM Surveying Site Conditions, BIM Tools for Planning and Control.

Stage 8: Use (USE)

In this stage, from As-built BIM Model, Project Leader collates the necessary data for the operation and maintenance works to create the Facility Management BIM Model. Meanwhile, the Consultant Team assess the building with the feedback from Inhabitant/End-user to perform the report related to the performance and sustainability of the building.

Therefore, the renovation work will start again if building failure happens, or the audit for end-of-life with demolition and rehabilitation strategy is decided. There are 3 BIM Tools Category appeared in this stage including BIM Asset Management, BIM Design Tools and BIM Integration Tools

Stage 9: End-of-Life (EOL)

For scheduling the work of revamping and dismantling the building, BIM Integration Tools is the most important category in this stage to make sure that the building is dismantled in corrected way.

Conclusion

There are totally 11 BIM Category Tools involved into the renovation works. The table below describes how BIM Tools Category is used in the renovation stages:

Table 7.1. BIM Tools Category used in renovation stages

BIM Tools \ Stage	INVE	INON	CD	PD	DPD	DD	CON	USE	EOL
Model Viewer	X	X							
Asset Management	X					X		X	
Point Cloud Data		X							
Design Tools		X	X	X	X	X	X	X	
Integration Tools		X	X	X	X	X	X	X	X
Cost Estimation		X	X	X	X	X			
Cloud/Server		X	X	X	X	X	X		
Model Checker		X	X	X	X	X	X		
Spec. Application			X	X	X	X	X		
4D Capability							X		
Surveying Site							X		
Planning & Control							X		

Based on BIM platform available in the market, the table below shows some BIM-based tool and add-on can be used now by 2 general BIM software provider:

Table 7.2. BIM Tools available in the market by Autodesk and Bentley

BIM Tools \ Platform	Autodesk	Bentley
Model Viewer	Autodesk BIM 360 Glue	Bentley View
Asset Management	Autodesk Building Operations	Bentley Facilities
Point Cloud Data	Autodesk Recap	Bentley ContextCapture
Design Tools	Autodesk Revit	Bentley OpenBuilding
Integration Tools	Autodesk Naviswork Manage	Bentley ProjectWise Integration

Cost Estimation	Innovaya (Revit add-on)	Bentley AECOSim
Cloud/Server	Autodesk BIM 360	Bentley ProjectWise
Model Checker	Autodesk Naviswork Manage	Bentley Navigator
Spec. Application	Speblink.e (Revit add-on)	N/A
4D Capability	Autodesk Naviswork Manage	Bentley ConstructSim
Surveying Site	Autodesk Recap	Bentley ContextCapture

Besides the BIM Tools available in the market, there are many activities of the renovation process which needs a tool to implement well enough, especially the facility management tool to get the feedback from Inhabitant. It is of great benefit if the BIM Asset management tool can be involved from early stage of the project to get the leaning and fast method of collaboration between all stakeholders.

7.1.3. User's profiles for accessing the BIM management system

After analysing the activities of renovation in building in case of private works, there are totally 18 user's profile is summary for all stakeholder that have BIM involved into their tasks. This user's profiles are defined in perspective of function, priority and information workflow in the previous chapter, section 5.3. However, based on their role and responsibility, 18 related stakeholders can be divided into 4 groups: designers & architects, construction company, services company and occupants. The list of stakeholders in each group to determine a group of user's profiles is in the table below:

Table 7.3. User's profiles divided into 4 groups

Designers & Architects	Construction Company	Services Company	Occupants
Project Leader Lead Designer Architectural Designer Engineer Quantity Surveyor Public Works Work Supervisor	Contactora Tenderer H&S Adviser Contract Administrator Public Works Local Authority Sub-Contractor	Client Adviser Site Surveyor Information Manager Sustainability Adviser Technical Adviser FM Adviser Bank or Financier Public Works Tester	Client/Owner Inhabitant/End-user

In detail, the priority and function of the user's profiles is divided into 3 categories, which are:

- Category I: view, feedback, make decision
- Category II: view, feedback, make decision, review, editing
- Category III: full access

Then, based on the group of user's profiles, to log in the BMS, the detail priority by category for each stakeholder, for each BIM Tools under the BMS is described as below tables:

Table 7.4. User's profile priority and functionality for Designers & Architects group

BIM Tools \ Stage	Project Leader	Lead Designer	Architect Designer	Engineer	Quantity Surveyor	Work Supervisor
Model Viewer	II		III			
Asset Management	III					
Point Cloud Data						
Design Tools	III	III	III	III		II
Integration Tools	III	I				II
Cost Estimation	II		III		II	
Cloud/Server	I	II				
Model Checker	II	I				II
Spec. Application	III		III	III		
4D Capability	II					
Surveying Site	II					II
Planning & Control	I					I

Table 7.5. User's profile priority and functionality for Construction Company group

BIM Tools \ Stage	Contractor	Tenderer	H&S Adviser	Contract Administrator
Model Viewer			II	I
Asset Management				
Point Cloud Data				
Design Tools	II			
Integration Tools			II	
Cost Estimation				
Cloud/Server		I		II
Model Checker				
Spec. Application				
4D Capability	III			
Surveying Site	II			
Planning & Control	II			

Table 7.6. User's profile priority and functionality for Occupant group

BIM Tools \ Stage	Client/Owner	Inhabitant/End-user
Model Viewer	I	I
Asset Management	I	I
Point Cloud Data		
Design Tools		
Integration Tools		
Cost Estimation		
Cloud/Server		I
Model Checker		
Spec. Application		
4D Capability		
Surveying Site		
Planning & Control		

Table 7.7. User's profile priority and functionality for Service Company group

BIM Tools \ Stage	Client Adviser	Site Surveyor	FM Adviser	Infor. Manager	Sustain. Adviser	Technical Adviser	Bank or Financier	Tester
Model Viewer							I	
Asset Management	II		II		I			
Point Cloud Data		III						
Design Tools		II						
Integration Tools	II	III				I		I
Cost Estimation								
Cloud/Server				III				
Model Checker								
Spec. Application								
4D Capability								
Surveying Site								
Planning & Control								

In conclusion, the user’s profile summarised above is not dependent on the stage of renovation process but depends on the information and functionality that relates to the stakeholder needs to be carried out in the renovation work to keep it simple and to maintain a lightweight approach through the whole work. Determining the user’s profile from the initial point of the project can improve the performance and the comfort in the use of system. These tables above help the collector, or administrator of a BIM-based toolkit to define which tool can each stakeholder can get access to, and the intended changes and missing pieces to be accredit in the future as well.

7.2. RESEARCH CONCLUSION

In this dissertation, based on the existing research results about Building Information Modelling, Building Management System, efficient renovation strategies and BIM adoption in renovation in building, combining with the research from BIM4EEB’s team, the user’s profiles for accessing the BIM management system are defined. Starting from analysing all activities in 9 stages of renovation process in building including initiative, initiation, concept design, preliminary design, develop design, detail design, construction, use, and end-of-life, the relevant stakeholders to each activity of each stage are defined as well as their workflow and information workflow. After that, the adoption of BIM to all this information is considered by priority of BIM involving. And this matrix of task, information, and actors is summarised as a user’s profile for each stakeholder. In summary, there are totally 18 profiles needed for accessing BIM management system for efficient renovation in building. The main research work and conclusions are as follow:

1. Literature review, theoretical deduction, and other research methodologies have been used to understand clearly about BIM, efficient renovation in building, and adoption of BIM into renovation process. There are 2 case studies that have been shown and analysed based on their covers to all stage of the renovation process. This result exemplifies how BIM involving into the renovation of building nowadays, which is a different perspective from adopting BIM into a new building project, which is shown in the figure 6.1 below.

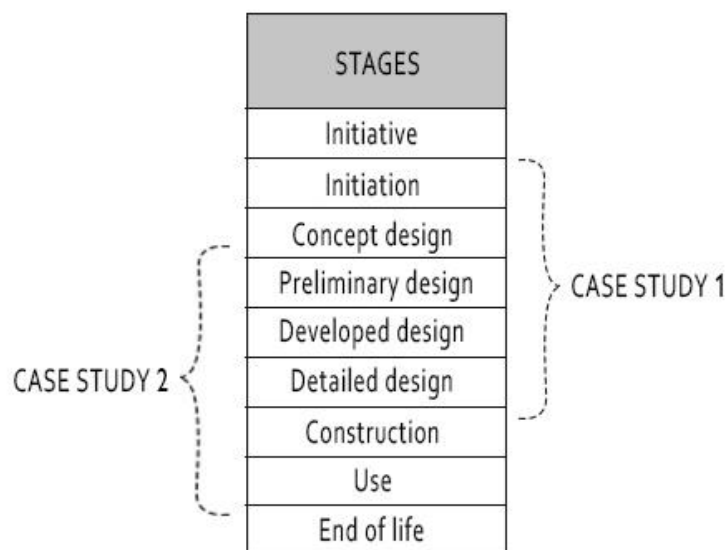


Figure 7.1. Case studies covering stages of renovation process



2. A deep analysis is performed to figure out all activities in the renovation process in building in Europe. There are 3 important parts that have been done. They are identifying the actors related to all activities of the process, identifying the task related to these actors, identifying the BIM involvement as well as BIM tools that is appropriate for these tasks. This analysis brings a big picture about the renovation activities.
3. The users' profile is defined for accessing to BIM management system, which include 3 important factors: function, information and priority. It is the essential criteria developed to create a suitable BIM management system for building renovation. Particularly, the BIM management system developed for allowing different functionalities according to logged profiles. The information that will be showed to different stakeholders will have a scalable approach according both to the specific subject and phase to maintain a lightweight approach that can improve the performance and the comfort in the use of the system

7.3. RESEARCH INOVATION

In terms of research ideas, this thesis starts from a real project BIM4EEB by European Commission. This project focuses on how to build a good BIM tools management system for efficient renovation in building in Europe, which is a major issue to cut down the carbon emission in the building sectors. This thesis contributes into a small part of the project, which is defining the users' profile for accessing to BIM management system for the whole building lifecycle of a renovation project.

In terms of research methodologies, this thesis has used literature research combining with deep analysis about BIM tools available in the market and all activities in the renovation project. It provides a good understanding about works in all stages of a project, which can be easily scalable and adapt into building needed renovation in both small and big scale.

USE-CASE Matrix scope: The use case matrix can be further developed into a detailed individual Cases in the form of a Use case template. The template consisting of the following fields:

- **Use case name:** The name of the Use case to be developed in detail.
- **Events:** The events/activities/workflow which supports the Use case.
- **Actors:** The actor/actor's who initiate this use case and all the other actors who participate in the activity.
- **Use case overview:** A description of the overall scope and content of the use case.
- **Precondition:** Constraints that must be met for the use case to be started.
- **Use case description:** List of actions the actor perform and the system response.
- **Use case association:** A list of other use cases that are associated with this particular use case.
- **Traceability to:** A list other related documents, models that are associated with the use case.
- **Input summary:** A brief summary that lists the data input by the Actor.
- **Output summary:** A brief summary that lists the data output by the system.



7.4. RESEARCH PROSPECTS

The study of Building information modelling in efficient renovation in building provides a research framework for creating of a good BIM management system for existing building, which does not exist in the market as of today.

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APPENDIX I:

TABLE OF DEEP ANALYSIS FOR ACTIVITIES IN RENOVATION PROCESS OF PRIVATE WORKS

Stage	Workflow task				BIM involved priority scaling bigger is more priority					Hypothesis for BIM priority scaling	Benefit of BIM integration in this process instead of doing traditional way.	Type of Input Information	Information Provider / Process	Type of Output Information	Information Receiver	BIM Tools can be used in the market		
	No.	Who	Action	Description	0	1	2	3	4							5	Category	BIM Tools Example
INITIATIVE	1	Inhabitant/ End-user	needs	a renovation intervention				X			A renovation intervention is called out by the Inhabitant/ End-user when the user notices a visible failure at the early stage and which has to be addressed. Eg. A broken window or a damaged wall, which is to be reported to the Owner or the facility manager to make an intervention before the failure. Traditionally, End-user report this problem by a call, an email, or a conversation to a responsible person. However, BIM is recommended to be integrated from this task. In this case, End-user need a user-friendly software interface and can interact with object in this model viewer software, add the failure based on type, write description, and upload the photos. Then this information is to be transferred to BIM server, which link to the BIM object in FM software for reviewing.	End-user can report the failure in the building in more precise location, with image or photos if necessary. Facility Management team and Owner have more information to decide the renovation intervention is needed or not.	Evidences	End-user	- Picture - Information: location, type of failure, description.	Owner, Facility Management Team	BIM Model Viewer	- Fuzor - Kubity
	2	Inhabitant/ End-user	communicates	the need of renovation to the owner				X			Following task 1, once the failure or problem is reported by the End-user, there should be an effort from owner, or facility management team needed to keep tracking of reported information. Then, a BIM tool for managing the communication is recommended, since it controls the information more efficiently. For example, there is a part of wall damaged, all reported information about this wall will be collected, and linked to the BIM object of this wall in FM software.	The owner have more accurate information about the failure in building, its location, its type and its level of damage by information from many people. Hence, the site inspection check or maintenance schedule could be decided based on the urgency of the problem.	- Picture - Information: location, type of failure, description.	End-user or FM Team	Information: failure report	Owner	BIM Tools for Asset Management: - ARCHIBUS - FM Systems - AssetWORKS Solutions - FAMIS - WebTMA - Corigo - Autodesk BIM 360 Building Operation	
	3	Client/Owner	makes	a site inspection to evaluate the necessity and the urgency of intervention					X		Owner could decide to make a site inspection alone at first or with a site inspector from facility management team, or another service company if the building doesn't have its FM team. In traditional way, this task is still implemented well but, with BIM tool for asset management that has full developed BIM FM model, Owner has full information with ongoing update from inspection activities to make their decision about the necessity of a renovation. It is desirable to get BIM involved to this task for a future record and maintenance.	- The site inspector knows exactly the location, type and level of damage of a failure. They also can inspect parts of building that is affected by the failure to determine the urgency of intervention. Result of this inspection is updated and linked into BIM object in BIM FM model. - Otherwise, the Owner manages more efficiently site inspection activities by better ongoing updates to the building, the Owner has an accurate record of building as a base model for future maintenance or renovation.	- Information: Failure report - BIM FM Model	Owner or FM Team	- Information: failure assessment - Updated BIM FM Model	Owner	BIM Tools for Asset Management:	
	4	Client/Owner	agrees	on the necessity of a renovation				X			In fact, Owner can have the ability to assess the necessity of a renovation or not hence, sometimes they need to hire a third party for these assessments. BIM is recommended in this process for both owner and third party decision as well as better collaboration between the Owner and third party if it is necessary.	Owner or third party has fully viewed of the building through BIM FM model. If a third party is necessary, Owner can collaborate with third party through BIM FM Tools, and get feedback and review as well.	- Information: failure assessment - Updated BIM FM Model	Owner or Third-party service	- Decision: approve for renovation process.	Owner		
	5	Client/Owner	appoints	an adviser to provide a cost-benefits appraisal and a preliminary business case	X						It is not necessary for BIM integration in this task. Owner can still perform well by the traditional way.	N/A	Owner	- Adviser appointment	Adviser	N/A	N/A	
	6	Client adviser	provides	a cost-benefits appraisal				X			From current financial situation of the Owner as well as estimating cost for the renovation, Client Adviser starts cost-benefits analysis procedure. Traditional way still work well, however, BIM is recommended in this process due to its ability of early conceptual cost estimation with high accuracy, which help to make better appraisal. For example, if a building is partly renovated or fully renovated by each stage, Adviser are aware which part of building related to renovation works are completed by each stage, and also affected occupied space in the building. It makes the cost-benefits more accurately.	BIM FM Model provide current financial information of a building like real estate and leasing management, current operation and maintenance works as well as space management.	- Information: failure assessment - BIM FM Model	Client Adviser	Information: Cost-benefits report	Owner	BIM Tools for asset management that provide financial information of building: - Maximo by IBM - ARCHIBUS - AssetWORKS Solutions - FAMIS	There are some BIM Tools available now for early cost
	7	Client/Owner	evaluates	cost-benefits of a renovation		X	X				In this task, Owner can have a background to review the cost-benefits report or not. If not, they can use traditional way to evaluate the report; if they are able to review, using BIM Tools is highly recommended.	BIM FM Model gives Owner full access to any information they need to review the cost-benefits.	- Information: Cost-benefits report	Owner	- Decision: approve for next task.	Client Adviser		
	8	Client adviser	prepares	preliminary business case which can be used for initial exploration of financing needs and options such as third party loans and Energy Performance Contracts (EPC's)				X			BIM can be useful in this task by quickly generate energy performance analysis from the BIM FM Model of the current building, which is an important indicator for Energy Performance Contracts. With this, the business case can be more accurate; however, with the limited ability of BIM Tools today, maybe, it is better to do this task by traditional way.	BIM FM Model has a ability to link with other BIM Tools for Energy Analysis, provide an early assessment about the Performance of the building as well as current situation of the building. This information are useful for preparing preliminary business case.	- BIM FM Model - Result from other linked BIM Tools	Client Adviser	- Preliminary Business Case	Owner	N/A	
	9	Client/Owner	evaluates	preliminary business case		X					The owner now evaluates the data and strategies provided by Client adviser and therefore decision is made to proceed further. The action of BIM in this doesn't seem necessary to be high priority as it is an evaluation and decision process by owner alone.	- Preliminary Business Case	Owner	- Information to make decision to start renovation process	Owner	N/A		
	10	Client/Owner	decides	to undertake a renovation process	X						It is not necessary for BIM integration in this task. It relate to the Owner business situation.	- Information to make decision to start renovation process	Owner	- Decision: to undertake renovation process	Owner	N/A	N/A	
	11	Client/Owner	appoints	a project leader to manage the renovation project	X						It is not necessary for BIM integration in this task	- Information about project leader	Owner	- Decision: to appoint project leader	Owner, Project Leader	N/A	N/A	
	12	Project leader	identifies	clients/owner needs and user requirements					X		Project leader (PL) need to consider the integration of BIM from this early task to get its benefits. From BIM FM Model (if available), PL identify the Owner need as well as End-user requirement based on the information on previous actions. Otherwise, PL has the ability to know exact which part of building need which renovation works, and End-user that be affected by the renovation works. Anyway, BIM Tools can provide a communication system between PL and End-user to get their requirements. A BIM server need to be set up from this task.	BIM FM Model brings essential information for PL, combining with the report from End-user, Owner; PL identify the needs and requirements quickly and efficiently. If there is a BIM Tools which has function as communication, surveying, the PL will get their information from End-user in detail.	- BIM FM Model - Information: all of previous report and assessment	Project Leader	- Data: Owner needs, User requirements.	Project Leader, Owner, End-user	BIM Tools for Asset Management: BIM Server for renovation project: - Autodesk BIM 360 - Graphisoft BIM Server and BIM cloud	
	13	Project leader	compiles	available information covering regulatory, infrastructure and geotechnical conditions		X					If the infrastructure surrounding building is not complete that can be defined as a BIM objects, it is recommended to using BIM. However, most of the BIM Tools today is not fully available to deal well with infrastructure and geotechnical conditions. Hence, PL should comply them as information in other softwares.	Infrastructure BIM object could be useful as a source of data for the context of feasibility study and pre-design stage, as well as through the whole design stage.	- Information: regulatory, infrastructural and geotechnical properties	Project Leader	- Information: regulatory, infrastructural and geotechnical properties	Project Leader	N/A	N/A
	14	Project leader	identifies	additional site investigations required including surveys of existing buildings and structures					X		From BIM FM Model, with information from previous task, PL identify parts of building that need further investigation. PL can markup it in a BIM Model Viewer. Then, this information and markup can be transfer to Site surveyor, for the accuracy and detail of site investigation. PL should set a initial model view definition for site surveyor to highlight areas of failure or concern.	BIM increasing the collaboration between PL and related stakeholder. PL can also identify the type of surveyor, the information they need from site surveyor, which problem should be checked in the building; for example: checking the durability of the structure in specific beam or columns; checking water penetration through a suspicious damaged wall; .	- BIM FM Model - Information from previous tasks	Project Leader	- Site investigation location - Type of site investigation - Needed condition data - Model View Definitions	Project Leader, Owner	BIM Model Viewer	- Autodesk BIM 360 Glue - Autodesk Design Review - Autodesk Navisworks - Fuzo - Kubity - Solibri Model Viewer
	15	Client/Owner	appoints	a site surveyor	X						It is not necessary for BIM integration in this task. Owner can still perform well by the traditional way.	- Type of site investigation	Owner	- Decision to appoint a site supervisor	Site Surveyor	N/A	N/A	
	16	Site surveyor	carries out	measured surveys and condition surveys of existing structures or buildings on site (site survey), measuring each room and building component in order to return a geometrical representation of the building to be renovated					X		The traditional measurement is ok, but it is better to use laser scanning, photogrammetry technologies to rapidly compile point cloud data (PCD), which can be used in BIM models. It is highly desirable for BIM involving from this process, since there are software tools that available in the market for this task.	PCD can be put into the BIM model as reference models, and can be snapped to however, the technology for scanning to BIM is still developing. PCD should be used as a reference model to build the BIM model of existing building.	- Type of site investigation - Site investigation location	Site surveyor	- Point Cloud Data - Geometrical data - Condition data	Site Surveyor Project Leader	Point Cloud Data Tools: - Autodesk RECAP - Trimble RealWorks - Leica Cloudw@re - Bentley Descartes	
	17	Site surveyor	documents	the present condition of the property, highlighting areas of failure or concern					X		Site surveyor transform the Point Cloud Data, geometrical data to a BIM model of existing building. The condition data should be included in this BIM model as well. Then, they set the model viewer following the definitions from PL to show the present condition of the property and highlight areas of failure or concern. It is mandatory that all of this task need to be conducted in BIM Tools. It is recommend that the Site surveyor should use a third-party in case they cannot preparing BIM model.	BIM is useful to highlight areas of failure or concern in different model viewer definitions. Anyway, creating BIM model from early could benefits the whole procedure of the project if the building doesn't have BIM FM model itself	- Point Cloud Data - Geometrical data - Condition data	Site Surveyor	- BIM Model for existing building - Specific model view	Site Surveyor Project Leader	Point Cloud Data Tools: BIM design tools: - Autodesk Revit - Other software of other platform.	
	18	Site surveyor	identifies	causes of past, or ongoing, deterioration and issues that need attention to prevent serious damage					X		Site surveyor identify these issues, then markup and input into BIM model as an associated data in initiation stage. However, these data should be showed in BIM Model Viewer as well, which makes the collaboration efficiently.	BIM is useful to link the data and object, creating a data set for PL to make decision in next tasks	- Data: causes and issues of deterioration	Site Surveyor	- Updated BIM Model	Site Surveyor Project Leader	BIM Design Tools: - Autodesk Revit - Other software of other platform.	
	19	Site surveyor	identifies	HVAC distribution and size of each building service component					X		Site surveyor identify building services system, updated into BIM model with useful data as building services distribution system and size.	MEP systems can easily model in BIM design tools, then combined with previous BIM model.	- Data: building services distribution and size.	Site surveyor	- Updated MEP BIM Model	Site Surveyor Project Leader	BIM Design Tools: - ArchiCAD - Bentley Building - Other software of other BIM platform.	
	20	Site surveyor	identifies	materials and classify according to environmental issues					X		Site surveyor identify the materials of building components, classify them, modeling and updated into original BIM model by changing type of building components.	BIM design tools provide the ability to change building components type, material and classify easily and massively.	- Data: materials and classify	Site surveyor	- Updated MEP BIM Model	Site Surveyor Project Leader	BIM Design Tools: - ArchiCAD - Bentley Building - Other software of other BIM platform.	
	21	Site surveyor	combines	the scanning data with installation schemes and existing drawings					X		Site surveyor combining all of previous BIM Model to a single model to delivery to the Project leader. They check the model with Point Cloud Data, existing drawings of the building to provide the consistency in the final BIM Model. It is mandatory to use BIM Tools to do all this task since there are many powerful tool for this available in the market.	Easy to check, combining different models with high accuracy and precision.	- Existing drawings - PCD Data - All of previous data from previous survey	Site surveyor	- Existing building BIM Model	Project Leader	BIM Design Tools; BIM Integration Tools: - Autodesk Naviswork - DP Manager - iTWO - Vice Office	
	22	Project leader	sets out	basic planning principles and possible construction strategies					X		From combined BIM model, PL set out planning principles and possible construction strategies as a report. PL could use common MS softwares for this, it is not necessary to use BIM in this task. But the report need to be linked into BIM server for later tasks.	BIM is useful assessment tool for PL since they have a digital version of existing model. They can try and test some possible construction strategies as well.	- Existing building BIM Model	Project Leader	- Report: planning principles and construction strategies	Owner	BIM Model Viewer - Autodesk Navisworks - Fuzo - Kubity - Solibri Model Viewer	
	23	Project leader	examines	how the project can meet stated requirements and aspirations					X		It is mandatory for PL to use BIM tools to examine project that meet stated requirements and aspirations. There are available BIM Model Checkers now that PL can added rules and automatically check the model with tool, and export the report about this.	BIM Model checkers have the ability for user to manually identify ruleset or using predefined ruleset to check the model. It also can generate the report of error.	- Existing building BIM Model - Ruleset of requirements and aspirations	Project Leader	- Report: requirements and aspirations that meet or not meet	Owner	BIM Model Checker - Autodesk Revit Model Review - SmartReview AFR	
	24	Project leader	informs	the client of technical and statutory constraints the project has to satisfy	X						It is not necessary for BIM integration in this task	- Report: requirements and aspirations that meet or not meet.	Owner		Owner			

Stage	Workflow task				BIM involved priority scaling bigger is more priority					Hypothesis for BIM priority scaling	Benefit of BIM integration in this process instead of doing traditional way.	Type of Input Information	Information Provider / Process	Type of Output Information	Information Receiver	BIM Tools can be used in the market			
	No.	Who	Action	Description	0	1	2	3	4							5	Category	BIM Tools Example	
INITIATION	25	Project leader	prepares	feasibility studies and assessment of options to enable the client to decide whether to proceed						X	PL can use BIM tools to do the feasibility study. Data from BIM Model can be useful to estimate aspects related to the existing building before and after renovation. However, it should not be mandatory since there are other good tool available for PL	BIM provide information to solve the assessment of this action	- Existing building BIM Model - Client needs	Project Leader	- Report: feasibility studies and assessed options	Owner	BIM Design Tools: - Autodesk Revit - Other software of other platform. BIM Integration Tools: - Autodesk Naviswork - DP Manager - iTWO - Vico Office		
	26	Project leader	investigates	expected budget requirements						X	PL can use BIM tools for quick estimation of budget requirements based on feasibility study report. But, it is not mandatory because there are only few BIM-based tools that can support well the budget requirement expectation task.	Most BIM platform enable immediate extraction of item count and area and volume calculations for the building components and materials. It helps the PL for first budget requirements expectation.	- Existing building BIM Model - Report: feasibility studies and assessed options	Project Leader	- Report: budget requirements	Owner	BIM Cost Estimation - Plug-ins to BIM platform: - Innovaya Visual Estimating - RB iTWO - Vico Takeoff Manager - Using OpenBIM file Exchange - Nomitech CostOS - Exactal CostX - Vico Takeoff Manager - Autodesk Naviswork - DP Manager - iTWO - Vico Office		
	27	Project leader	analyses	the kind of intervention and the tasks to be developed							X	PL use BIM model to simulate and check the kind of intervention and developed tasks. It is more easy to manage the kind of intervention and tasks in BIM-based tool than in a traditional way.	BIM Model Integration Tools provide common functions that are construction planning, scheduling and 4D simulation. It is useful for PL to simulate the intervention and task needed in the building	- Existing building BIM Model - previous reports	Project Leader	- Data: kind of intervention and developed tasks.	Owner	BIM Integration Tools - Autodesk Naviswork - DP Manager - iTWO - Vico Office	
	28	Project leader	defines	the project organisational structure and range of consultants and others to be engaged for the project, including definition of responsibilities							X	Based on report of kind of intervention and tasks to be developed, the project organisation need to be early defined in type of consultant, and number of consultant. Defined them early made the collaboration through BIM cloud-based application more efficiently as well as prepare an appropriate BIM server for the project.	Creating type of user in BIM cloud-based application, which increasing the collaboration between them as well as reducing the interoperability between the BIM tools each discipline use.	- Data: kind of intervention and developed tasks.	Project Leader	- Organisational structure - Type of users	Project Leader Owner	BIM cloud-base application - Autodesk BIM 360 - Other from other BIM platform	
	29	Project leader	defines	possible procurement strategy							X	Procurement strategy should be defined to get benefit from BIM. Traditional procurement strategy should be analysed carefully about the integration of BIM in this strategy. As usual, a good BIM model help PL a lot to identify which strategy is appropriate for the project	Integrated Project Delivery is a good procurement strategy that fit for BIM, since the projects are distinguished by effective collaboration among owner, designers, contractors from early design through project handover.	- All previous report	Project Leader	- Report: procurement strategy	Project Leader Owner	N/A N/A	
	30	Project leader	identifies	the procurement method							X	It is not necessary for BIM integration in this task since it is related more in contract and business documents.							N/A N/A
	31	Project leader	sets out	a project brief							X	It is recommended to extract the data from BIM model and linked files to sets out a project brief. PL could combine necessary data from previous task for the brief.	Quickly combining necessary data for a project brief	- Existing building BIM Model - Previous reports	Project Leader	- Report: Project Brief	Owner	N/A N/A	
	32	Project leader	produces	a room and function schedule							X	Room and function schedule can be easily extracted from BIM model. It is mandatory to use BIM.	Quickly export room and function schedule	- Existing building BIM Model	Project Leader	- Report: Room and function schedule	Owner	BIM Design Tools - Autodesk Revit - Other software of other platform	
	33	Project leader	identifies	required statutory approval process and building permit							X	From Task [23], [25], [27] and BIM Model Checker Tools, PL quickly identify the required statutory approval process and building permit	Fully access report and BIM model, identify required approval quickly by model checker	- Previous reports	Project Leader	- Report: required approval process and building permit	Owner	BIM Model Checker - BIM Assure - Solibri Model Checker - Autodesk Navis Model Review - SmartReview APR	
	34	Project leader	assembles	project team							X	It is not necessary for BIM integration in this task since it is related more in contract and business documents.							N/A N/A
	35	Lead designer	identifies	needs for specialist consultants							X	It is not necessary for BIM integration in this task since it is related more in contract and business documents.							N/A N/A
	36	Cost consultant/ quantity surveyor	estimates	costs and time							X	Cost Consultant / QS use BIM model to extract quantity takeoff data, combining with their experiences, estimates costs and time.	Most BIM platform enable immediate extraction of item count and area and volume calculations for the building components and materials.	- Existing building BIM Model - Previous reports	Cost Consultant Quantity Surveyor	- Report: costs and time	Project Leader	BIM Cost Estimation - Plug-ins to BIM platform: - Innovaya Visual Estimating - RB iTWO - Vico Takeoff Manager - Using OpenBIM file Exchange - Nomitech CostOS - Exactal CostX - Vico Takeoff Manager - Autodesk Naviswork - DP Manager - iTWO - Vico Office	
	37	Project leader	defines	an expected or desired time schedule, preparation of a project execution plan							X	BIM model is useful for PL to check the cost and time report, improve the desired time schedule, and provide data for execution plan. But, it is purely analytical decision of project leader	Provide data for PL tasks.	- Existing building BIM Model - Report: Cost and time	Project Leader	- Report: Time schedule - Project Execution Plan	Owner	BIM Integration Tools - Autodesk Naviswork - DP Manager - iTWO - Vico Office	
	38	Health and safety adviser	considers	health and safety strategy							X	H&S adviser use BIM model to identify health and safety strategy combined with report from previous data.	Provide a general view in Project	- Existing building BIM Model - Data: kind of intervention and developed tasks.	Health and Safety Adviser	- Report: health and safety strategy	Project Leader Owner	BIM Model Viewer - Autodesk BIM 360 Glue - Autodesk Design Review - Autodesk Navisworks - Furzo - Kubity - Solibri Model Viewer	
	39	Information manager	defines	information exchange objectives							X	BIM server and information exchange system is defined early from this task. BIM is different to traditional file-based information exchange way, that need specific requirement about IE objectives.	Good collaboration and information exchange between stakeholders	- Project Execution Plan - Organisation structure	Information Manager	- Report: Information Exchange Objectives	Project Leader Owner	BIM Server - Autodesk BIM 360 - Other from other BIM platform	
	40	Inhabitant/ End-user	wants to	receive info on work planning / schedules (pre during renovation)							X	It is recommended to use BIM, creating a model viewer for End-user, linked them with necessary report like work planning/schedules.	End-user easily understand the work planning, schedules, and easily feedback on them.	- Existing building BIM Model - Project Execution Plan	Project Leader	- End-user Model Viewer	End-user	BIM Model Viewer - Autodesk BIM 360 Glue - Autodesk Design Review - Autodesk Navisworks - Furzo - Kubity - Solibri Model Viewer	
	41	Inhabitant/ End-user	wants to	negotiate with contractors about the work planning							X	A BIM model viewer help End-user easily feedback and negotiate with contractors about work planning	Enhance communication	- End-user Model Viewer	End-user	- Feedback data	Project Leader		
	42	Inhabitant/ End-user	interested to	participate (jointly with contractors) for the optimal schedules of the renovation process							X	Schedules of the renovation process can be easily access through a BIM Model Viewer as a linked files. If End-user is interested, they can see it and give their opinion to optimise the schedule	Provide options for data accessibility	- End-user Model Viewer	End-user	- Feedback data	Project Leader		
	43	Inhabitant/ End-user	is interested to	receive security and safety recommendations about construction programming							X	It is recommend to have a model viewer definitions with security and safety data included, End-user easily access this information.	Provide options for data accessibility	- End-user Model Viewer	Project Leader Health and Safety Adviser	- H&S Model Viewer	End-user		
	44	Owner	is interested in	management and control of the renovation process							X	Owner should involve to the renovation process from early tasks, a specific Model Viewer is created for Owner with all information to manage and control the renovation process.	Provide fully data access, collaboration between owner and other stakeholder to making decision and reduce error through renovation process.	- Existing building BIM Model - Previous reports	Project Leader	- Owner Model Viewer	Owner	BIM Integration Tools - Autodesk Naviswork - DP Manager - iTWO - Vico Office	
	45	Owner	agrees	to share information about building							X	It is not necessary for BIM integration in this task since it is related more in contract and business documents.							
	46	Owner	monitors	the results of building renovation simulation							X	Renovation simulation is updated to BIM model, Owner can monitor it in a Owner model viewer	Provide fully data access, collaboration between owner and other stakeholder to making decision and reduce error through renovation process.	- Existing building BIM Model - Building renovation simulation	Project Leader	- Owner Model Viewer	Owner	BIM Integration Tools - Autodesk Naviswork - DP Manager - iTWO - Vico Office	
	47	Owner	monitors	building energy performance (near real time)							X	Renovation simulation is updated to BIM model, Owner can monitor it in a Owner model viewer	Provide fully data access, collaboration between owner and other stakeholder to making decision and reduce error through renovation process.	- Existing building BIM Model - Building Energy Performance	Project Leader	- Owner Model Viewer	Owner		
	48	Owner	controls	working times and economic sustainability of the renovation process							X	Working time and economic sustainability updated to BIM model, Owner can monitor it in a Owner model viewer	Provide fully data access, collaboration between owner and other stakeholder to making decision and reduce error through renovation process.	- Existing building BIM Model - Working times and economic sustainability	Project Leader	- Owner Model Viewer	Owner		
	49	Client adviser	prepares	detailed business case that can be used for soliciting financing from third parties							X	From Task [8], combining with updated BIM Model, Client Adviser now can prepare well detailed business case for the Owner	BIM provide data, and collaboration between Client Adviser and Project leader to understand fully about the project	- Existing building BIM Model - Preliminary business case	Client Adviser	- Detail business case	Owner		
	50	Bank or third party financier	assesses	detailed business case and feasibility of project through own cost assessments and potentially audits from external consultants to determine if savings guarantees are realistic							X	It is useful for financier to have a BIM Model Viewer to examine and understand the whole renovation project. A specific Model Viewer need to be created for Financier.	BIM provide good visual view, good understanding about the project.	- Existing building BIM Model	Project Leader	- Financier Model Viewer	Bank or third party financier	BIM Model Viewer - Autodesk BIM 360 Glue - Autodesk Design Review - Autodesk Navisworks - Furzo - Kubity - Solibri Model Viewer	
	51	Bank or third party financier	agrees	to finance the project							X	It is not necessary for BIM integration in this task since it is related more in contract and business documents.							
	52	Client/Owner	negotiates	financing terms with bank or third party. This includes percentage of project financed, how money is delivered over the course of the project, interest, time frame and payments schedule. This process will most likely involve contributions from the project lead							X	Based on BIM model and linked report, Owner has information to negotiate with financier. There is a specific Model Viewer needed to be defined in this task.	BIM provide good visual view, good understanding about the project.	- Existing building BIM Model - Related report	Project Leader	- Model Viewer	Owner, Bank or third party financier	BIM Model Viewer - Autodesk BIM 360 Glue - Autodesk Design Review - Autodesk Navisworks - Furzo - Kubity - Solibri Model Viewer	
	53	Client/Owner	signs	negotiated financing contract. The third party entity will generally monitor the progress of the project at different time intervals during the course of the following activities especially during the phases of developed and detailed design in order to observe any potential deviations							X	Based on BIM model and linked report, Financier identify what they want to monitor through the renovation process. There is a specific Model Viewer needed to be defined in this task.	BIM provide good visual view, good understanding about the project.	- Existing building BIM Model - Related report	Project Leader	- Model Viewer	Owner, Bank or third party financier		
	54	Lead designer	examines	the principal elements of the brief, if already defined by the client, or the objectives and requirements the project has to satisfy							X	Lead designer has an account on BIM server, and access to the project brief to examine, and update if necessary	BIM server is a perfect working collaboration environment for all stakeholders	- Report: Project Brief	Lead Designer	- Final Project Brief	Project Leader,	BIM Server - Autodesk BIM 360 - Other from other BIM platform	
	55	Architectural designer	produces	concept sketches and undertake preliminary investigations							X	There is not many 3D Concept design sketching tools available in market that has an ability to link with BIM Design Tools. Then, there are 2 options for Architectural Designer: using 3D Concept sketching tools like Sketch Up, Rhinoceros (able to link to BIM Tools through IFC), Form2 Pro and their analysis add-in; or using sketching concept tool within BIM Tools like Autodesk Revit, ArchiCAD... with their BIM-based analysis tool. However, BIM involved into this actions is highly desired, not mandatory, since Architect usually use their preferred sketch tools for concept design, but this tool must be able to link to BIM tools. Then all of the data and sketches must be translated into a BIM model.	Data from BIM Tools can bidirectional link to other analysis tools to easily do preliminary investigations.	- Existing building BIM Model - Report: Project Brief	Architectural designer	- Conceptual Arch. BIM Model	Project Leader, Owner	3D Sketching Tools: - Rhinoceros BIM Design Tools: - Autodesk Revit - ArchiCAD - Vectorworks - Bentley Architecture	

Stage	Workflow task			BIM involved priority scaling bigger is more priority					Hypothesis for BIM priority scaling	Benefit of BIM integration in this process instead of doing traditional way.	Type of Input Information	Information Provider / Process	Type of Output Information	Information Receiver	BIM Tools can be used in the market			
	No.	Who	Action	Description	0	1	2	3							4	5	Category	BIM Tools Example
CONCEPT DESIGN	56	Architectural designer	prepares	CONCEPT design proposals with design options, translating into drawings at an appropriate scale (typically 1:500-1:200) along with a preliminary design report and an initial cost estimate						X	From Conceptual Renovation BIM Model, Architectural designer creating set of drawings in BIM Design Tools, design report and initial cost estimate are products of other analysis BIM-based tools.	BIM automatically creates and updates the CONCEPT drawings, reduce the working times for documentation of designer. The designers have more time to focus on the concept and examine the analysed data from other BIM Tools	- Conceptual Arch. BIM Model	Architectural designer	- Local Authorities Model Viewer - Conceptual drawing set - Report: Preliminary Design - Report: Initial Cost Estimation	Project Leader	BIM Design Tools: BIM-based analysis tools BIM Cost Estimation	BIM Design Tools: - Autodesk Revit - Other software of other platform. BIM analysis tools and add-in BIM Cost Estimation: - Innovaya Visual Estimating - RIB iTWO - Vico Takeoff Manager
	57	Architectural designer	holds	preliminary discussions with local authorities on the basis of the conceptual design agreed by the client					X		Through BIM server, Architectural Design create a specific Model Viewer for this actions to discuss with the local authorities. It is desirable to have a 3D viewer, since it is helpful for the discussion and make the authorities understand the project better. But this action is also based on the availability of using BIM from local authorities as well.	Increasing working collaboration and project visualisation.	- Local Authorities Model Viewer - Conceptual Arch. BIM Model - Report: Preliminary Design - Report: Initial Cost Estimation	Architectural designer	- Report: Statutory Approvals	Project Leader	BIM Model Viewer	- Autodesk BIM 360 Glue - Autodesk Design Review - Autodesk Navisworks - Purzo - Kubity - Solibri Model Viewer
	58	Architectural designer	establishes	correct procedures to obtain statutory approvals						X	From Conceptual Renovation BIM Model, Architectural designer modify, edit the model to follow the statutory approvals that discussed in previous action.	BIM automatically creates and updates the CONCEPT drawings, reduce the working times for documentation of designer.	- Report: Statutory Approvals - Conceptual Arch. BIM Model	Architectural designer	- Final Conceptual Arch. BIM Model	Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.
	59	Project leader	explains	to the client correct procedures to obtain statutory approvals						X	Project leader using Owner Model Viewer to collaborate with Owner, and explain the correct procedures to obtain statutory approvals.	Increasing working collaboration and project visualisation.	- Report: Statutory Approvals - Conceptual Arch. BIM Model - Final Conceptual Arch. BIM Model	Project Leader	- Decision to obtain statutory approvals	Owner	BIM Model Viewer	- Autodesk BIM 360 Glue - Autodesk Design Review - Autodesk Navisworks - Purzo - Kubity - Solibri Model Viewer
	60	Project leader	undertakes	tender action - convert the project design into a set of pre-contract documents setting out an unambiguous set of tender requirements - collate project documents necessary for contractors to appreciate the type, the quantity, the quality and the scope of their works so that contractors can calculate their best offer						X	Project extract necessary data from Final Conceptual BIM Model to make a set of document related to tender action. BIM Integration tools are available to do this actions.	Extracting data easily, quick generate the quantity take-off report and other report related to tender actions	- Final Conceptual Arch. BIM Model	Project Leader	- Conceptual Tender data	Project Leader	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office
	61	Project leader	prepares	tender documentation in sufficient detail to enable a tender or tenders to be obtained for the project (i.e. a tender file to tenders, including: the conditions of tender, the proposed form of contract, plans, specifications, possibly a bill of quantities and a list of contractual documents with their order of priority, etc.)						X	Combining the tender data and Final Conceptual BIM Model, Project leader create a specific view for tendering process through BIM Integration Tool, and share it as a Tender Model Viewer. It is mandatory to use BIM tools in this actions, since all of the tender documentation are digital, and using traditional drawing should be ignored in the new BIM environment	A specific BIM model viewer bring a detail, unavoidable look for contractors to calculate their best offer to bid the project.	- Conceptual Tender data - Final Conceptual Arch. BIM Model	Project Leader	- Conceptual Tender documentation - Conceptual Tender Model Viewer	Tenderer	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office
	62	Tenderer	submit	a tender to the client			X				It is recommended to submit documents through BIM server by tenderer, Project Leader can manage and analyse the tender submission easily in next actions.	BIM environment create a good server to communicate and to transfer files between stakeholders.	- Conceptual Tender documentation - Conceptual Tender Model Viewer	Tenderer	- Conceptual Tender submission	Project Leader, Owner	BIM Server	- Autodesk BIM 360 - Other from other BIM platform
	63	Project leader	analyses	tender returns, make recommendations to client and enable him to pass construction contracts with each respective trade		X					Project Leader analyse the tender submission, examine the strength and weakness of each contractors. BIM is useful for managing the tender documents. Based on this analysis, Owner start pass construction contracts with each respective trade.	BIM as a file management tools to review the tender submission from tenderer	- Conceptual Tender submission	Project Leader, Owner	- Conceptual Construction Contracts	Owner	N/A	N/A
	64	Project leader	sets out	program dates						X	From Task [37], Project leader develop the time schedule by additional information in Concept design stage to a program dates. BIM integration tools is used in this actions as an initial of 4D BIM	BIM Integration Tools create a scheduling more easily, and the scheduling is attached to specific BIM object for construction management.	- Report: Time schedule - Final Conceptual Arch. BIM Model	Project Leader	- Program Dates	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office
	65	Project leader	updates and reviews	the project execution plan	X						Project leader reviews the work with added information, and update the Project Execution Plan from Task [37] this task is not involved to BIM.		- Data from previous tasks	Project Leader	- Conceptual Project Execution Plan	Project Leader, Owner		
	66	Project leader	considers	options for construction strategy						X	From Final Conceptual BIM Model, Project Leader use BIM Integration Tool to simulate, analyse some construction strategies, then create a report for possible strategies.	BIM Integration Tools provide construction management functions to schedule and 4D simulation.	- Final Conceptual BIM Model - Program Dates - Updated Project Execution Plan	Project Leader	- Report: Construction Strategy Options	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office
	67	Lead designer	checks	design from specialist consultants for compliance with the general design						X	Lead Designer use BIM Model Checkers to check design from other consultant, then coordinate by BIM Integration Tools with the general design.	BIM Model Checkers provide the ability to quick review by apply rulesets to a building model. BIM Integration Tools can merge multiple models to form a federated model and to check for clashes, and coordination between specialist discipline of the project.	- Final Conceptual Arch. BIM Model - Specific BIM Model from consultant - 2D Drawing CAD from consultants	Lead Designer	- Report: Conceptual design checking - Information for consultants update their model or CAD.	Project Leader, Specialist Consultants	BIM Integration Tools BIM Model Checkers	- Autodesk Naviswork - DP Manager - iTWO - Vico Office BIM Model Checkers: - BIM Assume - Solibri Model Checker - Autodesk Revit Model Review - SmartReview APR
	68	Lead designer	integrates	as necessary into overall design documentation (including technical sub-disciplines of construction such as structural, mechanical, electrical, HVAC, geotechnical, fire security, acoustics, lighting, etc.)						X	Lead Designer receive the updated BIM model and CAD drawing (not recommend) from other disciplines, combined in to a single BIM model if necessary. Then integrate them into overall conceptual design documentation.	BIM Design Tools easily link with tools of other BIM platform that disciplines would like to use. The design documentation, set up from the beginning, automatically change according to the revise of BIM models	- Final Conceptual Arch. BIM Model - Final specific BIM model from consultants	Lead Designer	- Conceptual Design Documentation - Integrated Conceptual BIM Model	Lead Designer, Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.
	69	Health and safety adviser	prepares	an outline for health and safety strategy					X		From Integrated Conceptual BIM model, H&S analyses all task, zones, program dates as well as project execution plan to create an outline for H&S strategy. This outline link to the BIM model, and sync to BIM server.	BIM is useful to provide information for input of H&S actions.	- Integrated Conceptual BIM Model - Updated Project Execution Plan - Program Dates	Health and Safety Adviser	- Health and safety strategy outline.	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office
	70	Information manager	manages	information exchange level 1 (brief and feasibility)						X	All information exchange are managed through a BIM server that the Information Manager set up from Task [39].	Easy to control the information flow, collaboration between related stakeholders	- Report: Information Exchange Objective - Type of information exchange from all stakeholders.	Information Manager	- Report: Information Exchange Level 1	Project Leader	BIM Server	- Autodesk BIM 360 - Other from other BIM platform
	71	Information manager	produces	end of stage report for client approval		X					Information manager examine the information exchange status of the project through BIM server, then create a report for Owner approval. BIM server is useful to manage and extract data for this task.	BIM server control the function of each type of user for specific stakeholder, has statistic data for information exchange to examine.	- Report: Information Exchange Level 1	Information Manager	- Decision: approval for information exchange process. - Changes for Information Exchange	Owner	N/A	N/A
	72	Information manager	considers	changes required to the brief						X	Based on Client decision from previous task, Information Manager considering changing the Information Exchange Level 1 report to be suitable for the project. For example: adjust the function of End-user profile on BIM server, ...	BIM server control the function of each type of user for specific stakeholder, has statistic data for information exchange to examine.	- Decision: approval for information exchange process. - Changes for Information Exchange	Information Manager	- Update Information Exchange configuration.	Information Manager, Project Leader	BIM Server	- Autodesk BIM 360 - Other from other BIM platform
	73	Project leader	develops	the concept design and chosen options as approved by the client and previewed with the authorities						X	In this stage, the concept design must be developed in BIM design tools to get all benefits from BIM. Project Leader use BIM Design Tools that support concept sketching to do this task, they can be more complex than usual 3D Sketching Tools, but the benefit from creating an early Preliminary BIM Model is worth it.	BIM helps Project Leader do preliminary analysis from early stage, that help build a suitable design. And, the BIM model is easily shared among all other stakeholder to get the feedback from them as well.	- Final Conceptual Arch. BIM Model	Project Team	- Preliminary Arch. BIM Model - Local Authorities Model Viewer	Project Leader	BIM Design Tools support concept sketching; BIM Integration Tools	- Autodesk Revit - ArchiCAD - Vectorworks - Bentley Architecture BIM Integration Tools: - Autodesk Naviswork - DP Manager - iTWO - Vico Office
	74	Local authority	gives	feedbacks on a preview of the concept design						X	Local Authority check the Preliminary Arch. BIM model through a specific model viewer on BIM Design Review Tool for them, then feedback to the Project Leader. When start getting BIM involved into a project, the local authority themselves need to change their traditional work to support the implementation of BIM as well.	BIM provide fast collaboration between stakeholders with better visualisation and feedback recording.	- Local Authorities Model Viewer	Local Authority	- Preliminary feedback	Project Leader	BIM Model Viewer	- Autodesk BIM 360 Glue - Autodesk Design Review - Autodesk Navisworks - Purzo - Kubity - Solibri Model Viewer
75	Architectural designer	prepares	graphic presentations of the project for discussions with the client and other interested parties						X	Architectural designer take rendering actions directly with Preliminary Arch. BIM Model. There are many add-in and software that provide the ability of rendering and graphic presentation of the project in BIM Design Tool.	Architectural Design use the same BIM model to render and create graphic presentations instead of remodeling it again in 3D Tools as traditional way.	- Preliminary Arch. BIM Model	Architectural designer	- Graphic Presentations	Architectural designer, Project Leader	BIM Design Tools, which link to rendering tools.	BIM Design Tools: - Autodesk Revit - ArchiCAD - Vectorworks - Bentley Architecture Rendering Tools: Lumion, Vray.	
76	Architectural designer	produces	a set of preliminary design drawings at an appropriate scale (typically 1:200-1:100) with floor plans, sections, elevations and 3d modelling						X	From Preliminary Arch. BIM Model, Architectural designer creating set of drawings in BIM Design Tools, design report and initial cost estimate are products of other analysis BIM-based tools.	BIM automatically creates and updates the CONCEPT drawings, reduce the working times for documentation of designer. The designers have more time to focus on the concept and examine the analysed data from other BIM Tools	- Preliminary Arch. BIM Model	Architectural designer	- Preliminary drawing set	Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.	
77	Architectural designer	produces	technical reports to explain design options						X	Architectural Designer use other analysis tools to creating a report for clarifying design options, these tools has an ability to link to BIM Design Tools for using Preliminary Arch. BIM Model. There are many tools for specific analysed purpose in the market, but not all of that link to BIM. Hence, it is highly desirable to use BIM-based tool for this task.	BIM share the geometric data, and other necessary information with analysed tools, which decrease time and error for designer in case of remodeling a building in other software.	- Preliminary Arch. BIM Model	Architectural designer	- Report: Preliminary technical.	Project Leader	BIM Design Tools support analysis tools	- Autodesk Revit - ArchiCAD - Vectorworks - Bentley Architecture	
78	Architectural designer	produces	architectural plans and documentation describing the project to a level of detail as required for Planning or Building permit applications (based on the approved design)						X	Architectural Design develop the Preliminary Arch. BIM model to an appropriate level of development that required for building permit applications. This action need to be done in BIM Design tool to follow the BIM workflow.	BIM object library is suitable for this development, there are predefined BIM object available in each BIM platform. And, the preliminary set of drawing is automatically updated based on changes and addition.	- Preliminary Arch. BIM Model	Architectural designer	- Pre-final Preliminary Arch. BIM model	Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.	
79	Architectural designer	collates	additional technical documentation from technical specialist consultants, such as acoustic, thermal, fire safety, environmental and other appraisals as required by applicable legislation						X	Architectural Designer collates the additional technical documentation, then cross-link them to BIM objects in the BIM model as specifications. There are only some application available now in the market for doing this. Hence, it is just highly desirable for BIM involving.	BIM create an opportunity to control and manage the technical documents by BIM objects in early stages, which make other stakeholder work with them more efficiently.	- Pre-final Arch. BIM model - Preliminary Technical Document	Architectural designer	- Final Preliminary Arch. BIM model	Project Leader	BIM Specification Application	- e-Specs - linkman e - Speclink.e	

Stage	Workflow task				BIM involved priority scaling bigger is more priority					Hypothesis for BIM priority scaling	Benefit of BIM integration in this process instead of doing traditional way.	Type of Input Information	Information Provider / Process	Type of Output Information	Information Receiver	BIM Tools can be used in the market		
	No.	Who	Action	Description	0	1	2	3	4							5	Category	BIM Tools Example
PRELIMINARY DESIGN	80	Project leader	assembles	documents required for building permit applications, draft and submit applications				X			From Final Preliminary Arch. BIM Model, Project leader extract necessary documents for building permit applications. There isn't an available tool for doing this directly in BIM Tools, it is better to use traditional software to assemble these documents. However, it is desirable to have a BIM Tools for this action. And the building permit documents is uploaded and shared with other stakeholders through BIM server.	BIM increasing the ability to control and extract data, documents and drawing quickly. However, a BIM server helps many stakeholders to control the information and document that they have.	- Final Preliminary Arch. BIM model - Preliminary Technical Document - Preliminary Drawing Set - Report: Preliminary Technical - Other documents	Project Leader	- Building permit application documentation set. - Specific model viewer for building permit application.	Local Authority	N/A	N/A
	81	Project leader	assists	during planning negotiations, monitor the approvals procedure (representing the client)					X		PL uses a specific BIM model viewer to explain during planning negotiations, and monitoring the approval procedures. BIM Integration Tools is ready for this action, hence, it is mandatory for BIM to involve in this actions.	Quick collaboration, quick visualisation for any part of the building through a 3D BIM model viewer.	- Building permit application documentation set. - Specific model viewer for building permit application.	Project Leader	- Additional files or certificates needed for approval procedure	Project Leader; Owner; Local Authority	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office
	82	Project leader	prepares	files for additional certificates as required by national legislation or by the specific nature of the asset					X		PL prepare files and additional certificates, and upload them on BIM server, link with the BIM model. It is like Task [79], this file or certificate link with appropriate BIM object in the BIM model.	With help of BIM-based application, the file crosslink to BIM model is easily updated by responsible stakeholders.	- Final Preliminary Arch. BIM model - Additional files or certificates needed for approval procedure	Project Leader	- Approval from local authority - Approved Preliminary Arch. BIM Model	Project Leader; Owner	BIM Specification Application	- e-Specs - linkman e - Speclink e
	83	Project leader	undertakes	tender action - convert the project design into a set of pre-contract documents setting out an unambiguous set of tender requirements - collate project documents necessary for contractors to appreciate the type, the quantity, the quality and the scope of their works so that contractors can calculate their best offer					X		Project leader extract necessary data from Approved Preliminary Arch. BIM Model to make a set of document related to tender action. BIM Integration tools are available to do this actions.	Extracting data easily, quick generate the quantity take-off report and other report related to tender actions	- Approved Preliminary Arch. BIM Model	Project Leader	- Preliminary Tender data	Project Leader	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office
	84	Project leader	prepares	tender documentation in sufficient detail to enable a tender or tenders to be obtained for the project (i.e. a tender file to tenders, including: the conditions of tender, the proposed form of contract, plans, specifications, possibly a bill of quantities and a list of contractual documents with their order of priority, etc.)					X		Combining the tender data and Approved Preliminary Arch. BIM Model, Project leader create a specific 'view' for tendering process through BIM Integration Tools, and share it as a Tender Model Viewer. It is mandatory to use BIM tools in this actions, since all of the tender documentation are digital, and using traditional drawing should be ignored in the new BIM environment.	A specific BIM model viewer bring a detail, unavoidable look for contractors to calculate their best offer to bid the project.	- Preliminary Tender data - Approved Preliminary Arch. BIM Model	Project Leader	- Preliminary Tender documentation - Preliminary Tender Model Viewer	Tenderer	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office
	85	Tenderer	submits	a tender to the client			X				It is recommended to submit documents through BIM server by tenderer, Project Leader can manage and analyse the tender submission easily in next actions.	BIM environment create a good server to communicate and to transfer files between stakeholders.	- Preliminary Tender documentation - Preliminary Tender Model Viewer	Tenderer	- Preliminary Tender submission	Project Leader	BIM Server	- Autodesk BIM 360 - Other from other BIM platform
	86	Project leader	analyses	tender returns, make recommendations to client and enable him to pass construction contracts with each respective trade.				X			Project Leader analyse the tender submission, examine the strength and weakness of each contractors. BIM is useful for managing the tender documents. Based on this analysis, Owner start pass construction contracts with each respective trade.	BIM as a file management tools to review the tender submission from tenderer	- Preliminary Tender submission	Project Leader; Owner	- Preliminary Construction Contracts	Owner	N/A	N/A
	87	Project leader	updates and reviews	the project execution plan	X						Project Leader review the work with added information, and update the Conceptual Project Execution Plan from Task [65], this task is not involved to BIM.		- Conceptual Project Execution Plan - Other information	Project Leader	- Preliminary Project Execution Plan	Project Leader; Owner		
	88	Project leader	devises	fundamental schedule in phases				X			From Task [64], Project leader go into detail of fundamental schedule in phases by analysing the required tasks related to the project. The availability of Preliminary BIM Model of the building let PL go deep into each phases. BIM integration tools is used in this actions as a 4D BIM application.	BIM Integration Tools create a scheduling more easily, and the scheduling is attached to specific BIM object for construction management.	- Program Data - Approved Preliminary Arch. BIM Model	Project Leader	- Schedule in phases	Project Leader; Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office
	89	Project leader	proposes	construction strategy				X			From Task [66], there are some construction strategies chosen in Conceptual stage. These strategy is analysed deeper by BIM Integration Tools, combining with the schedule for each phases, Project Leader proposes the most suitable construction strategy.	BIM Integration Tools provide construction management functions to schedule and 4D simulation.	- Report: Construction Strategy Options - Schedule in phases - Approved Preliminary Arch. BIM Model - Preliminary Project Execution Plan	Project Leader	- Report: Construction Strategy	Project Leader; Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office
	90	Lead designer	checks	design from specialist consultants for compliance with the general design					X		Lead Designer use BIM Model Checkers to check design from other consultant, then coordinate by BIM Integration Tools with the general design.	BIM Model Checkers provide the ability to quick review by apply rulesets to a building model. BIM Integration Tools can merge multiple models to form a federated model and to check for clashes, and coordination between specialist discipline of the project.	- Approved Preliminary Arch. BIM Model - Specific Preliminary BIM Model from consultant	Lead Designer	- Report: Preliminary design checking - Information for consultants update their BIM Model.	Project Leader; Specialist Consultants	BIM Integration Tools BIM Model Checkers; BIM Server for collaboration	- Autodesk Naviswork - DP Manager - iTWO - Vico Office BIM Model Checkers; - BIM Assure - Solibri Model Checker - Autodesk Revit Model Review - SmartReview APR
	91	Lead designer	integrates	as necessary into overall design documentation (including technical sub-disciplines of construction such as structural, mechanical, electrical, HVAC, geotechnical, fire security, acoustics, lighting, etc.)				X			Lead Designer receive the updated BIM model and CAD drawing (not recommend) from other disciplines, combined in to a single BIM model if necessary. Then integrate them into overall conceptual design documentation.	BIM Design Tools easily link with tools of other BIM platform that disciplines would like to use. The design documentation, set up from the beginning, automatically change according to the revise of BIM models	- Approved Preliminary Arch. BIM Model - Specific Preliminary BIM Model from consultant	Lead Designer	- Preliminary Design Documentation - Integrated Preliminary BIM Model	Lead Designer; Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.
	92	Health and safety adviser	establishes	health and safety strategy				X			From Integrated Preliminary BIM model, H&S simulate the strategy on BIM Integration Tools, analyse and modify the strategy to the most appropriate one for the project.	BIM Integration Tools has the temporary BIM object suitable for simulation this task.	- Integrated Preliminary BIM Model - Preliminary Project Execution Plan - Schedule in phases. - Report: Construction Strategy	Health and Safety Adviser	- Preliminary Health and Safety Strategy.	Project Leader; Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office
93	Information manager	manages	information exchange level 2					X		From Task [70], Information manager continue managing, adding necessary parts, and configuration for the BIM server to guarantee the collaboration work between stakeholder in this stage.	Easy to control the information flow, collaboration between related stakeholders	- Report: Information Exchange Level 1	Information Manager	- Report: Information Exchange Level 2	Project Leader;	BIM Server	- Autodesk BIM 360 - Other from other BIM platform	
94	Information manager	produces	end of stage report for client approval		X					Information manager examine the information exchange status of the project through BIM server, then create a report for Owner approval. BIM server is useful to manage and extract data for this task.	BIM server control the function of each type of user for specific stakeholder, has statistic data for information exchange to examine.	- Report: Information Exchange Level 2	Information Manager	- Decision: approval for information exchange process. - Changes for Information Exchange System	Owner	N/A	N/A	
95	Project leader	develops	the approved preliminary design up to an appropriate level, providing the basic information required for issue of contract plans and specifications					X		In this stage, from Integrated Preliminary BIM Arch. Model, Project Leader lead the Project teams develop this model into Developed Arch. BIM Model. The level of development of BIM Model changes in this task with new and additional information, which defined in Project Execution Plan. It is mandatory to use BIM Design Tools in this stage, and link the specification with the BIM object as well.	BIM brings too many benefits in this stage, from available BIM object library to quickly develop the building model.	- Approved Preliminary Arch. BIM Model - Preliminary Project Execution Plan	Project Team	- Pre-Developed BIM Arch. Model	Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.	
96	Project leader	prepares	a set of developed design drawings with floor plans, sections and elevations to determine the dimensions, appearance, principal technical solutions, materials and construction elements of the project at an appropriate scale (typically 1:100 1:50)					X		From set drawing in task [76] and Pre-Developed Arch. BIM Model, Project team develop a set of design drawing in BIM Design Tool. This set of drawing is developed from Preliminary drawing set, with more detail. It is mandatory to use BIM Design Tools for this tasks.	BIM automatically create and updates the developed drawings, reduce the working times for documentation of designer. The designers have more time to focus on the concept and examine the analysed data from other BIM Tools	- Preliminary drawing set - Pre-Developed BIM Arch. Model	Project Team	- Developed drawing set	Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.	
97	Project leader	produces	specification and detailed description of the works in the form of a written document describing the nature of the works and defining the technical specifications for each separate trade					X		From Pre-Developed Arch. BIM Model, Project team produces specification, and detail and link it to BIM Object through BIM-based Specification Tools; these tools has the ability to extract data into written documents for technical specifications. Some of detail can produce directly by BIM Design Tools. Hence, it is mandatory to let BIM involve into this tasks as much as possible.	BIM manage the specification, and link directly to the BIM object, BIM object type. This ability is useful for further model viewer, and application of using linked data.	- Pre-Developed BIM Arch. Model	Project Team	- Developed BIM Arch. Model without cost	Project Leader	BIM Design Tools; BIM Specification Application	- BIM Design Tool: - Autodesk Revit - Other software of other platform. BIM Specification Application: - e-Specs - linkman e - Speclink e	
98	Project leader	calculates	building costs based on customary prices and, if applicable, bills of quantities					X		From Developed Arch. BIM Model, Project Team start developing cost estimation work, calculate the building cost on customary prices by BIM Cost Estimation Tools. This prices is linked with BIM object in BIM Model. It is mandatory to use BIM tools for this task, since there are available tools for this action, and the bills of quantities can be exported from them.	BIM Cost Estimation Tools helps project team manage the cost, and control the cost linked to specific BIM objects.	- Developed BIM Arch. Model without cost - Customary prices	Project Team	- Developed BIM Arch. Model	Project Leader	BIM Cost Estimation	Plugins to BIM platform: - Innovaya Visual Estimating - RIB iTWO - Vico Takeoff Manager Using OpenBIM file Exchange - Nemetsch CostOS - Exactal CostX - Vico Takeoff Manager	
99	Architectural designer	produces	architectural plans and documentation describing the project to a level of detail as required for Planning or Building permit applications (based on the approved design)					X		Architectural Design develop the Developed Arch. BIM model to an appropriate level of development that required for building permit applications. This action need to be done in BIM Design tool to follow the BIM workflow.	BIM object library is suitable for this development, there are predefined BIM object available in each BIM platform. And, the preliminary set of drawing is automatically updated based on changes and addition.	- Developed BIM Arch. Model	Architectural designer	- Pre-final Developed Arch. BIM model	Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.	
100	Architectural designer	collates	additional technical documentation from technical specialist consultants; such as acoustic, thermal, fire safety, environmental and other appraisals as required by applicable legislation				X			Architectural Designer collates the additional technical documentation, then cross-link them to BIM objects in the BIM model as specifications. There are only some application available now in the market for doing this. Hence, it is just highly desirable for BIM involving.	BIM create an opportunity to control and manage the technical documents by BIM objects in early stages, which make other stakeholder work with them more efficiently.	- Pre-final Developed Arch. BIM model - Developed Technical Document	Architectural designer	- Final Developed Arch. BIM model	Project Leader	BIM Specification Application	- e-Specs - linkman e - Speclink e	
101	Project leader	assembles	documents required for building permit applications, draft and submit applications				X			From Final Developed Arch. BIM Model, Project leader extract necessary documents for building permit applications. There isn't an available tool for doing this directly in BIM Tools, it is better to use traditional software to assemble these documents. However, it is desirable to have a BIM Tools for this action. And the building permit documents is uploaded and shared with other stakeholders through BIM server.	BIM increasing the ability to control and extract data, documents and drawing quickly. However, a BIM server helps many stakeholders to control the information and document that they have.	- Final Developed Arch. BIM model - Developed Technical Document - Developed Drawing Set - Other documents	Project Leader	- Building permit application documentation set. - Specific model viewer for building permit application.	Local Authority	N/A	N/A	
102	Project leader	assists	during planning negotiations, monitor the approvals procedure (representing the client)					X		PL uses a specific BIM model viewer to explain during planning negotiations, and monitoring the approval procedures. BIM Integration Tools is ready for this action, hence, it is mandatory for BIM to involve in this actions.	Quick collaboration, quick visualisation for any part of the building through a 3D BIM model viewer.	- Building permit application documentation set. - Specific model viewer for building permit application.	Project Leader	- Additional files or certificates needed for approval procedure	Project Leader; Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office	
103	Project leader	prepares	files for additional certificates as required by national legislation or by the specific nature of the asset					X		PL prepare files and additional certificates, and upload them on BIM server, link with the BIM model. It is like Task [100], this file or certificate link with appropriate BIM object in the BIM model.	With help of BIM-based application, the file crosslink to BIM model is easily updated by responsible stakeholders.	- Final Developed Arch. BIM model - Additional files or certificates needed for approval procedure	Project Leader	- Approval from local authority - Approved Developed Arch. BIM Model	Project Leader; Owner	BIM Specification Application	- e-Specs - linkman e - Speclink e	
			tender action - convert the project design into a set of pre-contract documents setting out an unambiguous set of tender requirements - collate project															- Autodesk Naviswork

Stage	Workflow task				BIM involved priority scaling bigger is more priority					Hypothesis for BIM priority scaling	Benefit of BIM integration in this process instead of doing traditional way.	Type of Input Information	Information Provider / Process	Type of Output Information	Information Receiver	BIM Tools can be used in the market			
	No.	Who	Action	Description	0	1	2	3	4							5	Category	BIM Tools Example	
DEVELOP/DESIGN	105	Project leader	prepares	tender documentation in sufficient detail to enable a tender or tenders to be obtained for the project (i.e. a tender file to tenderers, including: the conditions of tender, the proposed form of contract, plans, specifications, possibly a bill of quantities and a list of contractual documents with their order of priority, etc.)						X	Combining the tender data and Approved Developed Arch. BIM Model, Project leader create a specific view for tendering process through BIM Integration Tools, and share it as a Tender Model Viewer. It is mandatory to use BIM tools in this action, since all of the tender documentation are digital, and using traditional drawing should be ignored in the new BIM environment.	A specific BIM model viewer bring a detail, unavoidable look for contractors to calculate their best offer to bid the project.	- Developed Tender data - Approved Developed Arch. BIM Model	Project Leader	- Developed Tender documentation - Developed Tender Model Viewer	Tenderer	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office	
	106	Tenderer	submits	a tender to the client			X					It is recommended to submit documents through BIM server by tenderer, Project Leader can manage and analyse the tender submission easily in next actions.	BIM environment create a good server to communicate and to transfer files between stakeholders.	- Developed Tender documentation - Developed Tender Model Viewer	Tenderer	- Developed Tender submission	Project Leader	BIM Server	- Autodesk BIM 360 - Other from other BIM platform
	107	Project leader	analyses	tender returns, make recommendations to client and enable him to pass construction contracts with each respective trade				X				Project Leader analyse the tender submission, examine the strength and weakness of each contractors. BIM is useful for managing the tender documents. Based on this analysis, Owner start pass construction contracts with each respective trade.	BIM as a file management tools to review the tender submission from tenderer	- Developed Tender submission	Project Leader, Owner	- Developed Construction Contracts	Owner	N/A	N/A
	108	Project leader	proposes	a construction schedule						X		From Task [88], Project leader develop the schedule in phases into a full construction schedule by the information from Approved Developed Arch. BIM Model. It is mandatory to use BIM Integration Tool for this action.	BIM Integration Tools create a scheduling more easily, and the scheduling is attached to specific BIM object for construction management.	- Schedule in phases - Approved Developed Arch. BIM Model	Project Leader	- Construction schedule	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office
	109	Project leader	updates and reviews	the project execution plan	X							Project Leader reviews the work with added information, and update the Preliminary Project Execution Plan from Task [87], this task is not involved to BIM.		- Preliminary Project Execution Plan - Other information	Project Leader	- Developed Project Execution Plan	Project Leader, Owner	N/A	N/A
	110	Project leader	updates and reviews	construction strategy						X		From Task [89], the construction strategy is analysed deeply and simulated in BIM Integration Tools to make appropriate updates for the construction strategy.	BIM Integration Tools provide construction management functions to schedule and 4D simulation.	- Report: Construction Strategy - Construction schedule - Approved Developed Arch. BIM Model - Developed Project Execution Plan	Project Leader	- Report: Construction Strategy updated	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office
	111	Lead designer	checks	design from specialist consultants for compliance with the general design							X	Lead Designer use BIM Model Checkers to check design from other consultant, then coordinate by BIM Integration Tools with the general design.	BIM Model Checkers provide the ability to quick review by apply rulesets to a building model. BIM Integration Tools can merge multiple models to form a federated model and to check for clashes, and coordination between specialist discipline of the project.	- Approved Developed Arch. BIM Model - Specific Developed BIM Model from consultant	Lead Designer	- Report: Developed design checking - Information for consultants update their BIM Model.	Project Leader, Specialist Consultants	BIM Integration Tools BIM Model Checkers; BIM Server for collaboration	- Autodesk Naviswork - DP Manager - iTWO - Vico Office BIM Model Checkers: - BIM Assure - Solibri Model Checker - Autodesk Revit Model Review - SmartReview APR
	112	Lead designer	integrates	as necessary into overall design documentation (including technical sub-disciplines of construction such as structural, mechanical, electrical, HVAC, geotechnical, fire security, acoustics, lighting, etc.)							X	Lead Designer receive the updated BIM model from other disciplines, combined in to a single BIM model if necessary. Then integrate them into overall conceptual design documentation.	BIM Design Tools easily link with tools of other BIM platform that disciplines would like to use. The design documentation, set up from the beginning, automatically change according to the revise of BIM models	- Approved Developed Arch. BIM Model - Specific Developed BIM Model from consultant	Lead Designer	- Developed Design Documentation - Integrated Developed BIM Model	Lead Designer, Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.
	113	Health and safety adviser	reviews and updates	health and safety strategy							X	From Integrated Developed BIM model, H&S simulate the strategy on BIM Integration Tools, analyse and modify the strategy to the most appropriate one for the project.	BIM Integration Tools has the temporary BIM object suitable for simulation this task.	- Integrated Developed BIM Model - Developed Project Execution Plan - Construction Schedule - Report: Construction Strategy updated	Health and Safety Adviser	- Developed Health and Safety Strategy.	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office
	114	Information manager	manages	information exchange level 3							X	From Task [93], Information manager continue managing, adding necessary parts, and configuration for the BIM server to guarantee the collaboration work between stakeholder in this state.	Easy to control the information flow, collaboration between related stakeholders	- Report: Information Exchange Level 2	Information Manager	- Report: Information Exchange Level 3	Project Leader,	BIM Server	- Autodesk BIM 360 - Other from other BIM platform
	115	Information manager	produces	end of stage report for client approval		X						Information manager examine the information exchange status of the project through BIM server, then create a report for Owner approval. BIM server is useful to manage and extract data for this task.	BIM server control the function of each type of user for specific stakeholder, has statistic data for information exchange to examine.	- Report: Information Exchange Level 3	Information Manager	- Decision: approval for information exchange process. - Changes for Information Exchange System	Owner	N/A	N/A
	116	Project leader	submits	documents required for building permit applications to Local Authorities			X					It is recommended to submit documents as a BIM model to the local authorities, but, most of local authorities work in a traditional way, which BIM is hardly involved into their work. There is a need of an online submission for construction project.		- Developed Design Documentation	Project Leader	- Building permit application documentation set.	Local Authority	N/A	N/A
	117	Local authority	issues	the building permit	X							It is not necessary for BIM integration in this task since it is related more in contract and business documents.		- Building permit application documentation set.	Local Authority	- Decision: issue the building permit.	Project Leader, Owner	N/A	N/A
	118	Architectural designer	develops	the developed design to provide execution and detail drawings at the required scale (typically 1:50, 1:20, 1:10; 1:5, 1:1)							X	From Approved Developed Arch. BIM Model, Architectural Designer continue develop it into Detail Arch. BIM Model. They prepare and generate the execution and detail at required scale, and enrichment the BIM model. It is mandatory to use BIM Design Tool for this actions.	BIM brings too many benefits in this stage, from available BIM object library to quickly develop the building model.	- Approved Developed Arch. BIM Model	Architectural designer	- Pre-Detail Arch. BIM Model without updated specification, detail and cost.	Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.
	119	Architectural designer	provides	calculations and specifications intended for construction and enabling contractors to build the works							X	From Pre-Detail Arch. BIM Model, Architectural Designer review the calculations and specifications. After that, they are updated into the BIM Model. It is mandatory to use BIM Design Tools and Specification Tools for this action.	BIM manage the specification, and link directly to the BIM object. BIM object type. This ability is useful for further model viewer, and application of using linked data.	- Pre-Detail Arch. BIM Model without updated specification, detail and cost.	Architectural designer	- Pre-Detail Arch. BIM Model without updated detail and cost.	Project Leader	BIM Design Tools; BIM Specification Application	- BIM Design Tools: - Autodesk Revit - Other software of other platform. BIM Specification Application: - e-Specs - linkman.e - Speclink.e
	120	Architectural designer	determines	all details including furniture and other elements that are specific to the project							X	Architectural designer added necessary details and furniture to enrich the BIM model. All of them is defined in BIM Design Tools, and link with BIM object through BIM Specification Tools.	There are BIM object available for this action in the market. They are from the manufacturer with detail BIM model as well as technical document. It is a good resource for Architectural Designer in this action.	- Pre-Detail Arch. BIM Model without updated detail and cost.	Architectural designer	- Pre-Detail Arch. BIM Model without updated cost.	Project Leader	BIM Design Tools; BIM Specification Application	- BIM Design Tools: - Autodesk Revit - Other software of other platform. BIM Specification Application: - e-Specs - linkman.e - Speclink.e
	121	Project leader	recalculate	building costs based on customary prices and possibly, bills of quantities incorporating quotations from specialist subcontractors							X	From Pre-Detail Arch. BIM Model, Project Team recalculate the cost with additional objects and information. They update these data into BIM Cost Estimation Tools, and link to the BIM object in the model. It is mandatory to use BIM tool in this action.	BIM Cost Estimation Tools helps project team manage the cost, and control the cost linked to specific BIM objects.	- Pre-Detail Arch. BIM Model without updated cost - Customary prices	Project Team	- Detail Arch. BIM Model	Project Leader	BIM Cost Estimation	- Plug-ins to BIM platform: - Inovaya Visual Estimating - RIB iTWO - Vico Takeoff Manager - Using OpenBIM file Exchange - Nomadic CostOS - Exactal CostX - Vico Takeoff Manager
122	Project leader	establishes	a project execution plan	X							Project Leader reviews the work with added information, and update the Developed Project Execution Plan from Task [109]. After this, the final Project Execution Plan is published.		- Developed Project Execution Plan - Other information	Project Leader	- Project Execution Plan	Project Leader, Owner	N/A	N/A	
123	Architectural designer	produces	architectural plans and documentation describing the project to a level of detail as required for building permit applications (based on the approved design)							X	Architectural Design develop the Detail Arch. BIM model to an appropriate level of development that required for building permit applications. This action need to be done in BIM Design tool to follow the BIM workflow.	BIM object library is suitable for this development, there are predefined BIM object available in each BIM platform. And, the preliminary set of drawing is automatically updated based on changes and addition.	- Detail Arch. BIM Model	Architectural designer	- Pre-final Detail Arch. BIM model	Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.	
124	Architectural designer	collates	additional technical documentation from technical specialist consultants, such as acoustic, thermal, fire safety, environmental and other appraisals as required by applicable legislation.							X	Architectural Designer collates the additional technical documentation, then cross-link them to BIM objects in the BIM model as specifications. There are only some application available now in the market for doing this. Hence, it is just highly desirable for BIM involving.	BIM create an opportunity to control and manage the technical documents by BIM objects in early stages, which make other stakeholder work with them more efficiently.	- Pre-final Detail Arch. BIM model - Detail Technical Document	Architectural designer	- Final Detail Arch. BIM model	Project Leader	BIM Specification Application	- e-Specs - linkman.e - Speclink.e	
125	Project leader	assembles	documents required for building permit applications, draft and submit applications	X			X				From Final Detail Arch. BIM Model, Project leader extract necessary documents for building permit applications. There isn't an available tool for doing this directly in BIM Tools, it is better to use traditional software to assemble these documents. However, it is desirable to have a BIM Tools for this action. And the building permit documents is uploaded and shared with other stakeholders through BIM server.	BIM increasing the ability to control and extract data documents and drawing quickly. However, a BIM server helps many stakeholders to control the information and document that they have.	- Final Detail Arch. BIM model - Detail Technical Document - Developed Drawing Set - Other documents	Project Leader	- Building permit application documentation set. - Specific model viewer for building permit application.	Local Authority	N/A	N/A	
126	Project leader	assists	during planning negotiations, monitor the approvals procedure (representing the client)		X					X	PL uses a specific BIM model viewer to explain during planning negotiations, and monitoring the approval procedures. BIM Integration Tools is ready for this action, hence, it is mandatory for BIM to involve in this actions.	Quick collaboration, quick visualisation for any part of the building through a 3D BIM model viewer.	- Building permit application documentation set. - Specific model viewer for building permit application.	Project Leader	- Additional files or certificates needed for approval procedure	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office	
127	Project leader	prepares	files for additional certificates as required by national legislation or by the specific nature of the asset							X	PL prepare files and additional certificates, and upload them on BIM server, link with the BIM model. It is like Task [100], this file or certificate link with appropriate BIM object in the BIM model.	With help of BIM-based application, the file crosslink to BIM model is easily updated by responsible stakeholders.	- Final Detail Arch. BIM model - Additional files or certificates needed for approval procedure	Project Leader	- Approval from local authority - Approved Detail Arch. BIM Model	Project Leader, Owner	BIM Specification Application	- e-Specs - linkman.e - Speclink.e	
128	Lead designer	checks	design from specialist consultants for compliance with the general design							X	Lead Designer use BIM Model Checkers to check design from other consultant, then coordinate by BIM Integration Tools with the general design.	BIM Model Checkers provide the ability to quick review by apply rulesets to a building model. BIM Integration Tools can merge multiple models to form a federated model and to check for clashes, and coordination between specialist discipline of the project.	- Approved Detail Arch. BIM Model - Specific Detail BIM Model from consultant	Lead Designer	- Report: Detail design checking - Information for consultants update their BIM Model.	Project Leader, Specialist Consultants	BIM Integration Tools BIM Model Checkers; BIM Server for collaboration	- Autodesk Naviswork - DP Manager - iTWO - Vico Office BIM Model Checkers: - BIM Assure - Solibri Model Checker - Autodesk Revit Model Review - SmartReview APR	

Stage	Workflow task				BIM involved priority scaling bigger is more priority					Hypothesis for BIM priority scaling	Benefit of BIM integration in this process instead of doing traditional way.	Type of Input Information	Information Provider / Process	Type of Output Information	Information Receiver	BIM Tools can be used in the market			
	No.	Who	Action	Description	0	1	2	3	4							5	Category	BIM Tools Example	
DESIGN	129	Lead designer	integrates	as necessary into overall design documentation (including technical sub-disciplines of construction such as structural, mechanical, electrical, HVAC, geotechnical, fire security, acoustics, lighting, etc.)						X	Lead Designer receive the updated BIM model from other disciplines, combined in to a single BIM model if necessary. Then integrate them into overall conceptual design documentation.	BIM Design Tools easily link with tools of other BIM platform that disciplines would like to use. The design documentation, set up from the beginning, automatically change according to the revise of BIM models.	- Approved Detail Arch. BIM Model - Specific Detail BIM Model from consultant	Lead Designer	- Detail Design Documentation - Integrated Detail BIM Model	Lead Designer, Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.	
	130	Health and safety adviser	reviews and updates	health and safety strategy						X	From Integrated Detail BIM model, H&S update the strategy on BIM Integration Tools, analyse and modify the strategy to the most appropriate one for the project.	BIM Integration Tools has the temporary BIM object suitable for simulation this task.	- Integrated Detail BIM Model. - Project Execution Plan - Construction Schedule - Report: Construction Strategy updated	Health and Safety Adviser	- Detail Health and Safety Strategy.	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office	
	131	Project leader	undertakes	tender action - convert the project design into a set of pre-contract documents setting out an unambiguous set of tender requirements - collate project documents necessary for contractors to appreciate the type, the quantity, the quality and the scope of their works so that contractors can calculate their best offer						X	Project leader extract necessary data from Integrated Detail BIM Model to make a set of document related to tender action. BIM Integration tools are available to do this actions.	Extracting data easily, quick generate the quantity take-off report and other report related to tender actions.	- Integrated Detail BIM Model	Project Leader	- Detail Tender data	Project Leader	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office	
	132	Project leader	prepares	tender documentation in sufficient detail to enable a tender or tenders to be obtained for the project (i.e. a tender file to tenderers, including: the conditions of tender, the proposed form of contract, plans, specifications, possibly a bill of quantities and a list of contractual documents with their order of priority, etc.)						X	Combining the tender data and Integrated Detail BIM Model, Project leader create a specific view for tendering process through BIM Integration Tools, and share it as a Tender Model Viewer. It is mandatory to use BIM tools in this actions, since all of the tender documentation are digital, and using traditional drawing should be ignored in the new BIM environment.	A specific BIM model viewer bring a detail, unavoidable look for contractors to calculate their best offer to bid the project.	- Detail Tender data - Integrated Detail BIM Model	Project Leader	- Detail Tender documentation - Detail Tender Model Viewer	Tenderer	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office	
	133	Tenderer	submits	a tender to the client			X					It is recommended to submit documents through BIM server by tenderer, Project Leader can manage and analyse the tender submission easily in next actions.	BIM environment create a good server to communicate and to transfer files between stakeholders.	- Detail Tender documentation - Detail Tender Model Viewer	Tenderer	- Detail Tender submission	Project Leader	BIM Server	- Autodesk BIM 360 - Other from other BIM platform
	134	Project leader	analyses	tender returns, make recommendations to client and enable him to pass construction contracts with each respective trade.				X				Project Leader analyse the tender submission, examine the strength and weakness of each contractors. BIM is useful for managing the tender documents. Based on this analysis, Owner start pass construction contracts with each respective trade.	BIM as a file management tools to review the tender submission from tenderer	- Detail Tender submission	Project Leader, Owner	- Construction Contracts	Owner	N/A	N/A
	135	Project leader	details and agrees	proposed construction schedule						X	From Task [108], Project leader develop the construction schedule in details by the information from Integrated Final BIM Model. It is mandatory to use BIM Integration Tools for this action.	BIM Integration Tools create a scheduling more easily, and the scheduling is attached to specific BIM object for construction management.	- Construction Schedule - Integrated Detail BIM Model	Project Leader	- Detail Construction schedule	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office	
	136	Project leader	establishes	handover and Commissioning Strategy						X	From Integrated Detail BIM Model, Project Leader analyse and establish a Handover Commissioning Strategy. It is mandatory to use BIM Tools in this task. There are BIM Facility Management Tool ready to support this action.	BIM FM Tools make it easy for both Owner and Contractor to handover and commissioning.	- Detail Construction schedule - Integrated Detail BIM Model	Project Leader	- Handover and Commissioning Strategy.	Project Leader, Owner	BIM Tools for Asset Management	- ARCHIBUS - FM Systems - AsseWORKS Solutions - FAMIS - W@TMA - Corigo - Autodesk BIM 360 Building Operation	
	137	Information manager	manages	information exchange level 4						X	From Task [114], Information manager continue managing, adding necessary parts, and configuration for the BIM server to guarantee the collaboration work between stakeholder in this stage.	Easy to control of the information flow, collaboration between related stakeholders	- Report: Information Exchange Level 3	Information Manager	- Report: Information Exchange Level 4	Project Leader,	BIM Server	- Autodesk BIM 360 - Other from other BIM platform	
	138	Information manager	produces	end of stage report for client approval		X						Information manager examine the information exchange status of the project through BIM server, then create a report for Owner approval. BIM server is useful to manage and extract data for this task.	BIM server control the function of each type of user for specific stakeholder, has statistic data for information exchange to examine.	- Report: Information Exchange Level 4	Information Manager	- Decision: approval for information exchange process. - Changes for Information Exchange System	Owner	N/A	N/A
	139	Contract administrator	prepares	contract administration			X					Based on Integrated Detail BIM Model, the Contractor has necessary information to prepare the contract. However, there is not available tool to support this action, to transform the construction task to a form of contract. Hence, BIM is useful, and recommend to use BIM server for this actions.	BIM Model provide fully information, and necessary task for Contractor assessment and prepare construction contract.	- Detail Construction schedule - Construction Contracts - Integrated Detail BIM Model - Handover and Commissioning Strategy - Report: Information Exchange Level 4 - Detail Health and Safety Strategy.	Contract Administrator	- Contract Administration	Project Leader, Owner	BIM Server	- Autodesk BIM 360 Docs - Other from other BIM platform
	140	Contract administrator	reviews	contracts and agreed project objectives				X				Then, the Contract Administrator review the contracts again after negotiating with the Owner. Finally, the Project Objectives is agreed between both sides. BIM is useful for this negotiation and review by specific model viewer for both stakeholders.	BIM Model viewer brings good visualisation, understanding about the project for both stakeholders.	- Contract Administration - BIM Model Viewer	Contract Administrator	- Final Construction Contract - Contract Project Objectives	Contract Administrator, Project Leader, Owner	BIM Server, BIM Model Viewer	BIM Server: - Autodesk BIM 360 Docs - Other from other BIM platform Model Viewer: - Autodesk BIM 360 Glue - Other from other BIM Platform
	141	Inhabitant/ End-user	uploads	information requested from contractors for the renovation process, if necessary					X			There is a need to create an UI for End-user to uploads requested information into BIM server for contractors. BIM server now has an ability to create a type of user for uploading documents. But, it is easier for End-user if they has a digital form, and fill into this form for necessary information, then submit them online. It is desirable to let BIM involved into this process.	BIM server help contractors manage the documents and information more efficiently.	- Information	End-user	- End-user Information Forms	Contractors	BIM Server	- Autodesk BIM 360 - Other from other BIM platform
	142	Project leader	oversees	the execution of the building contract		X						BIM model provides useful information for PL to oversee the execution of the building contract. But, it is analytical check of PL, and there is no support tool for this process. Hence, it is not recommend to let BIM involve in this action.	BIM Integration Tools help project leader manage task, objects, and oversees the activities in construction stage.	- Final Construction Contract - Detail Construction schedule - Contract Project Objectives	Project Leader	- Organised Execution	Project Leader, Owner	N/A	N/A
	143	Project leader	monitors	construction progress and compliance with plans						X		There are available BIM-based tools for monitoring the construction progress and compliance with design based on reality capture technologies. Project Leader use this tool to do this action, and it is highly desirable to use this in a project.	BIM tool for construction monitoring with 4D Capability helps PL compare schedules and track construction progress well.	- Integrated Detail BIM Model - Detail Health and Safety Strategy.	Project Leader, Contractor	- Pre-Finished Construction Works. - Construction Progress report	Project Leader, Owner	BIM Tools with 4D Capability	- Autodesk Revit + Naviswork Manage - Tekla Structures - DP Manager (Trimble) - ProjectWise Navigator and ConstructSIM Planner (Bentley) - Visual 4D Simulation (Innovaya)
144	Project leader	inspects	contractor's activity and execution of the works						X		Project Leader use BIM Tools for Surveying Site Conditioning to inspect contractor's activity and execution of the works. It is highly desirable to let BIM involve into this action, since inspection instrument is more advanced by reality capture technologies. There is more case study needed to make this mandatory.	BIM Tools have record the reality site, and has automatically rule check with the model.	- Pre-Finished Construction Works. - Construction Progress report	Project Leader, Contractor	- Finished Construction Work - Construction Inspection Report	Project Leader	BIM Surveying Site Conditions	- Bentley ContextCapture - Bentley Acute3D, Indoor Reality	
145	Project leader	considers	contractor's drawings						X		Project Leader use BIM Design Tools to manage and consider contractor's drawing. These drawing if cannot be performed by BIM Design Tools, is uploaded into BIM server, and link with responding components of the building. It is mandatory to use BIM in this action.	BIM Design Tool help project leader manage and link the drawing with suitable object quickly.	- Integrated Detail BIM Model - Contractor's drawings	Project Leader, Contractor	- Construction BIM Model	Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.	
146	Project leader	undertakes	random inspection of materials and quality of workmanship					X			There is some BIM-based tools for production planning and control that enable testing the efficacy of construction equipment. It is highly desirable to let BIM involve in this process due to its efficiency in managing building objects. But, there are some study cases needed to prove BIM involvement in this process to make it mandatory.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- Construction BIM Model	Project Leader, Contractor	- Construction Quality Control Report	Project Leader, Owner	BIM Tools for Planning and Control	- smartCON Planner add-in ArchiCAD - kinBIM - outPLAN - VisiLem	
147	Project leader	undertakes	final clarification of design details prior to implementation						X		Project Leader use BIM Integration Tools to clarify of design details. It is mandatory to use BIM in this action.	BIM Integration Tool create a general view for all discipline in the project, and visual well the building component parts as well as detailed link to that.	- Construction BIM Model - Integrated Detail BIM Model	Project Leader	- Final clarification of design details	Contractors, Project Leader	BIM Integration Tools	- Autodesk Naviswork - DP Manager - iTWO - Vico Office BIM Design Tools: - Autodesk Revit - Other software of other platform.	
148	Project leader	undertakes	process changes required by the client and issue relevant instructions to contractors						X		Project Leader review the construction again, then taking process changes from Owner, update it in BIM Construction model, then issue instructions to contractors. BIM is mandatory for this action, since all support tools are available.	BIM Design Tool help project leader update changes easily, combining with Integration Tools to make appropriate instructions to contractors.	- Construction BIM Model - Changes required by the client.	Project Leader, Contractor	- Final Construction BIM Model - Instructions to contractors	Contractors, Owner	BIM Design Tools, BIM Integration Tools	BIM Integration Tools: - Autodesk Naviswork - DP Manager - iTWO - Vico Office	
149	Project leader	checks	requests for payment issued by contractors			X					It is desirable to have a BIM Tool can check the payment issued by contractor upon BIM objects, or a group of BIM Objects. Project Leader can manage and organise the works more efficiently. However, the traditional way is still work well.	BIM manage the payment issued by BIM object, and by the progress, construction work of this object itself. Hence, the PL can easily check its status through a BIM Tools if available.	- Final Construction BIM Model - Finished Construction Work - Request for Payment	Project Leader	- Report: request for payment checked	Contractors, Owner	N/A	N/A	
150	Project leader	approves	requests for payment issued by contractors				X				It is desirable to have a BIM Tool manage the payment process for contractors. It is efficient for both Project Leader and Contractors to work within it, from submit payment form to payment approval.	BIM manage the payment issued by BIM object, and by the progress, construction work of this object itself. Hence, the PL can easily check its status through a BIM Tools if available.	- Report: request for payment checked	Project Leader	- Decision: payment approval	Contractors, Owner	N/A	N/A	
151	Project leader	checks	that all works have been carried out in accordance to contract, and that the building is fit for use and compliant to regulations and permits obtained						X		Project leader use BIM Site Surveying Conditions to check all the works have been carried out. The other method is checked and report by a specific viewer in BIM Integration Tools and BIM Checker Tools for its compliances to regulations and permits obtained.	BIM Model Checkers provide the ability to quick review by apply rulesets to a building model. BIM Integration Tools can merge multiple models to form a federated model and to check for clashes, and coordination between specialist discipline of the project.	- Final Construction BIM Model - Finished Construction Work	Project Leader	- Report: checked construction work	Project Leader, Owner	BIM Model Checkers, BIM Integration Tools, BIM Surveying Site Conditions	BIM Model Checkers: - BIM Assure - 5dRtM Model Checker - Autodesk Revit Model Review - SmartReview APR - Autodesk Revit + Naviswork Manage - Tekla Structures - DP Manager (Trimble) - ProjectWise Navigator and ConstructSIM Planner (Bentley) - Visual 4D Simulation (Innovaya)	
152	Project leader	organizes	eventual statutory procedures required to open the building						X		Project Leader use BIM Tools with 4D Capability to organise the planning for statutory procedures required. It is mandatory to use BIM.	BIM Tools with 4D Capability can link well with traditional construction project schedules as Microsoft Project, Primavera, ...	- Eventual Statutory Procedures	Project Leader	- Statutory procedures schedule	Project Leader, Owner, Contractors	BIM Tools with 4D Capability	- Autodesk Revit + Naviswork Manage - Tekla Structures - DP Manager (Trimble) - ProjectWise Navigator and ConstructSIM Planner (Bentley) - Visual 4D Simulation (Innovaya)	

CONSTRUCTION

Stage	Workflow task			BIM involved priority scaling bigger is more priority					Hypothesis for BIM priority scaling	Benefit of BIM integration in this process instead of doing traditional way.	Type of Input Information	Information Provider / Process	Type of Output Information	Information Receiver	BIM Tools can be used in the market				
	No.	Who	Action	Description	0	1	2	3							4	5	Category	BIM Tools Example	
USE	153	Project leader	oversees	preparation of as-built documentation						X	Project leader determine the preparation of as-built documentation, organise and schedule the plan for establishing as-built documentation. It is mandatory to use BIM Design Tools for overseeing this action.	BIM Design Tools help project leader create and foresee a set of as-built drawings; and, this set of drawing is extracted from Final Construction Model after modification for As-built model.	- Final Construction BIM Model	Project Leader	- Set of as-built documentation.	Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.	
	154	Project leader	checks	workmanship and compliance with contract documents						X	Project Leader use BIM Tools for Surveying Site Conditioning to checks workmanship and compliance with contract documents. It is highly desirable to let BIM involve into this action, since inspection instruments is more advanced by reality capture technologies. There is more case study needed to make this mandatory.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- Final Construction BIM Model - Finished Construction Work	Project Leader	- Report: checked workmanship.	Project Leader	BIM Surveying Site Conditions	- Bentley ContextCapture - Bentley Aucte3D Indoor Reality	
	155	Inhabitant/ End-user	updates	information about comfort conditions during renovation process							X	End-user need a specific model viewer and UI in a BIM server to update the information and comfort conditions during renovation process. Each End-user is linked with the room or apartment defined in BIM model. It is highly desirable to have an UI for this actions.	BIM Server easily collates End-user updates and informations.	- End-user experiences	End-user	- Renovation Process Comfort Conditions	Project Leader	N/A	N/A
	156	Inhabitant/ End-user	feels	comfort/ discomfort during the renovation process							X	End-user describe their feeling about comfort/discomfort during the renovation process, by a priority scaling. It is highly desirable to have an UI or BIM-based application for this actions and collates the information through BIM server.	BIM Server easily collates End-user updates and informations.	- End-user feelings	End-user	- Renovation Process Comfort Scale	Project Leader	N/A	N/A
	157	Project leader	supervises	handover to the client and building users as start of guarantee periods							X	It is highly desirable to let BIM involve in this process. BIM Assets Management Tools has an ability to managing the handover process based on Construction BIM Model.	BIM Assets Management Tools functioned for managing this actions	- Final Construction BIM Model - Finished Construction Work - Handover and Commissioning Strategy	Project Leader	- As-built Building	Owner	BIM Tools for Asset Management:	- ARCHIBUS - FM Systems - AssetWORKS Solutions - FAMIS - WebTMA - Corigo - Autodesk BIM 360 Building Operation
	158	Project leader	oversees	issue of as-built documentation and final accounts							X	Project Leader leads and oversees the issue of as-built documentation. The BIM model is updated to As-built level, and this model is capable of using in BIM Assets Management Tools. It is mandatory to use BIM in this actions.	BIM Design Tool help project leader manage and link the drawing with suitable object quickly.	- Final Construction BIM Model - As-built Building	Project Leader	- As-built BIM Model - As-built Documentation	Owner	BIM Design Tools	- Autodesk Revit - Other software of other platform.
	159	Project leader	applies for	for additional permits as required, enable possible monitoring by authorities during construction and produce documents to support registration of completion of the works with authorities, if necessary		X						As required by local authorities, Project Leader prepare a documentation set to apply for permits. BIM Design Tools is used to provide this set. BIM is useful for this action, but not recommended, because local authority usually prefer traditional way for doing this.	BIM Design Tool create a set of drawing for Project Leader to control this actions.	- As-built BIM Model - As-built Documentation - Required documents	Project Leader	- Permit document set	Local Authority	BIM Design Tools	- Autodesk Revit - Other software of other platform.
	160	Structural, Electrical, HVAC, water and waste designer	produces	architectural plans and documentation describing the project to a level of detail as required for Planning or Building permit applications (based on the approved design)							X	Designer generate the plans and documentations for permit application through BIM Design Tools. It is mandatory to use BIM.	BIM object library is suitable for this development, there are predefined BIM object available in each BIM platform. And, the preliminary set of drawing is automatically updated based on changes and addition.	- As-built BIM Model	Engineer (all)	- Permit application drawings	Project Leader	BIM Design Tools	- Autodesk Revit - Other software of other platform.
	161	Structural, Electrical, HVAC, water and waste designer	collates	additional technical documentation from technical specialist consultants; such as acoustic, thermal, fire safety, environmental and other appraisals as required by applicable legislation.							X	Designer generate the technical document and specifications for permit application through BIM Design Tools. It is mandatory to use BIM.	BIM create an opportunity to control and manage the technical documents by BIM objects in early stages, which make other stakeholder work with them more efficiently.	- As-built BIM Model	Engineer (all)	- Permit application specifications	Project Leader	BIM Specification Application	- e-Specs - linkman e - SpecLink e
	162	Project leader	monitors	revisions to construction contracts							X	It is desirable to use BIM for monitoring contract revision. There is some application related to this task, but there is more study cases needed.	BIM-based tool control well the construction contract, and manage it base on BIM model.	- Final Construction Contract - Contract Project Objectives	Project Leader	- Revised Contracts	Contractor; Owner	BIM Assets Management Tools	- Maximo (IBM) - WebTMA (TMA Systems)
	163	Project leader	monitors	construction schedule as agreed by contract							X	Using BIM Tools with 4D Capabilities, Project Leader monitor the construction schedule on contract. It is mandatory to use BIM in this action.	BIM Tools create a scheduling more easily, and the scheduling is attached to specific BIM object for construction management.	- Construction Schedule - As-built BIM Model - Revised Contracts	Project Leader	- Construction schedule result	Contractor; Owner	BIM Tools with 4D Capability	- Autodesk Revit + Naviswork Manage - Tekla Structures - DP Manager (Trimble) - ProjectWise Navigator and ConstructWise Planner (Bentley) - Visual 4D Simulation (Innovaya)
	164	Project leader	supports	the client to maximise the use of his investment							X	From As-built BIM Model, the FM BIM Model is created by PL. After that, choosing a facility management system is recommended. Project Leader and Owner list all the related actions and operation in this stage, and make estimation about the return of investment. It is mandatory to let BIM involve from the beginning of this stage by using FM BIM Tools.	FM BIM Tools has function as asset management, real estate and leasing management, capital planning, ... to support the use of investment.	- As-built BIM Model - As-built Documentation	Project Leader	- FM BIM Model - FM BIM Tools	Owner	BIM Assets Management Tools	
	165	Project leader	reviews	project performance and additional project information as required							X	Project leader review the project performance by some indicators as cost, time and quality. This review can be performed in As-built BIM Model and the cost tracking through all stage of the projects. It is desirable to use BIM Tools in this actions.	BIM Tools quickly check the As-built BIM model and real building for compare the quality. BIM Cost estimation provide cost information for all of the works, and also tracking the time in BIM 4D Tools.	- As-built BIM Model - As-built Documentation	Project Leader	- Report: Project Performance	Owner	BIM Integration Tools; BIM Tools with 4D Capability	BIM Integration Tools: - Autodesk Naviswork - DP Manager - ITWO - Vico Office 4D: - Autodesk Revit + Naviswork Manage - Tekla Structures - DP Manager (Trimble)
	166	Facilities management (FM) adviser	provides	advice to program planned maintenance and periodic performance testing							X	There is a need of maintenance planning and organisation for the building after renovation. FM adviser make schedule of periodical performance testing, which combined with specific maintenance intervention for building components. It is mandatory to use BIM in this action, since the FM BIM Model is already set up.	BIM FM Tools make it easy for both Owner and FM Adviser to set up a maintenance and operation plan, as well as reduce operating expense, risk and improve performances.	- FM BIM Model	Facilities management (FM) adviser	- Maintenance Plan	Project leader; Owner	BIM Assets Management Tools	- ARCHIBUS - FM Systems - AssetWORKS Solutions - FAMIS - WebTMA - Autodesk Building Operation - Corigo
	167	Sustainability adviser	monitors	sustainability performance							X	Sustainability performance is one of the most indicator for building renovation. But, there is not many BIM tools has this function. It is desirable to use BIM for fully sustainability monitoring.	Only FM Systems has the function of energy or water usage monitoring and WebTMA has the function of utility service management. It is useful as summarise and monitoring tool.	- FM BIM Model	Sustainability adviser	- Report: Sustainability performance	Sustainability adviser; Owner; End-user	BIM Assets Management Tools	- FM Systems - WebTMA
	168	Inhabitant/ End-user	updates	information about comfort conditions post renovation process							X	It is highly desirable to have a BIM-based application or tool for End-user to updates the information about comfort conditions after the renovation process. This information is linked with space management or room management in BIM FM Tools. End-user need a specific UI or mobile application that they can use for the whole life cycle of the building.	BIM FM Tools summarise and organise well the information received from End-user.	- User experiences	End-user	- FM BIM Model - Building comfort reports	Facilities management (FM) adviser	N/A	N/A
	169	Inhabitant/ End-user	feels	comfort/ discomfort during post renovation process							X	It is highly desirable to have a BIM-based application or tool for this action. It is the same with Task 168. In this UI, there is a specific part for End-user to describe discomfort - comfort range (ex. Scale 1-5 with 1 is discomfort).	BIM FM Tools summarise and organise well the information received from End-user.	- User experiences	End-user	- FM BIM Model - Building comfort reports	Facilities management (FM) adviser	N/A	N/A
	170	Inhabitant/ Owner	uploads	ad hoc information related to operational processes that may be useful for the renovation process							X	It is highly desirable to have a BIM-based server and application for both End-user and Owner share the information related to operational processes. These ad-hoc information maybe useful for the convenience of End-user and Owner when living in the building.	BIM based server help its user to share the information efficiently.	- End-user information - Owner information	End-user; Owner	- Operational information	End-user; Facilities management adviser	N/A	N/A
	171	Owner	monitors	The economic sustainability of the project							X	It is desirable to use BIM FM Tool for economic sustainability monitoring, since there is function in BIM FM Tool for capital planning, or cost management.	BIM FM Tools summarise the economic sustainability based on information collected from previous task.	- Project information	Facilities management adviser;	- Economic sustainability status	Owner	BIM Assets Management Tools	- WebTMA - AssetWORKS Solutions - Real estate and leasing management
172	Facilities management (FM) adviser	advises	for maintenance of the building and external works for upkeep of the client's investment							X	Based on the information from BIM FM Model and the maintenance plan, FM Adviser prepares the maintenance strategies and external works for upkeep the building. It is mandatory to update this information into BIM FM Model.	BIM FM Tools and BIM Integration Tools provide the FM adviser a full view on the current building to set up the maintenance plan.	- FM BIM Model - Maintenance Plan	Facilities management adviser;	- Maintenance strategy - Maintenance works	Project leader; Owner	BIM Assets Management Tools	- Maximo (IBM) - ARCHIBUS - FM Systems - AssetWORKS Solutions - FAMIS (Accruent) - WEBTMA	
173	Facilities management (FM) adviser	assists	with facility management, training, environmental monitoring, life-cycle strategy and energy-waste-water management procedures							X	FM Adviser works with FM Team for the facility management and other procedures in building operation. It is highly desired to use BIM in this process, since all of this function is available now in some BIM FM Tools.	BIM FM Tools has the function for facility management efficiently, as well as function to monitoring and generating monthly report for environmental and energy-waste-water issues.	- FM BIM Model - Environmental, energy-waste water information.	Facilities management adviser; FM Team	- Report: Facility Management - Report: Environmental Monitoring - Life-cycle Strategy - Report: Energy waste water management - Training documents	Project Leader; Owner; FM Team;	BIM Assets Management Tools	- FM Systems - WebTMA	
174	Project leader	prepares	documentation to obtain permits for possible changes of use, renovation or redesign							X	In case the building need renovation or redesign, from As-built BIM Model, and FM BIM Model, Project leader prepares appropriate documents to obtain the permits. The building is ready for next cycle of renovation. It is mandatory to use BIM in this task, since all BIM Model is ready.	BIM Design Tools help project leader organise the as-built drawing and documents to obtain permits quickly from available BIM model.	- FM BIM Model - As-built BIM Model - As-built Documentation	Project Leader	- Renovation documents	Local Authority; Owner	BIM Design Tools	- Autodesk Revit - Other software of other platform.	
175	Project leader	sets out	procurement documentation and tender procedures for facility management, maintenance, and possibly renovation							X	Project Leader use BIM tools to sets out these documents, and manage the tender procedures. The information from As-built BIM Model and FM BIM Model are combined and export to BIM Integration Tools for doing this task. It is mandatory to use BIM Tools.	BIM Integration Tools provide the ability to generating and managing documentation efficiently.	- FM BIM Model - As-built BIM Model - Renovation Documentation	Project Leader	- Procurement documents - Tender documents	Owner; Tenderer	BIM Integration Tools	- Autodesk Naviswork - DP Manager - ITWO - Vico Office	
176	Technical adviser	undertakes	end of life audit							X	It is desirable to use BIM Tool for this task. But there is no BIM Tools available in the market provide this function to audit end of life of a building. Technical adviser can perform the input data in BIM Integration Tools to use its quantity take off function for this task.	BIM Integration Tools provide quantity take off function, combined with additional parameter to manage the treatment and disposal of construction material in this task.	- FM BIM Model - As-built BIM Model	Technical Adviser	- Report: End of life audit	Owner; Project leader	BIM Integration Tools	- Autodesk Naviswork - DP Manager - ITWO - Vico Office	
177	Technical adviser	recommends	demolition and/or rehabilitation strategy							X	It is desirable to use BIM Tool for analyse and recommend demolition and rehabilitation strategy. BIM Integration Tools provide an ability to do that by 4D Simulation.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model - Report: End of life audit	Technical Adviser	- Report: Demolition and rehabilitation strategy.	Owner; Project leader	BIM Integration Tools	- Autodesk Naviswork - DP Manager - ITWO - Vico Office	
178	Technical adviser	provides	services for a new cycle taking the built asset through stages from 0. Initiative to 4. New Use. Possibly partial dismantling under controlled conditions if required							X	From BIM FM Model, Technical Adviser make analysis to examine the built assets, and makes partial dismantling if necessary. It is desirable to use BIM in this part to get sufficient information for Technical Adviser to make analysis. But, there is no available BIM Tools that has the function of this task.	The FM BIM Model has information through the Usage stage of the building, make it easy for Technical Adviser perform their services.	- FM BIM Model	Technical Adviser	- Built asset analysis - Partial dismantling works.	Owner; Project leader	N/A	N/A	
179	Project leader	schedules	works for re-wamping							X	From As-built BIM Model, Project Leader schedules all the work for re-wamping. It is mandatory to use BIM Tools in this task.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model - Built asset analysis - Partial dismantling works.	Project Leader	- Re-wamping schedule	Owner; Project Leader; End-user	BIM Integration Tools	- Autodesk Naviswork - DP Manager - ITWO - Vico Office	

Stage	Workflow task			BIM involved priority scaling bigger is more priority					Hypothesis for BIM priority scaling	Benefit of BIM integration in this process instead of doing traditional way.	Type of Input Information	Information Provider / Process	Type of Output Information	Information Receiver	BIM Tools can be used in the market				
	No.	Who	Action	Description	0	1	2	3							4	5	Category	BIM Tools Example	
END OF LIFE	180	Health and safety adviser	considers	Health and Safety when revamping						X	From A-s-built BIM Model, H&S analyse the building, and consider H&S strategies and requirement for revamping process. It is mandatory to use BIM Tools in this process.	BIM Integration Tools has the temporary BIM object suitable for simulation this task.	- A-s-built BIM Model - Partial dismantling works. - Revamping schedule	Health and Safety Adviser	- H&S Strategies and requirement for revamping	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - ITWO - Vico Office	
	181	Project leader	sets out	procurement documentation and tender procedures for revamping						X	From A-s-built BIM Model, Project Leader prepare the procurement document and tender procedures for revamping process. It is mandatory to use BIM Tools.	BIM Integration Tools provide the ability to generating and managing documentation efficiently.	- A-s-built BIM Model - Partial dismantling works. - Revamping schedule - H&S Strategies and requirement for revamping	Project Leader	- Revamping Procurement documents - Revamping Tender documents	Owner, Tenderer	BIM Integration Tools	- Autodesk Naviswork - DP Manager - ITWO - Vico Office	
	182	Client/Owner	enables	facility shutdown and closing off of the site. Identify services (electricity, gas, fluids ...) in order to make the building safe for decommissioning	X							It is not necessary for BIM integration in this task since it is the decision of the Owner after receiving information from Project Leader.	N/A	- Built asset analysis - Partial dismantling works. - Revamping schedule	Owner	- Decision: facility shutdown	Project Leader, End-user	N/A	N/A
	183	Project leader	applies for	any necessary closure permits, preparing documentation to obtain permits from authorities for dismantling or revamping as required		X						BIM is useful to provide the documentation, but is not recommend to use in this task, since the legal procedure for closure permits does not mention about BIM at this moment.	BIM prepare well the documentation for this application of the Project Leader.	- Partial dismantling works. - Revamping schedule - H&S Strategies and requirement for revamping	Project Leader	- Dismantling or Revamping Pending	Local Authority	N/A	N/A
	184	Project leader	identifies	Identify raw materials, waste and materials to be recycled						X	Using BIM Integration Tools, Project Leader quickly define the quantity of raw materials, waste and materials to be recycled from specific building components. It is mandatory to use BIM Tools in this task.	BIM Integration Tools provide quantity take off function, combined with additional parameter to manage the treatment and disposal of construction material in this task.	- A-s-built BIM Model - FM BIM Model	Project Leader	- Report: Materials & Waste	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - ITWO - Vico Office	
	185	Project leader	arranges	removal and treatment of contaminated materials, removal of structures, treatment and/or removal of contaminated soil and groundwater				X				It is desirable to let BIM involved into this task. The arrangement of removal and treatment is performed in 4D BIM Integration Tools.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- A-s-built BIM Model	Project Leader	- Report: Removal and treatment arrangement.	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - ITWO - Vico Office
	186	Project leader	selects	appropriate landfill (if necessary)	X							It is not necessary for BIM integration in this task since it is the decision of the Project Leader, and it is the result of site analysis.	N/A	- Site Analysis	Project Leader	- Landfill location	Project Leader, Owner	N/A	N/A
	187	Project leader	proposes	measures to control noise, air and ground water pollution		X						It is useful to use BIM in this task to determine the measurement point for control noise, air and water pollution, but it is not recommend since there is no available BIM Tools has this function in the market.	N/A	- A-s-built BIM Model	Project Leader	- Pollution Control Strategy	Project Leader, Owner	N/A	N/A
	188	Local authority	gives	permits for dismantling	X							It is not necessary for BIM integration in this task since it is the decision of the Local Authority	N/A	- Dismantling or Revamping Pending	Local Authority	- Dismantling Approval	Project Leader, Owner	N/A	N/A
	189	Project leader	schedules	works for dismantling						X	Project Leader use 4D BIM integration Tools to make the schedule for dismantling work. It is mandatory to use BIM Tools in this task.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- A-s-built BIM Model	Project Leader	- Dismantling schedule	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - ITWO - Vico Office	
	190	Project leader	sets out	procurement documentation and tender procedures for dismantling						X	Project Leader use 4D BIM Integration Tools to export procurement documentation and tender procedures for dismantling. It is mandatory to use BIM Tools in this task.	BIM 4D Integration Tools has an ability to extract document for procurement and tender procedures.	- A-s-built BIM Model - Dismantling schedule	Project Leader	- Dismantling Procurement documents - Dismantling Tender documents	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - ITWO - Vico Office	
	191	Project leader	inspects	dismantling of equipment and service disconnections			X					Project Leader inspects dismantling of equipment and service disconnections by normal way. But, it is recommended to use BIM to manage the inspection of equipment and services.	BIM Integration Tools create new parameter to supervise the dismantling of equipment and services.	- A-s-built BIM Model - Dismantling schedule	Project Leader	- Dismantling Inspection Report	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - ITWO - Vico Office
	192	Project leader	coordinates	demolition under controlled conditions to ensure health and safety of site operatives and the general public						X	It is mandatory for PL to use BIM Tools to coordinating and monitoring the demolition process. The process is simulation by step in 4D BIM Integration Tools.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- A-s-built BIM Model - Dismantling schedule - H&S Strategies and requirement for demolition	Project Leader, H&S adviser	- Site report	Project Leader, Owner	BIM Integration Tools	- Autodesk Naviswork - DP Manager - ITWO - Vico Office	
	193	Sustainability adviser	considers	waste management, environmental impacts, contamination	X							It is useful but not recommended for sustainability adviser to monitor and consider the waste management, environmental impacts and contamination from the information of BIM Model. Since, there is no available BIM Tools in the market for this purpose.	N/A	- A-s-built BIM Model - Dismantling schedule	Sustainability adviser	- Report of waste management	Project Leader,	N/A	N/A
	194	Contractor	selects	appropriate landfill (if necessary)	X							It is not necessary for BIM integration in this task since it is the decision of the Local Authority	N/A	- Landfill location	Contractor	- Updated landfill location	Project Leader	N/A	N/A
	195	Contractor	arranges	removal and treatment of contaminated materials, removal of structures, treatment and/or removal of contaminated soil and groundwater				X				It is desirable to let BIM involved into this task. The arrangement of removal and treatment is performed in 4D BIM Integration Tools.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- A-s-built BIM Model - Report: Removal and treatment arrangement	Contractor	- Finished dismantling works	Project Leader,	BIM Integration Tools	- Autodesk Naviswork - DP Manager - ITWO - Vico Office
196	Health and safety adviser	considers	Health and Safety when dismantling					X			It is highly desirable for H&S Adviser to consider the H&S through the 4D BIM Integration Tools.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- A-s-built BIM Model - H&S Strategies and requirement for demolition	H&S Adviser	- H&S Dismantling report	Project Leader	BIM Integration Tools	- Autodesk Naviswork - DP Manager - ITWO - Vico Office	

APPENDIX II:

TABLE OF DEEP ANALYSIS FOR ACTIVITIES IN RENOVATION PROCESS OF PUBLIC WORKS

The tasks highlighted in green colour are those which are different from the private works.

Stage	Workflow task				BIM involved priority scaling bigger is more priority					Hypothesis for BIM priority scaling	Benefit of BIM integration in this process instead of doing traditional way.	Type of Input Information	Information Provider / Process	Type of Output Information	Information Receiver	BIM Tools can be used in the market		
	No.	Who	Action	Description	0	1	2	3	4							5	Category	
INITIATIVE	1	Inhabitant/ End-user	needs	a renovation intervention				X			A renovation intervention is called out by the inhabitant/ End-user when the user notices a visible failure at the early stage and which has to be addressed. Eg. A broken window or a damaged wall, which is to be reported to the Owner or the facility manager to make an intervention before the failure. Traditionally, End-user report this problem by a call, an email, or a conversation to a responsible person. However, BIM is recommended to be integrated from this task. In this case, End-user need a user-friendly software interface and can interact with object in this model viewer software, add the failure based on type, write description, and upload the photos. Then this information is to be transferred to BIM server, which link to the BIM object in FM software for renovation.	End-user can report the failure in the building in more precise location, with image or photos, if necessary Facility Management team and Owner have more information to decide the renovation intervention is needed or not	-Evidences	End-user	- Picture - Information: location, type of failure, description.	Owner; Facility Management Team	BIM Model Viewer	
	2	Inhabitant/ End-user	communicates	the need of renovation to the owner				X			Following task 1, once the failure or problem is reported by the End-user, there should be an effort from owner, or facility management team needed to keep tracking of reported information. Then, a BIM tool for managing the communication is recommended, since it controls the information more efficiently. For example, there is a part of wall damaged, all reported information about this wall will be collected, and linked to the BIM object of this wall in FM software.	The owner have more accurate information about the failure in building, its location, its type and its level of damage by information from many people. Hence, the site inspection check or maintenance schedule could be decided based on the urgency of the problem.	- Picture - Information: location, type of failure, description.	End-user or FM Team	Information: failure report	Owner	BIM Tools for Asset Management	
	3	Client/Owner	makes	a site inspection to evaluate the necessity and the urgency of intervention					X		Owner could decide to make a site inspection alone at first or with a site inspector from facility management team, or another service company if the building doesn't have its FM team. In traditional way, this task is still implemented well but, with BIM tool for asset management that has full developed BIM FM model, Owner has full information with ongoing update from inspection activities to make their decision about the necessity of a renovation. It is desirable to get BIM involved in this task for a future record and maintenance.	- The site inspector knows exactly the location, type and level of damage of a failure. They also can inspect parts of building that is affected by the failure to determine the urgency of intervention. Result of this inspection is updated and linked into BIM object in BIM FM model. - Otherwise, the Owner manages more efficiently site inspection activities, by better ongoing updates to the building, the Owner has an accurate record of building as a base model for future maintenance or renovation.	- Information: Failure report - BIM FM Model	Owner or FM Team	- Information: failure assessment - Updated BIM FM Model	Owner	BIM Tools for Asset Management	
	4	Client/Owner	agrees	on the necessity of a renovation				X			In fact, Owner can have the ability to assess the necessity of a renovation or not hence, sometimes they need to hire a third party for these assessment. BIM is recommended in this process for both owner and third party decision as well as better collaboration between the Owner and third party if it is necessary.	Owner or third party has fully viewed of the building through BIM FM model. If a third party is necessary, Owner can collaborate with third party through BIM FM Tools, and get feedback and review as well.	- Information: failure assessment - Updated BIM FM Model	Owner or Third-party service	- Decision: approve for renovation process.	Owner	BIM Tools for Asset Management	
	5	Client/Owner	appoints	an adviser to provide a cost-benefits appraisal and a preliminary business case	X						It is not necessary for BIM integration in this task. Owner can still perform well by the traditional way.	N/A	Owner	- Adviser appointment	Adviser	NA		
	6	Client adviser	provides	a cost-benefits appraisal				X			From current financial situation of the Owner as well as estimating cost for the renovation, Client Adviser starts cost-benefits analysis procedure. Traditional way still work well, however, BIM is recommended in this process due to its ability of early conceptual cost estimation with high accuracy, which help to make better appraisal. For example, if a building is partly renovated or fully renovated by each stage, Adviser are aware which part of building related to renovation works are completed by each stage, and also affected occupied space in the building. It makes the cost-benefits more accurately.	BIM FM Model provide current financial information of a building like real estate and leasing management, current operation and maintenance works as well as space management	- Information: failure assessment - BIM FM Model	Client Adviser	- Information: Cost-benefits report	Owner	BIM Tools for asset management that provide financial information of building	
	7	Client/Owner	evaluates	cost-benefits of a renovation		X	X				In this task, Owner can have a background to review the cost-benefits report or not. If not, they can use traditional way to evaluate the report, if they are able to review, using BIM Tools is highly recommended.	BIM FM Model gives Owner full access to any information they need to review the cost-benefits.	- Information: Cost-benefits report	Owner	- Decision: approve for next task.	Client Adviser	BIM Tools for asset management that provide financial information of building	
	8	Client adviser	prepares	preliminary business case which can be used for initial exploration of financing needs and options such as third party loans and Energy Performance Contracts (EPCs)				X			BIM can be useful in this task by quickly generate energy performance analysis from the BIM FM Model of the current building, which is an important indicator for Energy Performance Contract. With this, the business case can be more accurate, however, with the limited ability of BIM Tools today, maybe, it is better to do this task by traditional way.	BIM FM Model has a ability to link with other BIM Tools for Energy Analysis, provide an early assessment about the Performance of the building as well as current situation of the building. This information are useful for preparing preliminary business case.	- BIM FM Model - Result from other linked BIM Tools	Client Adviser	- Preliminary Business Case	Owner	NA	
	9	Client/Owner	considers	available budget and opportunities to apply for public funding	X						The owner now evaluates the data and strategies provided by Client adviser and thereafter decision is made to proceed further. The action of BIM doesn't seem to be necessary to be a high priority as its to examine the available budget and existing opportunities to apply for public funding.	- Budget availability and public funding opportunities	Owner / Client Adviser	- Information to make decision to start renovation process	Owner	BIM Server		
INITIATION	10	Client/Owner	decides	to undertake a renovation process	X						It is not necessary for BIM integration in this task. It relate to the Owner business situation.	- Information to make decision to start renovation process	Owner	- Decision: to undertake renovation process	Owner	NA		
	11	Client/Owner	appoints	a project leader to manage the renovation project	X						It is not necessary for BIM integration in this task	- Information about project leader	Owner	- Decision: to appoint project leader	Owner; Project Leader	NA		
	12	Project leader	identifies	clients/owner needs and user requirements				X			Project leader (PL) need to consider the integration of BIM from this early task to get its benefits. From BIM FM Model (if available), PL identify the Owner need as well as End-user requirement based on the information on previous actions. Otherwise, PL has the ability to know exact which part of building need which renovation works, and End-user that be affected by the renovation works. Anyway, BIM Tools can provide a communication system between PL and End-user to get their requirements. A BIM server need to be set up from this task.	BIM FM Model brings essential information for PL, combining with the report from End-user, Owner, PL identify the needs and requirements quickly and efficiently. If there is a BIM Tools which has function as communication, surveying, the PL will get their information from End-user in detail.	- BIM FM Model - Information: all of previous report and assessment	Project Leader	- Data: Owner needs, User requirements.	Project Leader; Owner; End-user	BIM Tools for Asset Management	
	13	Project leader	identifies	other public administrations' objectives				X			It is necessary to have all the related public administration's objectives in the BIM 5 server by the PL in the form of document or report which has to followed considered as the project progresses into different stages.	BIM environment creates a good server to communicate and share files between stakeholders.	- Detailed public administration's objectives and requirements	Local Authority	- Data / information to be assigned or considered into the project at an early stage	Project Leader; Owner	BIM Server	
	14	Project leader	compiles	available information covering regulatory, infrastructure and geotechnical conditions		X					If the infrastructure surrounding building is not complex that can be defined as a BIM object, it is recommended to using BIM. However, most of the BIM Tools today is not fully available to deal with infrastructure and geotechnical conditions. Hence, PL should comply them as information in other softwares.	Infrastructure BIM object could be useful as a source of data for the content of feasibility study and redesign stage, as well as through the whole design stage.	- Information: regulatory, infrastructural and geotechnical properties	Project Leader	- Information: regulatory, infrastructural and geotechnical properties	Project Leader	NA	
	15	Project leader	identifies	additional site investigations required including surveys of existing buildings and structures				X			From BIM FM Model, with information from previous task, PL identify parts of building that need further investigation. PL can markup in a BIM Model Viewer. Then, this information and markup can be transfer to Site surveyor, for the accuracy and detail of site investigation. PL should set a initial model view definition for site surveyor to highlight areas of failure or concern.	BIM increasing the collaboration between PL and related stakeholder. PL can also identify the type of surveyor, the information they need from site surveyor, which problem should be checked in the building, for example: checking the durability of the structure in specific beam or columns; checking water penetration through a suspicious damaged wall.	- BIM FM Model - Information from previous tasks	Project Leader	- Site investigation location - Type of site investigation - Needed condition data - Model View Definitions	Project Leader; Owner	BIM Model Viewer	
	16	Client/Owner	appoints	a site surveyor	X						It is not necessary for BIM integration in this task. Owner can still perform well by the traditional way.	- Type of site investigation	Owner	- Decision to appoint a site supervisor	Site Surveyor	NA		
	17	Site surveyor	carries out	measured surveys and condition surveys of existing structures or buildings on site (site survey), measuring each room and building component in order to return a geometrical representation of the building to be renovated				X			The traditional measurement is ok, but it is better to use laser scanning, photogrammetry technologies to rapidly compile point cloud data (PCD), which can be used in BIM models. It is highly desirable for BIM involving from this process, since there are software tools that available in the market for this task.	PCD can be put into the BIM model as reference model, and can be tagged to, however, the technology for scanning to BIM is still developing PCD should be used as a reference model to build the BIM model of existing building.	- Type of site investigation - Site investigation location	Site surveyor	- Point Cloud Data - Geometrical data - Condition data	Site Surveyor Project Leader	Point Cloud Data Tools	
	18	Site surveyor	documents	the present condition of the property, highlighting areas of failure or concern				X			Site surveyor transform the Point Cloud Data, geometrical data to a BIM model of existing building. The condition data should be included in this BIM model as well. Then, they set the model viewer following the definitions from PL to show the present condition of the property and highlight areas of failure or concern. It is mandatory that all of this task need to be conducted in BIM Tools. It is recommended that the Site surveyor should use a third-party in case they cannot operate BIM model.	BIM is useful to highlight areas of failure or concern in different model viewer definitions. Anyway, creating BIM model from early could benefits the whole procedure of the project if the building doesn't have BIM FM model itself.	- Point Cloud Data - Geometrical data - Condition data	Site Surveyor	- BIM Model for existing building - Specific model view	Site Surveyor Project Leader	Point Cloud Data Tools	BIM design tools
	19	Site surveyor	identifies	causes of past, or ongoing, deterioration and issues that need attention to prevent serious damage				X			Site surveyor identify these issues, then markup and input into BIM model as an associated data in maintenance stage. However, these data should be showed in BIM Model Viewer as well, which makes the collaboration efficiently.	BIM is useful to link the data and object, creating a data set for PL to make decision in next tasks	- Data: causes and issues of deterioration	Site Surveyor	- Updated BIM Model	Site Surveyor Project Leader	BIM Design Tools	
	20	Site surveyor	identifies	HVAC distribution and size of each building service component				X			Site surveyor identify building services system, updated into BIM model with useful data as building services distribution system and size.	MEP systems can easily model in BIM design tools, then combined with previous BIM model.	- Data: building services distribution and size	Site surveyor	- Updated MEP BIM Model	Site Surveyor Project Leader	BIM Design Tools	
	21	Site surveyor	identifies	materials and classify according to environmental issues				X			Site surveyor identify the materials of building components, classify them, modeling and updated in original BIM model by changing type of building components.	BIM design tools provide the ability to change building components type, material and classify easily and massively.	- Data: materials and classify	Site surveyor	- Updated MEP BIM Model	Site Surveyor Project Leader	BIM Design Tools	
	22	Site surveyor	combines	the scanning data with installation schemes and existing drawings				X			Site surveyor combining all of previous BIM Model to a single model to delivery to the Project leader. They check the model with Point Cloud Data, existing drawings of the building to provide the consistency in the final BIM Model. It is mandatory to use BIM Tools to do all this task since there are many powerful tool for this available in the market.	Easy to check, combining different models with high accuracy and precision.	- Existing drawings - PCD Data - All of previous data from previous survey	Site surveyor	- Existing building BIM Model	Project Leader	BIM Design Tools; BIM Integration Tools	
23	Project leader	sets out	basic planning principles and possible construction strategies				X			From combined BIM model, PL sets out planning principles and possible construction strategies as a report. PL could use common MS softwares for this, it is not necessary to use BIM in this task. But, the report need to be linked into BIM server for later tasks.	BIM is useful assessment tool for PL, since they have a digital version of existing model. They can try and test some possible construction strategies as well.	- Existing building BIM Model	Project Leader	- Report: planning principles and construction strategies	Owner	BIM Model Viewer		
24	Project leader	examines	how the project can meet stated requirements and aspirations				X			It is mandatory for PL to use BIM tools to examine project that meet stated requirements and aspirations. There are available BIM Model Checker now that PL can added rules and automatically check the model with tool, and export the report about this.	BIM Model checkers have the ability for user to manually identify ruleset or using predefined ruleset to check the model. It also can generate the report of error.	- Existing building BIM Model - Ruleset of requirements and aspirations	Project Leader	- Report: requirements and aspirations that meet or not meet.	Owner	BIM Model Checker		
25	Project leader	informs	the client of technical and statutory constraints the project has to satisfy	X						It is not necessary for BIM integration in this task	- Report: requirements and aspirations that meet or not meet.	Owner		Owner				
26	Project leader	prepares	feasibility studies and assessment of options to enable the client to decide whether to proceed				X			PL can use BIM tools to do the feasibility study. Data from BIM Model can be useful to estimate aspects related to the existing building before and after renovation. However, it should not be mandatory since there are other model tool available for PL.	BIM provide information to solve the assessment of this action	- Existing building BIM Model - Client needs	Project Leader	- Report: feasibility studies and assessed options	Owner	BIM Design Tools; BIM Integration Tools		
27	Project leader	investigates	expected budget requirements				X			PL can use BIM tools for quick estimation of budget requirements based on feasibility study report. But, it is not mandatory because there are only few BIM-based tools that can support well the budget requirements expectation task.	Most BIM platform enable immediate extraction of item counts and area and volume calculations for the building components and materials. It helps the PL for first budget requirements expectation.	- Existing building BIM Model - Report: feasibility studies and assessed options	Project Leader	- Report: budget requirements	Owner	BIM Cost Estimation		
28	Project leader	analyses	the kind of intervention and the tasks to be developed				X			PL use BIM model to simulate and check the kind of intervention and developed tasks. It is more easy to manage the kind of intervention and tasks in BIM-based tool than in a traditional way.	BIM Model Integration Tools provide common functions that are construction planning, scheduling and 4D simulation. It is useful for PL to simulate the intervention and task needed in the building.	- Existing building BIM Model - previous reports	Project Leader	- Data: kind of intervention and developed tasks.	Owner	BIM Integration Tools		
29	Project leader	defines	the project organisational structure and range of consultants and others to be engaged for the project, including definition of responsibilities				X			Based on report of kind of intervention and tasks to be developed, the project organisation need to be early defined in type of consultants, and number of consultant. Defined them early made the collaboration through BIM cloud-based application more efficiently as well as prepare an appropriate BIM server for the project.	Creating type of user in BIM cloud-based application, which increasing the collaboration between them as well as reducing the interdependency between the BIM tools each discipline use.	- Data: kind of intervention and developed tasks.	Project Leader	- Organisational structure - Type of users	Project Leader Owner	BIM cloud-base application		
30	Project leader	evaluates	if it is necessary to appoint an external professional	X						The project leader now evaluates the data and studies about the project intervention from the above tasks, and thereafter decision is made to appoint an external professional if required. The action of BIM implementation is not necessary as it an evaluation and decision process by the Project leader alone.	- Developed kind of intervention	Project Leader	- To appoint external professional	Site surveyor	NA			
31	Client/Owner	appoints	designers to be engaged for the project (such as structural, mechanical, electrical, HVAC, geotechnical, fire security, acoustics, lighting, etc.)	X						It is not necessary for BIM integration in this task. Owner can perform this task with the help of Project Leader according to the type of intervention analysed in the above tasks.	- Developed kind of intervention	Owner; Project Leader	- Decision to appoint designers / Engineers	Engineer (All)	NA			
32	Project leader	defines	possible procurement strategy		X					Procurement strategy should be defined to get benefit from BIM. Traditional procurement strategy should be analysed carefully about the integration of BIM in this strategy. As usual, a good BIM model help PL a lot to identify which strategy is appropriate for the project	Integrated Project Delivery is a good procurement strategy that fit for BIM, since the projects are distinguished by effective collaboration among owner, designers, contractors from early design through project handover.	- All previous report	Project Leader	- Report: procurement strategy	Project Leader Owner	NA		

Stage	Workflow task				BIM involved priority scaling bigger is more priority					Hypothesis for BIM priority scaling	Benefit of BIM integration in this process instead of doing traditional way.	Type of Input Information	Information Provider / Process	Type of Output Information	Information Receiver	BIM Tools can be used in the market			
	No.	Who	Action	Description	0	1	2	3	4							5	Category		
CONCEPT DESIGN	33	Project leader	identifies	the procurement method	X						It is not necessary for BIM integration in this task since it is related more in contract and business documents.						N/A		
	34	Project leader	sets out	a project brief		X					It is recommended to extract the data from BIM model and linked files to set out a project brief. PL could combine necessary data from previous task for the brief.	Quickly combining necessary data for a project brief	- Existing building BIM Model - Previous reports	Project Leader	- Report: Project Brief	Owner	N/A		
	35	Project leader	produces	a room and function schedule			X				Room and function schedule can be easily extracted from BIM model. It is mandatory to use BIM.	Quickly export room and function schedule	- Existing building BIM Model	Project Leader	- Report: Room and function schedule	Owner	BIM Design Tools		
	36	Project leader	identifies	required statutory approval process and building permit			X				From Task [23], [25], [27] and BIM Model Checker Tools, PL quickly identify the required statutory approval process and building permit	Fully access report and BIM model, identify required approval quickly by model checker	- Previous reports	Project Leader	- Report: required approval process and building permit	Owner	BIM Model Checker		
	37	Project leader	assembles	project team	X						It is not necessary for BIM integration in this task since it is related more in contract and business documents.							N/A	
	38	Lead designer	identifies	needs for specialist consultants	X						It is not necessary for BIM integration in this task since it is related more in contract and business documents.							N/A	
	39	Cost consultant/ quantity surveyor	estems	costs and time			X				Cost Consultant / QS use BIM model to extract quantity takeoff data, combining with their experiences, estimate costs and time.	Most BIM platform enable immediate extraction of item counts and area and volume calculations for the building components and materials	- Existing building BIM Model - Previous reports	Cost Consultant Quantity Surveyor	- Report: costs and time	Project Leader	BIM Cost Estimation		
	40	Project leader	defines	an expected or desired time schedule, preparation of a project execution plan		X					BIM model is useful for PL to check the cost and time report, improve the desired time schedule, and provide data for execution plan. But, it is purely analytical decision of project leader	Provide data for PL tasks.	- Existing building BIM Model - Report: Cost and time	Project Leader	- Report: Time schedule - Project Execution Plan	Owner	BIM Integration Tools		
	41	Health and safety adviser	considers	health and safety strategy			X				HR-S adviser use BIM model to identify health and safety strategy combined with report from previous data.	Provide a general view in Project	- Existing building BIM Model - Data: kind of intervention and developed tasks.	Health and Safety Adviser	- Report: health and safety strategy	Project Leader Owner	BIM Model Viewer		
	42	Information manager	defines	information exchange objectives		X					BIM server and information exchange system is defined early from this task. BIM is different to traditional file-based information exchange way, that need specific requirement about IE objectives.	Good collaboration and information exchange between stakeholders	- Project Execution Plan - Organisation structure	Information Manager	- Report: Information Exchange Objectives	Project Leader Owner	BIM Server		
	43	Inhabitant/ End-user	is available to	upload information requested from contractors for the renovation process			X				There is a need to create a UI for End-user to uploads requested information into BIM server for contractors. BIM server now has an ability to create a type of user for uploading documents. But, it is easier for End-user if they have a digital form, and fill use this form for necessary information, then submit them online. It is desirable to let BIM involved into this process.	BIM server help contractors manage the documents and information more efficiently.	- Information	End-user	- End-user Information Forms	Contractors	BIM Server	BIM Model Viewer	
	44	Inhabitant/ End-user	wants to	receive info on work planning/ schedules (pre/ during renovation)		X					It is recommended to use BIM, creating a model viewer for End-user, linked them with necessary report like work planning/ schedules.	End-user easily understand the work planning, schedules, and easily feedback on them.	- Existing building BIM Model - Project Execution Plan	Project Leader	- End-user Model Viewer	End-user			
	45	Inhabitant/ End-user	wants to	negotiate with contractors about the work planning		X					A BIM model viewer help End-user easily feedback, and negotiate with contractors about work planning	Enhance communication	- End-user Model Viewer	End-user	- Feedback data	Project Leader			
	46	Inhabitant/ End-user	interested to	participate (jointly with contractors) for the optimal schedules of the renovation process		X					Schedules of the renovation process can be easily access through a BIM Model Viewer as a linked files. If End-user is interested, they can see it and give their opinion to optimise the schedule	Provide options for data accessibility	- End-user Model Viewer	End-user	- Feedback data	Project Leader			
	47	Inhabitant/ End-user	is interested to	receive security and safety recommendations about construction programming		X					It is recommended to have a model viewer definitions with security and safety data included. End-user easily access this information.	Provide options for data accessibility	- End-user Model Viewer	Project Leader Health and Safety Adviser	- HR-S Model Viewer	End-user			
	48	Owner	is interested in	management and control of the renovation process			X				Owner should involve to the renovation process from early tasks, a specific Model Viewer is created for Owner with all information to manage and control the renovation process.	Provide fully data access, collaboration between owner and other stakeholder to making decision and reduce error through renovation process.	- Existing building BIM Model - Previous reports	Project Leader	- Owner Model Viewer	Owner	BIM Integration Tools		
	49	Owner	agrees	to share information about building	X						It is not necessary for BIM integration in this task since it is related more in contract and business documents.								
	50	Owner	monitors	the results of building renovation simulation			X				Renovation simulation is updated to BIM model, Owner can monitor it in a Owner model viewer	Provide fully data access, collaboration between owner and other stakeholder to making decision and reduce error through renovation process.	- Existing building BIM Model - Building renovation simulation	Project Leader	- Owner Model Viewer	Owner			
	51	Owner	monitors	building energy performance (near real time)			X				Renovation simulation is updated to BIM model, Owner can monitor it in a Owner model viewer	Provide fully data access, collaboration between owner and other stakeholder to making decision and reduce error through renovation process.	- Existing building BIM Model - Building Energy Performance	Project Leader	- Owner Model Viewer	Owner			
	52	Owner	controls	working times and economic sustainability of the renovation process			X				Working time and economic sustainability updated to BIM model, Owner can monitor it in a Owner model viewer	Provide fully data access, collaboration between owner and other stakeholder to making decision and reduce error through renovation process.	- Existing building BIM Model - Working times and economic sustainability	Project Leader	- Owner Model Viewer	Owner	BIM Integration Tools		
	53	Client adviser	prepares	detailed business case that can be used for soliciting financing from third parties			X				From Task [8], combining with updated BIM Model, Client Adviser now can prepare well detailed business case for the Owner	BIM provide data, and collaboration between Client Adviser and Project leader to understand fully about the project	- Existing building BIM Model - Preliminary business case	Client Adviser	- Detail business case	Owner			
	54	Bank or third party financier	assesses	potential risks from external consultants to determine if savings guarantees are realistic		X					It is useful for financier to have a BIM Model Viewer to examine and understand the whole renovation project. A specific Model Viewer need to be created for Financier.	BIM provide good visual view, good understanding about the project.	- Existing building BIM Model	Project Leader	- Financier Model Viewer	Bank or third party financier	BIM Model Viewer		
	55	Bank or third party financier	agrees	to finance the project	X						It is not necessary for BIM integration in this task since it is related more in contract and business documents.								
	56	Client Owner	negotiates	financing terms with bank or third party. This includes percentage of project financed, how money is delivered over the course of the project, interest, time frame and payments schedule. This process will most likely involve contributions from the project lead			X				Based on BIM model and linked report, Owner has information to negotiate with financier. There is a specific Model Viewer needed to be defined in this task.	BIM provide good visual view, good understanding about the project.	- Existing building BIM Model - Related report	Project Leader	- Model Viewer	Owner, Bank or third party financier	BIM Model Viewer		
	57	Client Owner	signs	negotiated financing contract. The third party entity will generally monitor the progress of the project at different time intervals during the course of the following activities especially during the phases of developed and detailed design in order to observe any potential deviations			X				Based on BIM model and linked report, Financier identify what they want to monitor through the renovation process. There is a specific Model Viewer needed to be defined in this task.	BIM provide good visual view, good understanding about the project.	- Existing building BIM Model - Related report	Project Leader	- Model Viewer	Owner, Bank or third party financier	BIM Model Viewer		
	58	Lead designer	examines	the principal elements of the brief, if already defined by the client or the objectives and requirements the project has to satisfy		X					Lead designer has an account on BIM server, and access to the project brief to examine, and update if necessary	BIM server is a perfect working collaboration environment for all stakeholders	- Report: Project Brief	Lead Designer	- Final Project Brief	Project Leader;	BIM Server		
	59	Architectural designer	produces	concept sketches and undertake preliminary investigations			X				There is not many 3D Concept design sketching tools available in market that has an ability to link with BIM Design Tools. Then, there are 2 options for Architectural Designer: using 3D Concept sketching tool like Sketch Up, Rhinoceros (able to link to BIM Tools through IFC), FormZ Pro and their analysis add-on; or using sketching concept tool within BIM Tools like Autodesk Revit, ArchiCAD... with their BIM-based analysis tools. However, BIM involved into this actions is highly desired, not mandatory, since Architect usually use their preferred sketch tools for concept design; but, this tool must be able to link to BIM tools. Then all of the data and sketches must be translated into a BIM model.	Data from BIM Tools can bidirectional link to other analysis tools to easily do preliminary investigations.	- Existing building BIM Model - Report: Project Brief	Architectural designer	- Conceptual Arch. BIM Model	Project Leader; Owner	3D Concept Design Sketching Tools could link to BIM Tools;	BIM Design Tools support concept sketching	
	60	Architectural designer	prepares	CONCEPT design proposals with design options, translating into drawings at an appropriate scale (typically 1:500-1:200) along with a preliminary design report and an initial cost estimate			X				From Conceptual Renovation BIM Model, Architectural designer creating set of drawings in BIM Design Tools, design report and initial cost estimate are products of other analysis BIM-based tools.	BIM automatically creates and updates the CONCEPT drawings, reduce the working time for documentation of designer. The designers have more time to focus on the concept and examine the analysed data from other BIM Tools	- Conceptual Arch. BIM Model	Architectural designer	- Local Authorities Model Viewer - Conceptual drawing set - Report: Preliminary Design - Report: Initial Cost Estimation	Project Leader;	BIM Design Tools;	BIM-based analysis tools;	BIM Cost Estimation
61	Architectural designer	holds	preliminary discussions with local authorities on the basis of the conceptual design agreed by the client			X				Through BIM server, Architectural Design create a specific Model Viewer for this actions to discuss with the local authorities. It is desirable to have a 3D viewer, since it is helpful for the discussion and make the authorities understand the project better. But, this action is also based on the availability of using BIM from local authorities as well.	Increasing working collaboration and project visualisation.	- Local Authorities Model Viewer - Conceptual Arch. BIM Model - Report: Preliminary Design - Report: Initial Cost Estimation	Architectural designer	- Report: Statutory Approvals	Project Leader;	BIM Model Viewer			
62	Architectural designer	establishes	correct procedures to obtain statutory approvals			X				From Conceptual Renovation BIM Model, Architectural designer modify, edit the model to follow the statutory approach that discussed in previous action.	BIM automatically creates and updates the CONCEPT drawings, reduce the working time for documentation of designer.	- Report: Statutory Approvals - Conceptual Arch. BIM Model - Report: Statutory Approvals	Architectural designer	- Final Conceptual Arch. BIM Model	Project Leader;	BIM Design Tools			
63	Project leader	explains	to the client correct procedures to obtain statutory approvals			X				Project leader using Owner Model Viewer to collaborate with Owner, and explain the correct procedures to obtain statutory approvals.	Increasing working collaboration and project visualisation.	- Conceptual Arch. BIM Model - Final Conceptual Arch. BIM Model	Project Leader	- Decision to obtain statutory approvals	Owner	BIM Model Viewer			
64	Project leader	undertakes	tender action - convert the project design into a set of pre-contract documents setting out an unambiguous set of tender requirements - collate project documents necessary for contractors to appreciate the type, the quantity, the quality and the scope of their works so that contractors can calculate their best offer			X				Project extract necessary data from Final Conceptual BIM Model to make a set of document related to tender action. BIM Integration tools are available to do this actions.	Extracting data easily, quick generate the quantity take-off report and other report related to tender actions	- Final Conceptual Arch. BIM Model	Project Leader	- Conceptual Tender data	Project Leader	BIM Integration Tools			
65	Project leader	prepares	tender documentation in sufficient detail to enable a tender or tenders to be obtained for the project (i.e. a tender file to tenders, including the conditions of tender, the proposed form of contract, plans, specifications, possibly a bill of quantities and a list of contractual documents with their order of priority, etc.)			X				Combining the tender data and Final Conceptual BIM Model, Project leader create a specific view for tendering process through BIM Integration Tools, and share it as a Tender Model Viewer. It is mandatory to use BIM tools in this actions, since all of the tender documentation are digital, and using traditional drawing should be ignored in the new BIM environment.	A specific BIM model viewer bring a detail, unavoidable look for contractors to calculate their best offer to bid the project.	- Conceptual Tender data - Final Conceptual Arch. BIM Model	Project Leader	- Conceptual Tender documentation - Conceptual Tender Model Viewer	Tenderer	BIM Integration Tools			
66	Tenderer	submits	a tender to the client			X				It is recommended to submit documents through BIM server by tenderer, Project Leader can manage and analyse the tender submission easily in next actions.	BIM environment create a good server to communicate and to transfer files between stakeholders.	- Conceptual Tender documentation - Conceptual Tender Model Viewer	Tenderer	- Conceptual Tender submission	Project Leader; Owner	BIM Server			
67	Project leader	analyses	tender returns, make recommendations to client and enable him to pass construction contracts with each respective trade		X					Project Leader analyse the tender submission, examine the strength and weakness of each contractor. BIM is useful for managing the tender documents. Based on this analysis, Owner start pass construction contracts with each respective trade.	BIM as a file management tools to review the tender submission from tenderer	- Conceptual Tender submission	Project Leader; Owner	- Conceptual Construction Contracts	Owner	N/A			
68	Project leader	sets out	program dates			X				From Task [37], Project leader develop the time schedule by additional information in Concept design stage to a program dates. BIM integration tools is used in this actions as an initial of 4D BIM.	BIM Integration Tools create a scheduling more easily, and the scheduling is attached to specific BIM object for construction management.	- Report: Time schedule - Final Conceptual Arch. BIM Model	Project Leader	- Program Dates	Project Leader; Owner	BIM Integration Tools			
69	Project leader	updates and reviews	the project execution plan	X						Project Leader reviews the work with added information, and update the Project Execution Plan from Task [37], this task is not involved to BIM.		- Data from previous tasks	Project Leader	- Conceptual Project Execution Plan	Project Leader;				
70	Project leader	considers	options for construction strategy			X				From Final Conceptual BIM Model, Project Leader use BIM Integration Tool to simulate, analyse some construction strategies, then create a report for possible strategies.	BIM Integration Tools provide construction management functions to schedule and 4D simulation.	- Final Conceptual BIM Model - Program Dates - Updated Project Execution Plan	Project Leader	- Report: Construction Strategy Options	Project Leader; Owner	BIM Integration Tools			
71	Lead designer	checks	design from specialist consultants for compliance with the general design			X				Lead Designer use BIM Model Checkers to check design from other consultant, then coordinate by BIM Integration Tools with the general design.	BIM Model Checkers provide the ability to quick review by apply rulesets to a building model. BIM Integration Tools can merge multiple models to form a federated model and to check for clashes, and coordination between specialist discipline of the project.	- Final Conceptual Arch. BIM Model - Specific BIM Model from consultant - 2D Drawing CAD from consultant	Lead Designer	- Report: Conceptual design checking - Information for consultant update their model or CAD	Project Leader; Specialist Consultants	BIM Integration Tools	BIM Model Checkers		
72	Lead designer	integrates	as necessary into overall design documentation (including technical sub-disciplines of construction such as structural, mechanical, electrical, HVAC, geotechnical, fire security, acoustics, lighting, etc.)			X				Lead Designer receive the updated BIM model and CAD drawing (not recommend) from other disciplines, combined in to a single BIM model if necessary. Then integrate them into overall conceptual design documentation.	BIM Design Tools easily link with tools of other BIM platform that disciplines would like to use. The design documentation, set up from the beginning, automatically change according to the revise of BIM models	- Final Conceptual Arch. BIM Model - Final specific BIM model from consultant	Lead Designer	- Conceptual Design Documentation - Integrated Conceptual BIM Model	Lead Designer; Project Leader	BIM Design Tools			

Stage	Workflow task				BIM involved priority scaling bigger is more priority					Hypothesis for BIM priority scaling	Benefit of BIM integration in this process instead of doing traditional way.	Type of Input Information	Information Provider / Process	Type of Output Information	Information Receiver	BIM Tools can be used in the market				
	No	Who	Action	Description	0	1	2	3	4							5	Category			
PRELIMINARY DESIGN	73	Health and safety adviser	prepares	an outline for health and safety strategy					X		From Integrated Conceptual BIM model, H&S analyses all task, zones, program data as well as project execution plan to create an outline for H&S strategy. This outline link to the BIM model, and sync to BIM server.	BIM is useful to provide information for input of H&S actions.	- Integrated Conceptual BIM Model - Updated Project Execution Plan - Program Dates	Health and Safety Adviser	- Health and safety strategy outline	Project Leader; Owner	BIM Integration Tools			
	74	Information manager	manages	information exchange level 1 (brief and feasibility)						X	All information exchange are managed through a BIM server that the Information Manager set up from Task [39].	Easy to control the information flow, collaboration between related stakeholders	- Report: Information Exchange Objectives - Type of information exchange from all stakeholders.	Information Manager	- Report: Information Exchange Level 1	Project Leader;	BIM Server			
	75	Information manager	produces	end of stage report for client approval			X				Information manager examine the information exchange status of the project through BIM server, then create a report for Owner approval. BIM server is useful to manage and extract data for this task.	BIM server control the function of each type of user for specific stakeholder, has statistic data for information exchange to examine	- Report: Information Exchange Level 1	Information Manager	- Decision: approval for information exchange process. - Changes for Information Exchange	Owner	N/A			
	76	Information manager	considers	changes required to the brief					X		Based on Client decision from previous task, Information Manager considering changing the Information Exchange Level 1 report to be suitable for the project. For example, adjust the function of End-user profile on BIM server, ...	BIM server control the function of each type of user for specific stakeholder, has statistic data for information exchange to examine	- Decision: approval for information exchange process. - Changes for Information Exchange	Information Manager	- Update Information Exchange configuration.	Information Manager; Project Leader	BIM Server			
	77	Project leader	develops	the concept design and chosen options as approved by the client and pre-verified with the authorities						X	In this stage, the concept design must be developed in BIM design tools to get all benefits from BIM. Project Leader use BIM Design Tools that support concept sketching to do this task, they can be more complex than usual 3D Sketching Tool, but the benefit from creating an early Preliminary BIM Model is worth it.	BIM helps Project Leader do preliminary analysis from early stage, that help build a suitable design. And, the BIM model is easily shared among all other stakeholder to get the feedback from them as well.	- Final Conceptual Arch. BIM Model	Project Team	- Preliminary Arch. BIM Model - Local Authorities Model Viewer	Project Leader	BIM Design Tools support concept sketching.	BIM Integration Tools		
	78	Local authority	gives	feedbacks on a preview of the concept design						X	Local Authority check the Preliminary Arch. BIM model through a specific model viewer on BIM Design Review Tool for them, then feedback to the Project Leader. When start getting BIM involved into a project, the local authority themselves need to change their traditional work to support the implementation of BIM as well.	BIM provide fast collaboration between stakeholders with better visualisation and feedback recording.	- Local Authorities Model Viewer	Local Authority	- Preliminary feedback	Project Leader	BIM Model Viewer			
	79	Architectural designer	prepares	graphic presentations of the project for discussions with the client and other interested parties						X	Architectural designer take rendering actions directly with Preliminary Arch. BIM Model. There are many add-in and software that provide the ability of rendering and graphic presentation of a project in BIM Design Tools.	Architectural Design use the same BIM model to render and create graphic presentations instead of remodeling it again in 3D Tools as traditional way.	- Preliminary Arch. BIM Model	Architectural designer	- Graphic Presentations	Architectural designer; Project Leader	BIM Design Tools, which link to rendering tools			
	80	Architectural designer	produces	a set of preliminary design drawings at an appropriate scale (typically 1:200-1:100) with floor plans, sections, elevations and 3d modelling						X	From Preliminary Arch. BIM Model, Architectural designer creating set of drawings in BIM Design Tools, design report and initial cost estimate are products of other analysis BIM-based tools.	BIM automatically creates and updates the CONCEPT drawings, reduce the working times for documentation of designer. The designers have more time to focus on the concept and examine the analysed data from other BIM Tools.	- Preliminary Arch. BIM Model	Architectural designer	- Preliminary drawing set.	Project Leader	BIM Design Tools			
	81	Architectural designer	produces	technical reports to explain design options						X	Architectural Designer use other analysis tools to creating a report for clarifying design options, these tools has an ability to link to BIM Design Tools for using Preliminary Arch. BIM Model. There is many tools for specific analysed purpose in the market, but not all of that link to BIM. Hence, it is highly desirable to use BIM-based tool for this task.	BIM share the geometric data, and other necessary information with analysed tools, which decrease time and error for designer in case of remodeling a building in other software.	- Preliminary Arch. BIM Model	Architectural designer	- Report: Preliminary technical.	Project Leader	BIM Design Tools support analysis tools			
	82	Architectural designer	produces	architectural plans and documentation describing the project to a level of detail as required for Planning or Building permit applications (based on the approved design)						X	Architectural Design develop the Preliminary Arch. BIM model to an appropriate level of development that required for building permit applications. This action need to be done in BIM Design tool to follow the BIM workflow.	BIM object library is suitable for this development, there are predefined BIM object available in each BIM platform. And, the preliminary set of drawing is automatically updated based on changes and addition.	- Preliminary Arch. BIM Model	Architectural designer	- Pre-final Preliminary Arch. BIM model	Project Leader	BIM Design Tools			
83	Architectural designer	collates	additional technical documentation from technical specialist consultants, such as acoustic, thermal, fire safety, environmental and other appraisals as required by applicable legislation						X	Architectural Designer collates the additional technical documentation, then cross-link them to BIM objects in the BIM model as specifications. There are only some application available now in the market for doing this. Hence, it is just highly desirable for BIM involving.	BIM create an opportunity to control and manage the technical documents by BIM objects in early stages, which make other stakeholder work with them more efficiently.	- Pre-final Arch. BIM model - Preliminary Technical Document	Architectural designer	- Final Preliminary Arch. BIM model	Project Leader	BIM Specification Application				
84	Project leader	assembles	documents required for building permit applications, draft and submit applications						X	From Final Preliminary Arch. BIM Model, Project leader extract necessary documents for building permit applications. There isn't an available tool for doing this directly in BIM Tools, it is better to use traditional software to assemble these documents. However, it is desirable to have a BIM Tool for this action. And the building permit documents is uploaded and shared with other stakeholders through BIM server.	BIM increasing the ability to control and extract data, documents and drawing quickly. However, a BIM server helps many stakeholders to control the information and documents that they have.	- Final Preliminary Arch. BIM model - Preliminary Technical Document - Preliminary Drawing Set - Report: Preliminary Technical - Other documents	Project Leader	- Building permit application documentation set. - Specific model viewer for building permit application.	Local Authority	N/A				
85	Project leader	assists	during planning negotiations, monitor the approvals procedure (representing the client)						X	PL uses a specific BIM model viewer to explain during planning negotiations, and monitoring the approval procedures. BIM Integration Tools is ready for this action, hence, it is mandatory for BIM to involve in this actions.	Quick collaboration, quick visualisation for any part of the building through a 3D BIM model viewer.	- Building permit application documentation set. - Specific model viewer for building permit application.	Project Leader	- Additional files or certificates needed for approval procedure	Project Leader; Owner; Local Authority	BIM Integration Tools				
86	Project leader	prepares	files for additional certificates as required by national legislation or by the specific nature of the asset						X	PL prepare files and additional certificates, and upload them on BIM server, link with the BIM model. It is like Task [79], this file or certificate link with appropriate BIM object in the BIM model.	With help of BIM-based application, the file crosslink to BIM model is easily updated by responsible stakeholders.	- Final Preliminary Arch. BIM model - Additional files or certificates needed for approval procedure	Project Leader	- Approval from local authority - Approved Preliminary Arch. BIM Model	Project Leader; Owner	BIM Specification Application				
87	Project leader	undertakes	tender action - convert the project design into a set of pre-contract documents setting out an unambiguous set of tender requirements - collate project documents necessary for contractors to appreciate the type, the quantity, the quality and the scope of their works so that contractors can calculate their best offer						X	Project leader extract necessary data from Approved Preliminary Arch. BIM Model to make a set of document related to tender action. BIM Integration tools are available to do this actions.	Extracting data easily, quick generate the quantity take-off report and other report related to tender actions	- Approved Preliminary Arch. BIM Model	Project Leader	- Preliminary Tender data	Project Leader	BIM Integration Tools				
88	Project leader	prepares	tender documentation in sufficient detail to enable a tender or tenders to be obtained for the project (i.e. a tender file to tenderers, including the conditions of tender, the proposed form of contract, plans, specifications, possibly a bill of quantities and a list of contractual documents with their order of priority, etc.)						X	Combining the tender data and Approved Preliminary Arch. BIM Model, Project leader create a specific view for tendering process through BIM Integration Tools, and share it as a Tender Model Viewer. It is mandatory to use BIM tools in this actions, since all of the tender documentation are digital, and using traditional drawing should be ignored in the new BIM environment.	A specific BIM model viewer bring a detail, unavoidable look for contractors to calculate their best offer to bid the project.	- Preliminary Tender data - Approved Preliminary Arch. BIM Model	Project Leader	- Preliminary Tender documentation - Preliminary Tender Model Viewer	Tenderer	BIM Integration Tools				
89	Tenderer	submits	a tender to the client						X	It is recommended to submit documents through BIM server by tenderer, Project Leader can manage and analyse the tender submission easily in next actions.	BIM environment create a good server to communicate and to transfer files between stakeholders.	- Preliminary Tender documentation - Preliminary Tender Model Viewer	Tenderer	- Preliminary Tender submission	Project Leader	BIM Server				
90	Project leader	analyses	tender returns, make recommendations to client and enable him to pass construction contracts with each respective trade						X	Project Leader analyse the tender submission, examine the strength and weakness of each contractors. BIM is useful for managing the tender documents. Based on this analysis, Owner start pass construction contracts with each respective trade.	BIM as a file management tools to review the tender submission from tenderer	- Preliminary Tender submission	Project Leader; Owner	- Preliminary Construction Contracts	Owner	N/A				
91	Project leader	updates and reviews	the project execution plan						X	Project Leader reviews the work with added information, and update the Conceptual Project Execution Plan from Task [65], this task is not involved to BIM.		- Conceptual Project Execution Plan - Other information	Project Leader	- Preliminary Project Execution Plan	Project Leader; Owner					
92	Project leader	derives	fundamental schedule in phases						X	From Task [64], Project leader go into detail of fundamental schedule in phases by analysing the required task related to the project. The availability of Preliminary BIM Model of the building let PL go deep into each phases. BIM integration tools is used in this actions as a 4D BIM application.	BIM Integration Tools create a scheduling more easily, and the scheduling is attached to specific BIM object for construction management.	- Program Dates - Approved Preliminary Arch. BIM Model	Project Leader	- Schedule in phases	Project Leader; Owner	BIM Integration Tools				
93	Project leader	proposes	construction strategy						X	From Task [66], there are some construction strategies chosen in Conceptual stage. These strategy is analysed deeper by BIM Integration Tools, combining with the schedule for each phases, Project Leader proposes the most suitable construction strategy.	BIM Integration Tools provide construction management functions to schedule and 4D simulation.	- Report: Construction Strategy Options - Schedule in phases - Approved Preliminary Arch. BIM Model - Preliminary Project Execution Plan	Project Leader	- Report: Construction Strategy	Project Leader; Owner	BIM Integration Tools				
94	Lead designer	checks	design from specialist consultants for compliance with the general design						X	Lead Designer use BIM Model Checkers to check design from other consultant, then coordinate by BIM Integration Tools with the general design.	BIM Model Checkers provide the ability to quick review by apply rulesets to a building model. BIM Integration Tools can merge multiple models to form a federated model and to check for clashes, and coordination between specialist discipline of the project.	- Approved Preliminary Arch. BIM Model - Specific Preliminary BIM Model from consultant	Lead Designer	- Report: Preliminary design checking. - Information for consultant update their BIM Model.	Project Leader; Specialist Consultants	BIM Integration Tools	BIM Model Checkers	BIM Server for collaboration		
95	Lead designer	integrates	as necessary into overall design documentation (including technical sub-disciplines of construction such as structural, mechanical, electrical, HVAC, geotechnical, fire security, acoustics, lighting, etc.)						X	Lead Designer receive the updated BIM model and CAD drawing (not recommend) from other disciplines, combined in to a single BIM model if necessary. Then integrate them into overall conceptual design documentation.	BIM Design Tools easily link with tools of other BIM platform that disciplines would like to use. The design documentation, set up from the beginning, automatically change according to the revise of BIM models	- Approved Preliminary Arch. BIM Model - Specific Preliminary BIM Model from consultant	Lead Designer	- Preliminary Design Documentation - Integrated Preliminary BIM Model	Lead Designer; Project Leader	BIM Design Tools				
96	Health and safety adviser	establishes	health and safety strategy						X	From Integrated Preliminary BIM model, H&S simulate the strategy on BIM Integration Tools, analyse and modify the strategy to the most appropriate one for the project.	BIM Integration Tools has the temporary BIM object suitable for simulation this task.	- Integrated Preliminary BIM Model - Preliminary Project Execution Plan - Schedule in phases. - Report: Construction Strategy	Health and Safety Adviser	- Preliminary Health and Safety Strategy.	Project Leader; Owner	BIM Integration Tools				
97	Information manager	manages	information exchange level 2						X	From Task [70], Information manager continue managing, adding necessary parts, and configuration for the BIM server to guarantee the collaboration work between stakeholder in this stage.	Easy to control the information flow, collaboration between related stakeholders	- Report: Information Exchange Level 1	Information Manager	- Report: Information Exchange Level 2	Project Leader;	BIM Server				
98	Information manager	produces	end of stage report for client approval						X	Information manager examine the information exchange status of the project through BIM server, then create a report for Owner approval. BIM server is useful to manage and extract data for this task.	BIM server control the function of each type of user for specific stakeholder, has statistic data for information exchange to examine	- Report: Information Exchange Level 2	Information Manager	- Decision: approval for information exchange process. - Changes for Information Exchange System	Owner	N/A				
99	Client/Owner	approves	Preliminary design and spending plan						X	The final preliminary design is updated to the BIM model with all of the linked data, the owner can now view and approve the design on Owner model viewer and spending plan.	BIM Model viewer brings good visualisation for better understanding about the project at each design stage for the Owner/Client with the required spending plan for the developed design.	- Final Preliminary design BIM Model	Project Leader; Lead designer	- Owner Model Viewer	Owner	BIM Model Viewer				
100	Project leader	develops	the approved preliminary design up to an appropriate level, providing the basic information required for issue of contract plans and specifications						X	In this stage from Integrated Preliminary Arch. Model Project Leader lead the Project team develop this model into Developed Arch. BIM Model. The level of development of BIM Model changes in this task with new and additional information, which defined in Project Execution Plan. It is mandatory to use BIM Design Tools in this stage, and link the specification with the BIM object as well.	BIM brings too many benefits in this stage, from available BIM object library to quickly develop the building model.	- Approved Preliminary Arch. BIM Model - Preliminary Project Execution Plan	Project Team	- Pre-Developed BIM Arch. Model	Project Leader	BIM Design Tools				
101	Project leader	prepares	a set of developed design drawings with floor plans, sections and elevations to determine the dimensions, appearance, principal technical solutions, materials and construction elements of the project at an appropriate scale (typically 1:100-1:50)						X	From set drawing in task [76] and Pre-Developed Arch. BIM Model, Project team develop a set of design drawing in BIM Design Tool. This set of drawing is developed from Preliminary drawing set, with more detail. It is mandatory to use BIM Design Tools for this tasks.	BIM automatically creates and updates the developed drawings, reduce the working times for documentation of designer. The designers have more time to focus on the concept and examine the analysed data from other BIM Tools	- Preliminary drawing set - Pre-Developed BIM Arch. Model	Project Team	- Developed drawing set	Project Leader	BIM Design Tools				

Stage	Workflow task			BIM involved priority scaling bigger is more priority					Hypothesis for BIM priority scaling	Benefit of BIM integration in this process instead of doing traditional way.	Type of Input Information	Information Provider / Process	Type of Output Information	Information Receiver	BIM Tools can be used in the market			
	No.	Who	Action	Description	0	1	2	3							4	5	Category	
DEVELOPED DESIGN	102	Project leader	produces	specification and detailed description of the works in the form of a written document describing the nature of the works and defining the technical specifications for each separate trade						X	From Pre-Developed Arch. BIM Model, Project team produces specification, and detail and link it to BIM Object through BIM-based Specifications. Tools that have the ability to extract data into written documents for technical specifications. Some of detail can produce directly by BIM Design Tools. Hence, it is mandatory to let BIM involve into this task as much as possible	BIM manage the specification, and link directly to the BIM object, BIM object type. This ability is useful for further model viewer, and application of using linked data.	-Pre-Developed BIM Arch. Model	Project Team	-Developed BIM Arch. Model without cost	Project Leader	BIM Design Tools	BIM Specification Application
	103	Project leader	calculates	building costs based on customary prices and, if applicable, bills of quantities						X	From Developed Arch. BIM Model, Project Team start developing cost estimation work, calculate the building cost as customary prices by BIM Cost Estimation Tools. This prices is linked with BIM object in BIM Model. It is mandatory to use BIM tools for this task, since these are available tools for this action, and the bills of quantities can be exported from them.	BIM Cost Estimation Tools helps project team manage the cost, and control the cost linked to specific BIM objects.	-Developed BIM Arch. Model without cost -Customary prices	Project Team	-Developed BIM Arch. Model	Project Leader	BIM Cost Estimation	
	104	Architectural designer	produces	architectural plans and documentation describing the project to a level of detail as required for Planning or Building permit applications (based on the approved design)						X	Architectural Design develop the Developed Arch. BIM model to an appropriate level of development that required for building permit applications. This action need to be done in BIM Design tool to follow the BIM workflow.	BIM object library is suitable for this development there are predefined BIM object available in each BIM platform. And, the preliminary set of drawing is automatically updated based on changes and addition.	-Developed BIM Arch. Model	Architectural designer	-Pre-final Developed Arch. BIM model	Project Leader	BIM Design Tools	
	105	Architectural designer	collects	additional technical documentation from technical specialist consultants, such as acoustic, thermal, fire safety, environmental and other appraisals as required by applicable legislation						X	Architectural Designer collect the additional technical documentation, then cross-link them to BIM objects in the BIM model as specifications. There are only some application available now in the market for doing this. Hence, it is just highly desirable for BIM involving.	BIM create an opportunity to control and manage the technical documents by BIM objects in early stages, which make other stakeholder work with them more efficiently.	-Pre-final Developed Arch. BIM model -Developed Technical Document	Architectural designer	-Final Developed Arch. BIM model	Project Leader	BIM Specification Application	
	106	Project leader	assembles	documents required for building permit applications, draft and submit applications						X	From Final Developed Arch. BIM Model, Project leader extract necessary documents for building permit applications. There isn't an available tool for doing this directly in BIM Tools, it is better to use traditional software to assemble these documents. However, it is desirable to have a BIM Tool for this action. And the building permit documents is updated and shared with other stakeholders through BIM server.	BIM increasing the ability to control and extract data, documents and drawing quickly. However, a BIM server helps many stakeholders to control the information and document that they have.	-Final Developed Arch. BIM model -Developed Technical Document -Developed Drawing Set -Other documents	Project Leader	-Building permit application documentation set. -Specific model viewer for building permit application.	Local Authority	N/A	
	107	Project leader	assists	during planning negotiations, monitor the approval procedure (representing the client)						X	PL uses a specific BIM model viewer to explain during planning negotiations, and monitoring the approval procedure. BIM Integration Tools is ready for this action, hence, it is mandatory for BIM to involve in this action.	Quick collaboration, quick visualisation for any part of the building through a 3D BIM model viewer.	-Building permit application documentation set. -Specific model viewer for building permit application.	Project Leader	-Additional files or certificates needed for approval procedure.	Project Leader, Owner	BIM Integration Tools	
	108	Project leader	prepares	files for additional certificates as required by national legislation or by the specific nature of the asset						X	PL prepare files and additional certificates, and upload them on BIM server, link with the BIM model. It is like Task [100], this file or certificate link with appropriate BIM object in the BIM model.	With help of BIM-based application, the file crosslink to BIM model is easily updated by responsible stakeholders.	-Final Developed Arch. BIM model -Additional files or certificates needed for approval procedure.	Project Leader	-Approval from local authority -Approved Developed Arch. BIM Model	Project Leader, Owner	BIM Specification Application	
	109	Project leader	undertakes	tender action - convert the project design into a set of pre-contract documents setting out an unambiguous set of tender requirements - collate project documents necessary for contractors to appreciate the type, the quantity, the quality and the scope of their works so that contractors can calculate their best offer.						X	Project leader extract necessary data from Approved Developed Arch. BIM Model to make a set of documents related to tender action. BIM Integration tools are available to do this actions.	Extracting data easily, quick generate the quantity take-off report and other report related to tender actions.	-Approved Developed Arch. BIM Model	Project Leader	-Developed Tender data	Project Leader	BIM Integration Tools	
	110	Project leader	prepares	tender documentation in sufficient detail to enable a tender or tenders to be obtained for the project (i.e. a tender file to tenders, including the conditions of tender, the proposed form of contract, plans, specifications, possibly a bill of quantities and a list of contractual documents with their order of priority, etc.)						X	Combining the tender data and Approved Developed Arch. BIM Model, Project leader create a specific view for tendering process through BIM Integration Tools, and share it as a Tender Model Viewer. It is mandatory to use BIM tools in this action, since all of the tender documentation are digital, and using a additional drawing should be ignored in the new BIM environment.	A specific BIM model viewer bring a detail, unavoidable look for contractors to calculate their best offer to bid the project.	-Developed Tender data -Approved Developed Arch. BIM Model	Project Leader	-Developed Tender documentation -Developed Tender Model Viewer	Tenderer	BIM Integration Tools	
	111	Tenderer	submits	a tender to the client						X	It is recommended to submit documents through BIM server by tenderer, Project Leader can manage and analyse the tender submission easily in next actions.	BIM environment create a good server to communicate and to transfer files between stakeholders.	-Developed Tender documentation -Developed Tender Model Viewer	Tenderer	-Developed Tender submission	Project Leader	BIM Server	
	112	Project leader	analyses	tender returns, make recommendations to client and enable him to pass construction contracts with each respective trade						X	Project Leader analyse the tender submission, examine the strength and weakness of each contractors. BIM is useful for managing the tender documents. Based on this analysis, Owner start pass construction contracts with each respective trade.	BIM as a file management tools to review the tender submission from tenderer	-Developed Tender submission	Project Leader, Owner	-Developed Construction Contracts	Owner	N/A	
	113	Project leader	proposes	a construction schedule						X	From Task [83], Project leader develop the schedule in phases into a full construction schedule by the information from Approved Developed Arch. BIM Model. It is mandatory to use BIM Integration Tools for this action.	BIM Integration Tools create a scheduling more easily, and the scheduling is attached to specific BIM object for construction management.	-Schedule in phases -Approved Developed Arch. BIM Model	Project Leader	-Construction schedule	Project Leader, Owner	BIM Integration Tools	
	114	Project leader	updates and reviews	the project execution plan						X	Project Leader reviews the work with added information, and update the Preliminary Project Execution Plan from Task [87], this task is not involved to BIM.		-Preliminary Project Execution Plan -Other information	Project Leader	-Developed Project Execution Plan	Project Leader, Owner	N/A	
	115	Project leader	updates and reviews	construction strategy						X	From Task [99], the construction strategy is analysed deeply and simulated in BIM Integration Tools to make appropriate updates for the construction strategy.	BIM Integration Tools provide construction management functions to schedule and 4D simulation.	-Report: Construction Strategy -Construction schedule -Approved Developed Arch. BIM Model -Developed Project Execution Plan	Project Leader	-Report: Construction Strategy updated	Project Leader, Owner	BIM Integration Tools	
116	Lead designer	checks	design from specialist consultants for compliance with the general design						X	Lead Designer use BIM Model Checkers to check design from other consultant, then coordinate by BIM Integration Tools with the general design.	BIM Model Checkers provide the ability to quick review by apply rulesets to a building model. BIM Integration Tools can merge multiple models to form a federated model and to check for clashes, and coordination between specialist discipline of the project.	-Approved Developed Arch. BIM Model -Specific Developed BIM Model from consultant	Lead Designer	-Report: Developed design checking -Information for consultants update their BIM Model.	Project Leader, Specialist Consultants			
117	Lead designer	integrates	as necessary into overall design documentation (including technical sub-disciplines of construction such as structural, mechanical, electrical, HVAC, geotechnical, fire security, acoustics, lighting, etc.)						X	Lead Designer receive the updated BIM model from other disciplines, combined in to a single BIM model if necessary. Then integrate them into overall conceptual design documentation.	BIM Design Tools easily link with tools of other BIM platform that disciplines would like to use. The design documentation, set up from the beginning, automatically change according to the revise of BIM models.	-Approved Developed Arch. BIM Model -Specific Developed BIM Model from consultant	Lead Designer	-Developed Design Documentation -Integrated Developed BIM Model	Lead Designer, Project Leader	BIM Design Tools		
118	Health and safety adviser	reviews and updates	health and safety strategy						X	From Integrated Developed BIM model, H&S simulate the strategy on BIM Integration Tools, analyse and modify the strategy to the most appropriate use for the project.	BIM Integration Tools has the temporary BIM object suitable for simulation this task.	-Integrated Developed BIM Model -Developed Project Execution Plan -Construction Schedule -Report: Construction Strategy updated	Health and Safety Adviser	-Developed Health and Safety Strategy.	Project Leader, Owner	BIM Integration Tools		
119	Information manager	manages	information exchange level 3						X	From Task [93], Information manager continue managing, adding necessary parts, and configuration for the BIM server to guarantee the collaboration work between stakeholder in this stage.	Easy to control the information flow, collaboration between related stakeholders	-Report: Information Exchange Level 2	Information Manager	-Report: Information Exchange Level 3	Project Leader,	BIM Server		
120	Information manager	produces	end of stage report for client approval						X	Information manager examine the information exchange status of the project through BIM server, then create a report for Owner approval. BIM server is useful to manage and extract data for this task.	BIM server control the function of each type of user for specific stakeholder, has statistic data for information exchange to examine.	-Report: Information Exchange Level 3	Information Manager	-Decision: approval for information exchange process. -Changes for Information Exchange System	Owner	N/A		
121	Project leader	submits	documents required for building permit applications to Local Authorities						X	It is recommended to submit documents as a BIM model to the local authorities, but, most of local authorities work in a traditional way, which BIM is hardly involved into their work. There is a need of an online submission for construction project.		-Developed Design Documentation	Project Leader	-Building permit application documentation set.	Local Authority	N/A		
122	Local authority	issues	the building permit						X	It is not necessary for BIM integration in this task since it is related more in contract and business documents.		-Building permit application documentation set.	Local Authority	-Decision: issue the building permit	Project Leader, Owner	N/A		
123	Client/Owner	approves	Developed design and spending plan						X	The final developed design is updated to the BIM model with all of the linked data, the owner can now view and approve the design on Owner model viewer and spending plan.	BIM Model viewer brings good visualisation for better understanding about the project at each design stage for the Owner/Client with the required spending plan for the developed design.	-Final Developed design BIM Model	Project Leader, Lead designer	-Owner Model Viewer	Owner	BIM Model Viewer		
124	Architectural designer	develops	the developed design to provide execution and detail drawings at the required scale (typically 1:50, 1:20, 1:10, 1:5, 1:1)						X	From Approved Developed Arch. BIM Model, Architectural Designer continue develop it into Detail Arch. BIM Model. They prepare and generate the execution and detail at required scale, and enrichment the BIM model. It is mandatory to use BIM Design Tool for this actions.	BIM brings too many benefits in this stage, from available BIM object library to quickly develop the building model.	-Approved Developed Arch. BIM Model	Architectural designer	-Pre-Detail Arch. BIM Model without updated specification, detail and cost.	Project Leader	BIM Design Tools		
125	Architectural designer	provides	calculations and specifications intended for construction and enabling contractors to build the works						X	From Pre-Detail Arch. BIM Model, Architectural Designer review the calculations and specifications. After that they are updated into the BIM Model. It is mandatory to use BIM Design Tools and Specification Tool for this action.	BIM manage the specification, and link directly to the BIM object, BIM object type. This ability is useful for further model viewer, and application of using linked data.	-Pre-Detail Arch. BIM Model without updated specification, detail and cost.	Architectural designer	-Pre-Detail Arch. BIM Model without updated detail and cost.	Project Leader	BIM Design Tools	BIM Specification Application	
126	Architectural designer	determines	all details including furniture and other elements that are specific to the project						X	Architectural designer added necessary details and furniture to enrich the BIM model. All of them is defined in BIM Design Tools, and link with BIM objects through BIM Specification Tools.	There are BIM object available for this action in the market. They are from the manufacturer with detail BIM model as well as technical documents. It is a good resource for Architectural Designer in this action.	-Pre-Detail Arch. BIM Model without updated detail and cost.	Architectural designer	-Pre-Detail Arch. BIM Model without updated cost.	Project Leader	BIM Design Tools	BIM Specification Application	
127	Project leader	reviews and updates	building costs based on customary prices and possibly, bills of quantities incorporating quotations from specialist subcontractors						X	From Pre-Detail Arch. BIM Model, Project Team re-calculate the cost with additional objects and information. They update these data into BIM Cost Estimation Tools, and link to the BIM object in the model. It is mandatory to use BIM tools in this action.	BIM Cost Estimation Tools helps project team manage the cost, and control the cost linked to specific BIM objects.	-Pre-Detail Arch. BIM Model without updated cost. -Customary prices.	Project Team	-Detail Arch. BIM Model	Project Leader	BIM Cost Estimation		
128	Project leader	establishes	a project execution plan						X	Project Leader reviews the work with added information, and update the Developed Project Execution Plan from Task [109]. After this, the final Project Execution Plan is published.		-Developed Project Execution Plan -Other information	Project Leader	-Project Execution Plan	Project Leader, Owner	N/A		
129	Architectural designer	produces	architectural plans and documentation describing the project to a level of detail as required for Planning or Building permit applications (based on the approved design)						X	Architectural Design develop the Detail Arch. BIM model to an appropriate level of development that required for building permit applications. This action need to be done in BIM Design tool to follow the BIM workflow.	BIM object library is suitable for this development there are predefined BIM object available in each BIM platform. And, the preliminary set of drawing is automatically updated based on changes and addition.	-Detail Arch. BIM Model	Architectural designer	-Pre-final Detail Arch. BIM model	Project Leader	BIM Design Tools		
130	Architectural designer	collects	additional technical documentation from technical specialist consultants, such as acoustic, thermal, fire safety, environmental and other appraisals as required by applicable legislation						X	Architectural Designer collect the additional technical documentation, then cross-link them to BIM objects in the BIM model as specifications. There are only some application available now in the market for doing this. Hence, it is just highly desirable for BIM involving.	BIM create an opportunity to control and manage the technical documents by BIM objects in early stages, which make other stakeholder work with them more efficiently.	-Pre-final Detail Arch. BIM model -Detail Technical Document	Architectural designer	-Final Detail Arch. BIM model	Project Leader	BIM Specification Application		
131	Project leader	assembles	documents required for building permit applications, draft and submit applications						X	From Final Detail Arch. BIM Model, Project leader extract necessary documents for building permit applications. There isn't an available tool for doing this directly in BIM Tools, it is better to use traditional software to assemble these documents. However, it is desirable to have a BIM Tools for this action. And the building permit documents is updated and shared with other stakeholders through BIM server.	BIM increasing the ability to control and extract data, documents and drawing quickly. However, a BIM server helps many stakeholders to control the information and document that they have.	-Final Detail Arch. BIM model -Detail Technical Document -Developed Drawing Set -Other documents	Project Leader	-Building permit application documentation set. -Specific model viewer for building permit application.	Local Authority	N/A		
132	Project leader	assists	during planning negotiations, monitor the approval procedure (representing the client)						X	PL uses a specific BIM model viewer to explain during planning negotiations, and monitoring the approval procedure. BIM Integration Tools is ready for this action, hence, it is mandatory for BIM to involve in this action.	Quick collaboration, quick visualisation for any part of the building through a 3D BIM model viewer.	-Building permit application documentation set. -Specific model viewer for building permit application.	Project Leader	-Additional files or certificates needed for approval procedure.	Project Leader, Owner	BIM Integration Tools		
133	Project leader	prepares	files for additional certificates as required by national legislation or by the specific nature of the asset						X	PL prepare files and additional certificates, and upload them on BIM server, link with the BIM model. It is like Task [100], this file or certificate link with appropriate BIM object in the BIM model.	With help of BIM-based application, the file crosslink to BIM model is easily updated by responsible stakeholders.	-Final Detail Arch. BIM model -Additional files or certificates needed for approval procedure. -Approved Detail Arch. BIM Model	Project Leader	-Approval from local authority -Approved Detail Arch. BIM Model	Project Leader, Owner	BIM Specification Application		
134	Lead designer	checks	design from specialist consultants for compliance with the general design						X	Lead Designer use BIM Model Checkers to check design from other consultant, then coordinate by BIM Integration Tools with the general design.	BIM Model Checkers provide the ability to quick review by apply rulesets to a building model. BIM Integration Tools can merge multiple models to form a federated model and to check for clashes, and coordination between specialist discipline of the project.	-Approved Detail Arch. BIM Model -Specific Detail BIM Model from consultant	Lead Designer	-Report: Detail design checking -Information for consultants update their BIM Model.	Project Leader, Specialist Consultants	BIM Integration Tools	BIM Model Checkers	BIM Server for collaboration

Stage	Workflow task			BIM involved priority scaling bigger is more priority					Hypothesis for BIM priority scaling	Benefit of BIM integration in this process instead of doing traditional way.	Type of Input Information	Information Provider / Process	Type of Output Information	Information Receiver	BIM Tools can be used in the market						
	No.	Who	Action	Description	0	1	2	3							4	5	Category				
DETAIL DESIGN	135	Lead designer	integrates	as necessary into overall design documentation (including technical sub-disciplines of construction such as structural, mechanical, electrical, HVAC, geotechnical, fire security, acoustics, lighting, etc.)						X	Lead Designer receive the updated BIM model from other disciplines, combined in to a single BIM model if necessary. Then integrate them into overall conceptual design documentation.	BIM Design Tools easily link with tools of other BIM platform that disciplines would like to use. The design documentation, set up from the beginning, automatically change according to the revise of BIM models	-Approved Detail Arch. BIM Model -Specific Detail BIM Model from consultant	Lead Designer	-Detail Design Documentation -Integrated Detail BIM Model	Lead Designer; Project Leader	BIM Design Tools				
	136	Health and safety adviser	reviews and updates	health and safety strategy							X	From Integrated Detail BIM model, H&S update the strategy on BIM Integration Tools, analyse and modify the strategy to the most appropriate one for the project.	BIM Integration Tools has the temporary BIM object suitable for simulation this task.	-Integrated Detail BIM Model -Project Execution Plan -Construction Schedule -Report: Construction Strategy updated	Health and Safety Adviser	-Detail Health and Safety Strategy	Project Leader; Owner	BIM Integration Tools			
	137	Project leader	undertakes	tender action - convert the project design into a set of pre-contract documents setting out an unambiguous set of tender requirements - collate project documents necessary for contractors to appreciate the type, the quantity, the quality and the scope of their works so that contractors can calculate their best offer							X	Project leader extract necessary data from Integrated Detail BIM Model to make a set of document related to tender action. BIM Integration tools are available to do this actions.	Extracting data easily, quick generate the quantity take-off report and other report related to tender actions	-Integrated Detail BIM Model	Project Leader	-Detail Tender data	Project Leader	BIM Integration Tools			
	138	Project leader	prepares	tender documentation in sufficient detail to enable a tender or tenders to be obtained for the project (i.e. a tender file to tenders, including: the conditions of tender, the proposed form of contract, plans, specifications, possibly a bill of quantities and a list of contractual documents with their order of priority, etc.)							X	Combining the tender data and Integrated Detail BIM Model, Project leader create a specific view for tendering process through BIM Integration Tools, and share it as a Tender Model Viewer. It is mandatory to use BIM tools in this actions, since all of the tender documentation are digital, and using traditional drawing should be ignored in the new BIM environment.	A specific BIM model viewer bring a detail, unavoidable look for contractors to calculate their best offer to bid the project.	-Detail Tender data -Integrated Detail BIM Model	Project Leader	-Detail Tender documentation -Detail Tender Model Viewer	Tenderer	BIM Integration Tools			
	139	Client/Owner	approves and authorizes	Detailed design - tender documentation - tender procedure and spending plan			X					The final detailed design is updated to the BIM model with all of the linked data, the owner can now view and approve the design on Owner model viewer and spending plan.	BIM Model viewer brings good visualisation for better understanding about the project at each design stage for the Owner/Client with the required spending plan for the developed design.	-Final Preliminary design BIM Model	Project Leader; Lead designer; Tenderer	-Owner Model Viewer	Owner	BIM Model Viewer			
	140	Project leader	checks and manages	tender action with the appointed office (contract administrator)				X				From the above extracted tender documents for the tender actions, it is necessary for the PL to check and manage in order to assure all of the extracted data is addressed during the tender action.	BIM Integration Tools help project leader manage, check and oversees the activities in tender actions.	-Detailed Tender data and documentation	Tenderer	-Detailed Tender data	Project leader; Contract administrator	BIM Integration Tools			
	141	Tenderer	submits	a tender to the client			X					It is recommended to submit documents through BIM server by tenderer, Project Leader can manage and analyse the tender submission easily in next actions.	BIM environment create a good server to communicate and to transfer files between stakeholders.	-Detail Tender documentation -Detail Tender Model Viewer	Tenderer	-Detail Tender submission	Project Leader	BIM Server			
	142	Project leader	analyses	tender returns, make recommendations to client and enable him to pass construction contracts with each respective trade.				X				Project Leader analyse the tender submission, examine the strength and weakness of each contractor. BIM is useful for managing the tender documents. Based on this analysis, Owner start pass construction contracts with each respective trade.	BIM as a file management tools to review the tender submission from tenderer	-Detail Tender submission	Project Leader; Owner	-Construction Contracts	Owner	NA			
	143	Project leader	details and agrees	proposed construction schedule					X			From Task [108], Project leader develop the construction schedule in details by the information from Integrated Final BIM Model. It is mandatory to use BIM Integration Tools for this action.	BIM Integration Tools create a scheduling more easily, and the scheduling is attached to specific BIM object for construction management	-Construction Schedule -Integrated Detail BIM Model	Project Leader	-Detail Construction schedule	Project Leader; Owner	BIM Integration Tools			
	144	Project leader	establishes	handover and Commissioning Strategy					X			From Integrated Detail BIM Model, Project Leader analyse and establish a Handover and Commissioning Strategy. It is mandatory to use BIM Tools in this task. There are BIM Facility Management Tools ready to support this action.	BIM FM Tools make it easy for both Owner and Contractor to handover and commissioning.	-Detail Construction schedule -Integrated Detail BIM Model	Project Leader	-Handover and Commissioning Strategy	Project Leader; Owner	BIM Tools for Asset Management			
	145	Information manager	manages	information exchange level 4					X			From Task [114], Information manager continue managing adding necessary parts, and configuration for the BIM server to guarantee the collaboration work between stakeholder in this stage.	Easy to control the information flow, collaboration between related stakeholders	-Report: Information Exchange Level 3	Information Manager	-Report: Information Exchange Level 4	Project Leader;	BIM Server			
	146	Information manager	produces	end of stage report for client approval		X						Information manager examine the information exchange status of the project through BIM server then create a report for Owner approval. BIM server is useful to manage and extract data for this task.	BIM server control the function of each type of user for specific stakeholder, has statistic data for information exchange to examine.	-Report: Information Exchange Level 4	Information Manager	-Decision: approval for information exchange process. -Changes for Information Exchange System	Owner	NA			
	147	Client/Owner	approves and authorizes	the tender - spending plan			X					It is recommended to submit documents through BIM server by tenderer, the owner can now view and approve the tender document submission for approval and authorization.	BIM environment create a good server to communicate and to transfer files between stakeholders.	-Detail Tender documentation -Detail Tender Model Viewer	Tenderer	-Detail Tender submission	Owner	BIM Server			
	148	Contract administrator	prepares	contract administration (pre-construction)				X				Based on Integrated Detail BIM Model, the Contractor has necessary information to prepare the contract. However, there is not available tool to support this action, to transform the construction task to a form of contract. Hence, BIM is useful, and recommend to use BIM server for this actions	BIM Model provide fully information, and necessary task for Contractor assessment, and prepare construction contract.	-Detail Construction schedule -Construction Contracts -Integrated Detail BIM Model -Handover and Commissioning Strategy -Report: Information Exchange Level 4 -Detail Health and Safety Strategy.	Contract Administrator	-Contract Administration	Project Leader; Owner	BIM Server			
	149	Contract administrator	reviews	contracts and agreed project objectives (pre-construction)				X				Then, the Contract Administrator review the contracts again after negotiating with the Owner. Finally, the Project Objectives is agreed between both sides. BIM is useful for this negotiation and review by specific model viewer for both stakeholders.	BIM Model viewer brings good visualisation, understanding about the project for both stakeholders.	-Contract Administration -BIM Model Viewer	Contract Administrator	-Final Construction Contract -Contract Project Objectives	Contract Administrator; Project Leader; Owner	BIM Server	BIM Model Viewer		
	150	Client/Owner	submits	contract with the construction lead (Construction contracting)			X					It is recommended to submit documents through BIM server by Owner, Project Leader can manage and analyse the construction contracts easily in next actions.	BIM environment create a good server to communicate and to transfer files between stakeholders.	-Construction contracts documents	Owner/Client Construction admin.	-Construction contracts documents	Project Leader	BIM Server			
	151	Inhabitants' End-user	uploads	information requested from contractors for the renovation process, if necessary				X				There is a need to create an UI for End-user to uploads requested information into BIM server for contractors. BIM server now has an ability to create a type of user for uploading documents. But, it is easier for End-user if they has a digital form, and fill into this form for necessary information, then submit them online. It is desirable to let BIM involved into this process.	BIM server help contractors manage the documents and information more efficiently.	-Information	End-user	-End-user Information Forms	Contractors	BIM Server			
152	Project leader	oversees	the execution of the building contract		X						BIM model provides useful information for PL to oversee the execution of the building contract. But, it is analytical check of PL, and, there is no support tool for this process. Hence, it is not recommended to let BIM involve in this action.	BIM Integration Tools help project leader manage task, objects, and oversees the activities in construction stage.	-Final Construction Contract -Detail Construction schedule -Contract Project Objectives	Project Leader	-Organised Execution	Project Leader; Owner	NA				
153	Project leader	monitors	construction progress and compliance with plans (Commissioning)				X				There are available BIM-based tools for monitoring the construction progress and compliance with design based on reality capture technologies. Project Leader use this tool to do this action, and it is highly desirable to use this in a project.	BIM tool for construction monitoring with 4D Capability helps PL compare schedules and track construction progress well.	-Integrated Detail BIM Model -Detail Health and Safety Strategy.	Project Leader Contractor	-Pre-Finished Construction Works -Construction Progress report	Project Leader Owner	BIM Tools with 4D Capability				
154	Work supervisor	inspects	contractors' activity and execution of the works (Commissioning)					X			Work supervisor uses BIM Tools for Surveying Site Conditioning to inspect contractor's activity and execution of the works. It is highly desirable to let BIM involve into this action, since inspection instruments is more advanced by reality capture technologies. There is more case study needed to make this mandatory.	BIM Tools have a record of the realtime site construction, and has automatically rule check with the model.	-Pre-Finished Construction Works -Construction Progress report	Work supervisor Contractor	-Finished Construction Work -Construction Inspection Report	Project Leader; Project Leader Team	BIM Surveying Site Conditions				
155	Work supervisor	considers	contractors' drawings (Commissioning)					X			Work supervisor uses BIM Design Tools to manage and consider contractor's drawing. These drawing if cannot be performed by BIM Design Tools, is uploaded into BIM server, and link with responding components of the building. It is mandatory to use BIM in this action.	BIM Design Tool help project leader manage and link the drawing with suitable object quickly.	-Integrated Detail BIM Model -Contractor's drawings	Work supervisor Contractor	-Construction BIM Model	Project Leader; Project Leader Team	BIM Design Tools				
156	Work supervisor	undertakes	random inspection of materials and quality of workmanship (Commissioning)				X				There is some BIM-based tools for production planning and control that enable testing the efficacy of construction equipment. It is highly desirable to let BIM involve in this process due to its efficiency in managing building objects. But, there are some study cases needed to prove BIM involvement in this process to make it mandatory.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	-Construction BIM Model	Work supervisor Contractor	-Construction Quality Control Report	Project Leader;	BIM Tools for Planning and Control				
157	Work supervisor	undertakes	final clarification of design details prior to implementation (Commissioning)					X			BIM Integration Tool create a general view for all discipline in the project, and visual view the building component parts as well as detailed link to that.	BIM Integration Tool create a general view for all discipline in the project, and visual view the building component parts as well as detailed link to that.	-Construction BIM Model -Integrated Detail BIM Model	Work supervisor	-Final clarification of design details	Contractors Project Leader	BIM Integration Tools				
158	Project leader	undertakes	process changes required by the client and issue relevant instructions to contractors (Commissioning)					X			BIM Design Tool help project leader update changes easily, combining with Integration Tools to make appropriate instructions to contractors	BIM Design Tool help project leader update changes easily, combining with Integration Tools to make appropriate instructions to contractors	-Construction BIM Model -Changes required by the client.	Project Leader Contractor	-Final Construction BIM Model -Instructions to contractors	Contractors Owner	BIM Design Tools	BIM Integration Tools			
159	Work supervisor	checks	requests for payment issued by contractors (Commissioning)				X				It is desirable to have a BIM Tool can check the payment issued by contractor upon BIM objects, or a group of BIM Objects. Work supervisor can manage and organise the works more efficiently. However, the traditional way is still work well.	BIM manage the payment issued by BIM object, and by the progress, construction work of this object itself. Hence, the PL can easily check its status through a BIM Tools if available.	-Final Construction BIM Model -Finished Construction Work -Request for Payment	Work supervisor	-Report: request for payment checked	Contractors Owner	NA				
160	Project leader	approves	requests for payment issued by contractors (Commissioning)				X				It is desirable to have a BIM Tool manage the payment process for contractors. It is efficient for both Project Leader and Contractors to work within it, from submit payment form to payment arrangement.	BIM manage the payment issued by BIM object, and by the progress, construction work of this object itself. Hence, the PL can easily check its status through a BIM Tools if available.	-Report: request for payment checked	Project Leader	-Decision: payment approval	Contractors; Owner	NA				
161	Work supervisor	checks	that all works have been carried out in accordance to contract, and that the building is fit for use and compliant to regulations and permits obtained					X			BIM Model Checkers provide the ability to quick review by apply releases to a building model. BIM Integration Tools can merge multiple models to form a federated model and check for clashes, and coordination between specialist disciplines of the project.	BIM Model Checkers provide the ability to quick review by apply releases to a building model. BIM Integration Tools can merge multiple models to form a federated model and check for clashes, and coordination between specialist disciplines of the project.	-Final Construction BIM Model -Finished Construction Work	Work supervisor	-Report: checked construction work	Project Leader; Owner	BIM Model Checkers;	BIM Integration Tools;	BIM Surveying Site Conditions		
162	Project leader	organizes	eventual statutory procedures required to open the building					X			Project Leader use BIM Tools with 4D Capability to organise the planning for statutory procedures required, it is mandatory to use BIM.	BIM Tools with 4D Capability can link well with traditional construction project schedules as Microsoft Project, Primavera.	-Eventual Statutory Procedures	Project Leader	-Statutory procedures schedule	Project Leader; Owner; Contractors	BIM Tools with 4D Capability				
163	Work supervisor	oversees	preparation of as-built documentation					X			Work supervisor determine the preparation of as-built documentation, organise and schedule the plan for establishing as-built documentation. It is mandatory to use BIM Design Tools for overseeing this action.	BIM Design Tools help project leader create and foresee a set of as-built drawings, and this set of drawing is extracted from Final Construction Model after modification for As-built model.	-Final Construction BIM Model	Work supervisor	-Set of as-built documentation	Project Leader	BIM Design Tools				
164	Work supervisor	checks	workmanship and compliance with contract documents					X			Work supervisor uses BIM Tools for Surveying Site Conditioning to checks workmanship and compliance with contract documents. It is highly desirable to let BIM involve into this action, since inspection instruments is more advanced by reality capture technologies. There is more case study needed to make this mandatory.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	-Final Construction BIM Model -Finished Construction Work	Work supervisor	-Report: checked workmanship	Project Leader	BIM Surveying Site Conditions				
165	Inhabitants' End-user	updates	information about comfort conditions during renovation process					X			End-user need a specific model viewer and UI in a BIM server to update the information and comfort conditions during renovation process. Each End-user is linked with the room or apartment defined in BIM model. It is highly desirable to have an UI for this actions.	BIM Server easily collates End-user updates and informations.	-End-user experiences	End-user	-Renovation Process Comfort Conditions	Project Leader	NA				
166	Inhabitants' End-user	feels	comfort/discomfort during the renovation process					X			End-user describe their feeling about comfort/discomfort during the renovation process, by a priority scaling. It is highly desirable to have an UI or BIM-based application for this actions and collates the information through BIM server.	BIM Server easily collates End-user updates and informations.	-End-user feelings	End-user	-Renovation Process Comfort Scale	Project Leader	NA				
167	Project leader	supervises	handover to the client and building users as start of guarantee periods					X			It is highly desirable to let BIM involve in this process. BIM Assets Management Tools has an ability to managing the handover process based on Construction BIM Model.	BIM Assets Management Tools functioned for managing this actions	-Final Construction BIM Model -Finished Construction Work -Handover and Commissioning Strategy	Project Leader	-As-built Building	Owner	BIM Tools for Asset Management				
168	Project leader	oversees	issue of as-built documentation and final accounts					X			Project Leader leads and oversees the issue of as-built documentation. The BIM model is updated to As-built level, and this model is capable of using in BIM Assets Management Tools. It is mandatory to use BIM in this actions.	BIM Design Tool help project leader manage and link the drawing with suitable object quickly.	-Final Construction BIM Model -As-built Building	Project Leader	-As-built BIM Model -As-built Documentation	Owner	BIM Design Tools				
169	Project leader	applies for	for additional permits as required, enable possible monitoring by authorities during construction and produce documents to support registration of completion of the works with authorities if necessary		X						As required by local authorities, Project Leader prepare a documentation set to apply for permits. BIM Design Tools is used to provide this set. BIM is useful for this action, but not recommended, because local authority usually prefer traditional way for doing this.	BIM Design Tool create a set of drawing for Project Leader to control this actions.	-As-built BIM Model -As-built Documentation -Required documents	Project Leader	-Permit document set	Local Authority	BIM Design Tools				

Stage	Workflow task				BIM involved priority scaling bigger is more priority					Hypothesis for BIM priority scaling	Benefit of BIM integration in this process instead of doing traditional way.	Type of Input Information	Information Provider / Process	Type of Output Information	Information Receiver	BIM Tools can be used in the market		
	No.	Who	Action	Description	0	1	2	3	4							5	Category	
USE	170	Structural, Electrical, HVAC, water and waste designer	produces	architectural plans and documentation describing the project to a level of detail as required for Planning or Building permit applications (based on the approved design)						X	Designer generate the plans and documentations for permit application through BIM Design Tools. It is mandatory to use BIM.	BIM object library is suitable for this development, there are predefined BIM object available in each BIM platform. And, the preliminary set of drawing is automatically updated based on changes and addition.	- As-built BIM Model	Engineer (all)	- Permit application drawings	Project Leader	BIM Design Tools	
	171	Structural, Electrical, HVAC, water and waste designer	collates	additional technical documentation from technical specialist consultants, such as acoustic, thermal, fire safety, environmental and other appraisals as required by applicable legislation.						X	Designer generate the technical document and specifications for permit application through BIM Design Tools. It is mandatory to use BIM.	BIM create an opportunity to control and manage the technical documents by BIM objects in early stages, which make other stakeholder work with them more efficiently.	- As-built BIM Model	Engineer (all)	- Permit application specifications	Project Leader	BIM Specification Application	
	172	Project leader	monitors	revisions to construction contracts						X	It is desirable to use BIM for monitoring contract revision. There is some application related to this task, but there is more study cases needed.	BIM-based tool control well the construction contract, and manage it base on BIM model.	- Final Construction Contract - Contract Project Objectives	Project Leader	- Revised Contracts	Contractor; Owner	BIM Assets Management Tools	
	173	Project leader	monitors	construction schedule as agreed by contract (Commissioning)						X	Using BIM Tools with 4D Capabilities, Project Leader monitor the construction schedule on contract. It is mandatory to use BIM in this action.	BIM Tools create a scheduling more easily, and the scheduling is attached to specific BIM object for construction management.	- Construction Schedule - As-built BIM Model - Revised Contracts	Project Leader	- Construction schedule result	Contractor; Owner	BIM Tools with 4D Capability	
	174	Tester	produces	Final administrative and technical test of renovation works (Commissioning)						X	After the final construction the Tester conducts and a final administrative & technical test of the renovation works on-site and uploads the results on the BIM server in the form of a report or document.	BIM server helps manage the documents and information more efficiently and share it among different stakeholders.	- As-built BIM Model - Finished construction works	Tester	- Report : Administrative and technical test report	Client / Owner	BIM Server	
	175	Client/Owner	approves	Final administrative and technical test of renovation works (Procurement)						X	It is recommended to submit documents through BIM server by Tester, the owner can now view and approve the document submission for approval.	BIM environment create a good server to communicate and to transfer files between stakeholders.	- Report : Administrative and technical test report	Owner	- Report : Administrative and technical test report	Owner; Project leader	BIM Server	
	176	Project leader	supports	the client to maximise the use of his investment						X	From As-built BIM Model, the FM BIM Model is created by PL. After that, choosing a facility management system is recommended. Project Leader and Owner list all the related actions and operation in this stage, and make estimation about the return of investment. It is mandatory to let BIM involve from the beginning of this stage by using FM BIM Tools.	FM BIM Tools has function as asset management, real estate and leasing management, capital planning, ... to support the use of investment.	- As-built BIM Model - As-built Documentation	Project Leader	- FM BIM Model - FM BIM Tools	Owner	BIM Assets Management Tools	
	177	Project leader	reviews	project performance and additional project information as required						X	Project leader review the project performance by some indicators as cost, time and quality. This review can be performed in As-built BIM Model and the cost tracking through all stage of the project. It is desirable to use BIM Tools in this action.	BIM Tools quickly check the As-built BIM model and real building for compare the quality. BIM Cost estimation provide cost information for all of the works, and also tracking the time in BIM-4D Tools.	- As-built BIM Model - As-built Documentation	Project Leader	- Report: Project Performance	Owner	BIM Integration Tools; BIM Tools with 4D Capability	
	178	Facilities management (FM) adviser	provides	advice to program planned maintenance and periodical performance testing						X	There is a need of maintenance planning and organization for the building after renovation. FM adviser make schedule of periodical performance testing, which combined with specific maintenance intervention for building components. It is mandatory to use BIM in this action, since the FM BIM Model is already set up.	BIM FM Tools make it easy for both Owner and FM Adviser to set up a maintenance and operation plan, as well as reduce operating expense, risk and improve performance.	- FM BIM Model	Facilities management (FM) adviser	- Maintenance Plan	Project leader; Owner	BIM Assets Management Tools	
	179	Sustainability adviser	monitors	sustainability performance						X	Sustainability performance is one of the most indicator for building renovation. But, there is not many BIM tools has this function. It is desirable to use BIM for fully sustainability monitoring.	Only FM Systems has the function of energy or water usage monitoring and WebIMA has the function of utility service management. It is useful as summarise and monitoring tool.	- FM BIM Model	Sustainability adviser	- Report: Sustainability performance	Sustainability adviser; Owner; End-user	BIM Assets Management Tools	
	180	Inhabitant/ End-user	updates	information about comfort conditions post renovation process						X	It is highly desirable to have a BIM-based application or tool for End-user to update the information about comfort conditions after the renovation process. This information is linked with space management or room management in BIM FM Tools. End-user need a specific UI or mobile application that they can use for the whole life cycle of the building.	BIM FM Tools summarise and organise well the information received from End-user.	- User experiences	End-user	- FM BIM Model - Building comfort reports	Facilities management (FM) adviser	N/A	
	181	Inhabitant/ End-user	feels	comfort/discomfort during post renovation process						X	It is highly desirable to have a BIM-based application or tool for this action. It is the same with Task [165]. In this UI, there is a specific part for End-user to describe discomfort - comfort range (ex. Scale 1-5 with 1 is discomfort).	BIM FM Tools summarise and organise well the information received from End-user.	- User experiences	End-user	- FM BIM Model - Building comfort reports	Facilities management (FM) adviser	N/A	
	182	Facilities management (FM) adviser	uploads	ad hoc information related to operational processes that may be useful for the renovation process (Operation)						X	It is highly desirable to have a BIM-based server share the information related to operational processes. These ad-hoc information may be useful for the convenience of End-user and Owner when living in the building.	BIM based server help its user to share the information efficiently.	- Operational information	Facility manager	- Operational information	Facilities management adviser; End user, Owner	N/A	
	183	Owner	monitors	The economic sustainability of the project						X	It is desirable to use BIM FM Tool for economic sustainability monitoring, since there is function in BIM FM Tool for capital planning, or cost management.	BIM FM Tools summarise the economic sustainability based on information collected from previous task.	- Project information	Facilities management adviser	- Economic sustainability status	Owner	BIM Assets Management Tools	
	184	Facilities management (FM) adviser	advises	for maintenance of the building and external works for upkeep of the client's investment						X	Based on the information from BIM FM Model and the maintenance plan, FM Adviser prepares the maintenance strategies and external works for upkeep the building. It is mandatory to update this information into BIM FM Model.	BIM FM Tools and BIM Integration Tools provide the FM adviser a full view on the current building to set up the maintenance plan.	- FM BIM Model - Maintenance Plan	Facilities management adviser	- Maintenance strategy - Maintenance works	Project leader; Owner	BIM Assets Management Tools	
	185	Facilities management (FM) adviser	assists	with facility management, training, environmental monitoring, life-cycle strategy and energy-waste-water management procedures						X	FM Adviser works with FM Team for the facility management and other procedures in building operation. It is highly desired to use BIM in this process, since all of this function is available now in some BIM FM Tools.	BIM FM Tools has the function for facility management efficiently, as well as function to monitoring and generating monthly report for environmental and energy-waste-water issues.	- FM BIM Model - Environmental, energy-waste water information	Facilities management adviser; FM Team	- Report: Facility Management - Report: Environmental Monitoring - Life-cycle Strategy - Report: Energy waste water management - Training documents	Project Leader; Owner; FM Team;	BIM Assets Management Tools	
	186	Project leader	prepares	documentation to obtain permits for possible changes of use, renovation or redesign						X	In case the building need renovation or redesign, from As-built BIM Model, and FM BIM Model, Project leader prepares appropriate documents to obtain the permits. The building is ready for next cycle of renovation. It is mandatory to use BIM in this task, since all BIM Model is ready.	BIM Design Tools help project leader organise the as-built drawing and documents to obtain permits quickly from available BIM model.	- FM BIM Model - As-built BIM Model - As-built Documentation	Project Leader	- Renovation documents	Local Authority; Owner	BIM Design Tools	
	187	Project leader	undertakes	procurement documentation and tender procedures for facility management, maintenance, and possible renovation (Maintenance)						X	Project Leader use BIM tools to set out these documents, and manage the tender procedures. The information from As-built BIM Model and FM BIM Model are combined and export to BIM Integration Tools for doing this task. It is mandatory to use BIM Tools.	BIM Integration Tools provide the ability to generating and managing documentation efficiently.	- FM BIM Model - As-built BIM Model - Renovation Documentation	Project Leader	- Procurement documents - Tender documents	Owner; Tenderer	BIM Integration Tools	
	188	Project leader	recommends	end of life audit (Maintenance)						X	It is desirable to use BIM Tool for this task. But, there is no BIM Tools available in the market provide this function to audit end of life of a building. Project leader can perform the input data in BIM Integration Tool to use its quantity take off function for this task.	BIM Integration Tools provide quantity take off function, combined with additional parameter to manage the treatment and disposal of construction material in this task.	- FM BIM Model - As-built BIM Model	Project Leader	- Report: End of life audit	Owner; Project leader	BIM Integration Tools	
189	Project leader	recommends	demolition and/or rehabilitation strategy (Maintenance)						X	It is desirable to use BIM Tool for analyse and recommend demolition and rehabilitation strategy. BIM Integration Tools provide an ability to do that by 4D Simulation.	BIM-4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model - Report: End of life audit	Project Leader	- Report: Demolition and rehabilitation strategy	Owner; Project leader	BIM Integration Tools		
190	Project leader	provides	services for a new cycle taking the built asset through stages from 0. Initiative to 4. New Use. Possibly partial dismantling under controlled conditions if required						X	From BIM FM Model, Technical Adviser make analysis to examine the built assets, and makes partial dismantling if necessary. It is desirable to use BIM in this part to get sufficient information for Technical Adviser to make analysis. But, there is no available BIM Tools that has the function of this task.	The FM BIM Model has information through the Usage stage of the building, make it easy for Technical Adviser perform these services.	- FM BIM Model	Technical Adviser	- Built asset analysis - Partial dismantling works	Owner; Project leader	N/A		
191	Project leader	schedules	works for revamping						X	From As-built BIM Model, Project Leader schedules all the work for revamping. It is mandatory to use BIM Tools in this task.	BIM-4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model - Built asset analysis - Partial dismantling works	Project Leader	- Revamping schedule	Owner; Project Leader; End-user	BIM Integration Tools		
192	Health and safety adviser	considers	Health and Safety when revamping						X	From As-built BIM Model, H&S analyse the building, and consider H&S strategies and requirement for revamping process. It is mandatory to use BIM Tools in this process.	BIM Integration Tools has the temporary BIM object suitable for simulation this task.	- As-built BIM Model - Partial dismantling works - Revamping schedule	Health and Safety Adviser	- H&S Strategies and requirement for revamping	Project Leader; Owner	BIM Integration Tools		
193	Project leader	sets out	procurement documentation and tender procedures for revamping						X	From As-built BIM Model, Project Leader prepare the procurement document and tender procedures for revamping process. It is mandatory to use BIM Tools.	BIM Integration Tools provide the ability to generating and managing documentation efficiently.	- As-built BIM Model - Partial dismantling works - H&S Strategies and requirement for revamping	Project Leader	- Revamping Procurement documents - Revamping Tender documents	Owner; Tenderer	BIM Integration Tools		
194	Client/Owner	enables	facility shutdown and closing off of the site. Identify services (electricity, gas, fluids, ...) in order to make the building safe for decommissioning						X	It is not necessary for BIM integration in this task since it is the decision of the Owner after receiving information from Project Leader.	N/A	- Built asset analysis - Partial dismantling works - Revamping schedule	Owner	- Decision: facility shutdown	Project Leader; End-user	N/A		
195	Project leader	applies for	any necessary closure permits, preparing documentation to obtain permits from authorities for dismantling or revamping as required						X	BIM is useful to provide the documentation, but is not recommend to use in this task, since the legal procedure for closure permits does not mention about BIM at this moment.	BIM prepare well the documentation for this application of the Project Leader.	- Built asset analysis - Partial dismantling works - Revamping schedule - H&S Strategies and requirement for revamping	Project Leader	- Dismantling or Revamping Pending	Local Authority	N/A		
196	Project leader	identifies	Identify raw materials, waste and materials to be recycled						X	Using BIM Integration Tools, Project Leader quickly define the quantity of raw materials, waste and materials to be recycled from specific building components. It is mandatory to use BIM Tools in this task.	BIM Integration Tools provide quantity take off function, combined with additional parameter to manage the treatment and disposal of construction material in this task.	- As-built BIM Model - FM BIM Model	Project Leader	- Report: Materials & Waste	Project Leader; Owner;	BIM Integration Tools		
197	Project leader	arranges	removal and treatment of contaminated materials, removal of structures, treatment and/or removal of contaminated soil and groundwater						X	It is desirable to let BIM involved into this task. The arrangement of removal and treatment is performed in 4D BIM Integration Tools.	BIM-4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model	Project Leader	- Report: Removal and treatment arrangement	Project Leader; Owner;	BIM Integration Tools		
198	Project leader	selects	appropriate landfill (if necessary)						X	It is not necessary for BIM integration in this task since it is the decision of the Project Leader, and it is the result of site analysis.	N/A	- Site Analysis	Project Leader	- Landfill location	Project Leader; Owner	N/A		
199	Project leader	proposes	measures to control noise, air and ground water pollution						X	It is useful to use BIM in this task to determine the measurement point for control noise, air and water pollution, but it is not recommend since there is no available BIM Tools has this function in the market.	N/A	- As-built BIM Model	Project Leader	- Pollution Control Strategy	Project Leader; Owner	N/A		
200	Local authority	gives	permits for dismantling						X	It is not necessary for BIM integration in this task since it is the decision of the Local Authority	N/A	- Dismantling or Revamping Pending	Local Authority	- Dismantling Approval	Project Leader; Owner;	N/A		
201	Project leader	schedules	works for dismantling						X	Project Leader use 4D BIM Integration Tools to make the schedule for dismantling work. It is mandatory to use BIM Tools in this task.	BIM-4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model	Project Leader	- Dismantling schedule	Project Leader; Owner	BIM Integration Tools		
202	Project leader	sets out	procurement documentation and tender procedures for dismantling						X	Project Leader use 4D BIM Integration Tools to export procurement documentation and tender procedures for dismantling. It is mandatory to use BIM Tools in this task.	BIM-4D Integration Tools has an ability to extract document for procurement and tender procedures.	- As-built BIM Model - Dismantling schedule	Project Leader	- Dismantling Procurement documents - Dismantling Tender documents	Project Leader; Owner	BIM Integration Tools		
203	Project leader	inspects	dismantling of equipment and service disconnections						X	Project Leader inspects dismantling of equipment and service disconnections by normal way. But, it is recommended to use BIM to manage the inspection of equipment and services.	BIM Integration Tools create new parameter to supervise the dismantling of equipment and services.	- As-built BIM Model - Dismantling schedule	Project Leader	- Dismantling Inspection Report	Project Leader; Owner	BIM Integration Tools		
204	Project leader	coordinates	demolition under controlled conditions to ensure health and safety of site operatives and the general public						X	It is mandatory for PL to use BIM Tools to coordinating and monitoring the demolition process. The process is simulation by step in 4D BIM Integration Tools.	BIM-4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model - Dismantling schedule - H&S Strategies and requirement for demolition	Project Leader; H&S adviser	- Site report	Project Leader; Owner	BIM Integration Tools		
205	Sustainability adviser	considers	waste management, environmental impacts, contamination						X	It is useful but not recommended for sustainability adviser to monitor and consider the waste management, environmental impacts and contamination from the information of BIM Model. Since, there is no available BIM Tools in the market for this purpose.	N/A	- As-built BIM Model - Dismantling schedule	Sustainability adviser	- Report of waste management	Project Leader;	N/A		
206	Contractor	selects	appropriate landfill (if necessary)						X	It is not necessary for BIM integration in this task since it is the decision of the Local Authority	N/A	- Landfill location	Contractor	- Updated landfill location	Project Leader	N/A		
207	Contractor	arranges	removal and treatment of contaminated materials, removal of structures, treatment and/or removal of contaminated soil and groundwater						X	It is desirable to let BIM involved into this task. The arrangement of removal and treatment is performed in 4D BIM Integration Tools.	BIM-4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model - Report: Removal and treatment arrangement	Contractor	- Finished dismantling works	Project Leader;	BIM Integration Tools		
208	Health and safety adviser	considers	Health and Safety when dismantling						X	It is highly desirable for H&S Adviser to consider the H&S through the 4D BIM Integration Tools.	BIM-4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model - H&S Strategies and requirement for demolition	H&S Adviser	- H&S Dismantling report	Project Leader	BIM Integration Tools		

ESE	180	Inhabitant/ End-user	updates	information about comfort conditions post renovation process				X	It is highly desirable to have a BIM-based application or tool for End-user to update the information about comfort conditions after the renovation process. This information is linked with space management or room management in BIM FM Tools. End-user need a specific UI or mobile application that they can use for the whole life cycle of the building.	BIM FM Tools summarise and organise well the information received from End-user.	- User experiences	End-user	- FM BIM Model - Building comfort reports	Facilities management (FM) adviser	N/A
	181	Inhabitant/ End-user	feels	comfort/ discomfort during post renovation process				X	It is highly desirable to have a BIM-based application or tool for this action. It is the same with Task [168]. In this UI, there is a specific part for End-user to describe discomfort - comfort range (ex. Scale 1-5 with 1 is discomfort).	BIM FM Tools summarise and organise well the information received from End-user.	- User experiences	End-user	- FM BIM Model - Building comfort reports	Facilities management (FM) adviser	N/A
	182	Facilities management (FM) adviser	uploads	ad hoc information related to operational processes that may be useful for the renovation process (Operation)				X	It is highly desirable to have a BIM-based server share the information related to operational processes. These ad-hoc information may be useful for the convenience of End-user and Owner when living in the building.	BIM based server help its user to share the information efficiently.	- Operational information	Facility manager	- Operational information	Facilities management adviser; End user, Owner	N/A
	183	Owner	monitors	The economic sustainability of the project				X	It is desirable to use BIM FM Tool for economic sustainability monitoring, since there is function in BIM FM Tool for capital planning, or cost management.	BIM FM Tools summarise the economic sustainability based on information collected from previous task.	- Project information	Facilities management adviser;	- Economic sustainability status	Owner	BIM Assets Management Tools
	184	Facilities management (FM) adviser	advises	for maintenance of the building and external works for upkeep of the client's investment				X	Based on the information from BIM FM Model and the maintenance plan, FM Adviser prepares the maintenance strategies and external works for upkeep the building. It is mandatory to update this information into BIM FM Model.	BIM FM Tools and BIM Integration Tools provide the FM adviser a full view on the current building to set up the maintenance plan.	- FM BIM Model - Maintenance Plan	Facilities management adviser;	- Maintenance strategy - Maintenance works	Project leader; Owner	BIM Assets Management Tools
	185	Facilities management (FM) adviser	assists	with facility management, training, environmental monitoring, life-cycle strategy and energy-waste-water management procedures				X	FM Adviser works with FM Team for the facility management and other procedures in building operation. It is highly desired to use BIM in this process, since all of this function is available now in some BIM FM Tools	BIM FM Tools has the function for facility management efficiently, as well as function to monitoring and generating monthly report for environmental and energy-waste-water issues.	- FM BIM Model - Environmental, energy-waste water information	Facilities management adviser; FM Team	- Report: Facility Management - Report: Environmental Monitoring - Life-cycle Strategy - Report: Energy waste water management - Training documents	Project Leader; Owner; FM Team;	BIM Assets Management Tools
	186	Project leader	prepares	documentation to obtain permits for possible changes of use, renovation or redesign				X	In case the building need renovation or redesign, from As-built BIM Model, and FM BIM Model, Project leader prepares appropriate documents to obtain the permits. The building is ready for next cycle of renovation. It is mandatory to use BIM in this task, since all BIM Model is ready.	BIM Design Tools help project leader organise the as-built drawing and documents to obtain permits quickly from available BIM model.	- FM BIM Model - As-built BIM Model - As-built Documentation	Project Leader	- Renovation documents	Local Authority; Owner	BIM Design Tools
	187	Project leader	undertakes	procurement documentation and tender procedures for facility management, maintenance, and possibly renovation (Maintenance)				X	Project Leader use BIM tools to set out these documents, and manage the tender procedures. The information from As-built BIM Model and FM BIM Model are combined and export to BIM Integration Tools for doing this task. It is mandatory to use BIM Tools.	BIM Integration Tools provide the ability to generating and managing documentation efficiently.	- FM BIM Model - As-built BIM Model - Renovation Documentation	Project Leader	- Procurement documents - Tender documents	Owner; Tenderer	BIM Integration Tools
	188	Project leader	recommends	end of life audit (Maintenance)				X	It is desirable to use BIM Tool for this task. But, there is no BIM Tools available in the market provide this function to audit end of life of a building. Project leader can perform the input data in BIM Integration Tools to use its quantity take off function for this task.	BIM Integration Tools provide quantity take off function, combined with additional parameter to manage the treatment and disposal of construction material in this task.	- FM BIM Model - As-built BIM Model	Project Leader	- Report: End of life audit	Owner; Project leader	BIM Integration Tools
189	Project leader	recommends	demolition and/or rehabilitation strategy (Maintenance)				X	It is desirable to use BIM Tool for analyse and recommend demolition and rehabilitation strategy. BIM Integration Tools provide an ability to do that by 4D Simulation.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model - Report: End of life audit	Project Leader	- Report: Demolition and rehabilitation strategy.	Owner; Project leader	BIM Integration Tools	
END OF LIFE	190	Project leader	provides	services for a new cycle taking the built asset through stages from 0. Initiative to 4. New Use. Possibly partial dismantling under controlled conditions if required				X	From BIM FM Model, Technical Adviser make analysis to examine the built assets, and makes partial dismantling if necessary. It is desirable to use BIM in this part to get sufficient information for Technical Adviser to make analysis. But, there is no available BIM Tools that has the function of this task.	The FM BIM Model has information through the Usage stage of the building, make it easy for Technical Adviser perform their services.	- FM BIM Model	Technical Adviser	- Built asset analysis - Partial dismantling works.	Owner; Project leader	N/A
	191	Project leader	schedules	works for revamping				X	From As-built BIM Model, Project Leader schedules all the work for revamping. It is mandatory to use BIM Tools in this task.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model - Built asset analysis - Partial dismantling works.	Project Leader	- Revamping schedule	Owner; Project Leader; End-user	BIM Integration Tools
	192	Health and safety adviser	considers	Health and Safety when revamping				X	From As-built BIM Model, H&S analyse the building, and consider H&S strategies and requirement for revamping process. It is mandatory to use BIM Tools in this process.	BIM Integration Tools has the temporary BIM object suitable for simulation this task.	- As-built BIM Model - Partial dismantling works. - Revamping schedule - As-built BIM Model	Health and Safety Adviser	- H&S Strategies and requirement for revamping	Project Leader; Owner	BIM Integration Tools
	193	Project leader	sets out	procurement documentation and tender procedures for revamping				X	From As-built BIM Model, Project Leader prepare the procurement document and tender procedures for revamping process. It is mandatory to use BIM Tools.	BIM Integration Tools provide the ability to generating and managing documentation efficiently.	- As-built BIM Model - Revamping schedule - H&S Strategies and requirement for revamping	Project Leader	- Revamping Procurement documents - Revamping Tender documents	Owner; Tenderer	BIM Integration Tools
	194	Client/Owner	enables	facility shutdown and closing off of the site. Identify services (electricity, gas, fluids ...) in order to make the building safe for decommissioning	X				It is not necessary for BIM integration in this task since it is the decision of the Owner after receiving information from Project Leader.	N/A	- Built asset analysis - Partial dismantling works. - Revamping schedule	Owner	- Decision: facility shutdown	Project Leader; End-user	N/A
	195	Project leader	applies for	any necessary closure permits, preparing documentation to obtain permits from authorities for dismantling or revamping as required		X			BIM is useful to provide the documentation, but it is not recommend to use in this task, since the legal procedure for closure permits does not mention about BIM at this moment.	BIM prepare well the documentation for this application of the Project Leader.	- Partial dismantling works. - Revamping schedule - H&S Strategies and requirement for revamping	Project Leader	- Dismantling or Revamping Pending	Local Authority	N/A
	196	Project leader	identifies	Identify raw materials, waste and materials to be recycled				X	Using BIM Integration Tools, Project Leader quickly define the quantity of raw materials, waste and materials to be recycled from specific building components. It is mandatory to use BIM Tools in this task.	BIM Integration Tools provide quantity take off function, combined with additional parameter to manage the treatment and disposal of construction material in this task.	- As-built BIM Model - FM BIM Model	Project Leader	- Report: Materials & Waste	Project Leader; Owner;	BIM Integration Tools
	197	Project leader	arranges	removal and treatment of contaminated materials, removal of structures, treatment and/or removal of contaminated soil and groundwater				X	It is desirable to let BIM involved into this task. The arrangement of removal and treatment is performed in 4D BIM Integration Tools.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model	Project Leader	- Report: Removal and treatment arrangement	Project Leader; Owner	BIM Integration Tools
	198	Project leader	selects	appropriate landfill (if necessary)	X				It is not necessary for BIM integration in this task since it is the decision of the Project Leader, and it is the result of site analysis.	N/A	- Site Analysis	Project Leader	- Landfill location	Project Leader; Owner	N/A
	199	Project leader	proposes	measures to control noise, air and ground water pollution		X			It is useful to use BIM in this task to determine the measurement point for control noise, air and water pollution, but it is not recommend since there is no available BIM Tools has this function in the market.	N/A	- As-built BIM Model	Project Leader	- Pollution Control Strategy	Project Leader; Owner	N/A
	200	Local authority	gives	permits for dismantling	X				It is not necessary for BIM integration in this task since it is the decision of the Local Authority	N/A	- Dismantling or Revamping Pending	Local Authority	- Dismantling Approval	Project Leader; Owner	N/A
	201	Project leader	schedules	works for dismantling				X	Project Leader use 4D BIM integration Tools to make the schedule for dismantling work. It is mandatory to use BIM Tools in this task.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model	Project Leader	- Dismantling schedule	Project Leader; Owner	BIM Integration Tools
	202	Project leader	sets out	procurement documentation and tender procedures for dismantling				X	Project Leader use 4D BIM Integration Tools to export procurement documentation and tender procedures for dismantling. It is mandatory to use BIM Tools in this task.	BIM 4D Integration Tools has an ability to extract document for procurement and tender procedures.	- As-built BIM Model - Dismantling schedule	Project Leader	- Dismantling Procurement documents - Dismantling Tender documents	Project Leader; Owner	BIM Integration Tools
	203	Project leader	inspects	dismantling of equipment and service disconnections				X	Project Leader inspects dismantling of equipment and service disconnections by normal way. But, it is recommended to use BIM to manage the inspection of equipment and services.	BIM Integration Tools create new parameter to supervise the dismantling of equipment and services.	- As-built BIM Model - Dismantling schedule	Project Leader	- Dismantling Inspection Report	Project Leader; Owner	BIM Integration Tools
	204	Project leader	coordinates	demolition under controlled conditions to ensure health and safety of site operatives and the general public.				X	It is mandatory for PL to use BIM Tools to coordinating and monitoring the demolition process. The process is simulation by step in 4D BIM Integration Tools.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model - Dismantling schedule - H&S Strategies and requirement for demolition	Project Leader; H&S adviser	- Site report	Project Leader; Owner	BIM Integration Tools
	205	Sustainability adviser	considers	waste management, environmental impacts, contamination	X				It is useful but not recommended for sustainability adviser to monitor and consider the waste management, environmental impacts and contamination from the information of BIM Model. Since, there is no available BIM Tools in the market for this purpose.	N/A	- As-built BIM Model - Dismantling schedule	Sustainability adviser	- Report of waste management	Project Leader;	N/A
	206	Contractor	selects	appropriate landfill (if necessary)	X				It is not necessary for BIM integration in this task since it is the decision of the Local Authority	N/A	- Landfill location	Contractor	- Updated landfill location	Project Leader	N/A
	207	Contractor	arranges	removal and treatment of contaminated materials, removal of structures, treatment and/or removal of contaminated soil and groundwater				X	It is desirable to let BIM involved into this task. The arrangement of removal and treatment is performed in 4D BIM Integration Tools.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model - Report: Removal and treatment arrangement	Contractor	- Finished dismantling works	Project Leader;	BIM Integration Tools
	208	Health and safety adviser	considers	Health and Safety when dismantling				X	It is highly desirable for H&S Adviser to consider the H&S through the 4D BIM Integration Tools.	BIM 4D Simulation Tool has an ability to use BIM model directly, enabling users to associate activities and constraints with model objects.	- As-built BIM Model - H&S Strategies and requirement for demolition	H&S Adviser	- H&S Dismantling report	Project Leader	BIM Integration Tools

The BIM Tools highlighted in the Appendix II are described below in detail:

Tool Name	Tool Description
Model Viewer	A software application allowing users to inspect and navigate Modelling Project Information according to ad-hoc or standard Model View Definitions. As opposed to Model Servers, models accessed by a model viewer (MV) are read-only and cannot be modified.
Asset management	BIM-enabled asset management is characterized by linking virtual objects and spaces within a model to an external database for the purpose of operating and maintaining a Facility or a portfolio of facilities.
Financial information of building	A Model Use representing how BIM models are linked with financial networks, booking systems, and a variety of web-based services.
BIM Server	A software solution (installed on a local server or hosted in the cloud) allowing Multi-Discipline Models to be centrally collated and managed. Model Servers are a type of Federated Modelling Environments and typically depend on non-proprietary open formats similar to Industry Foundation Classes (IFC).
Point cloud data	A set of data points in 3D which are typically created by 3D Laser Scanners to capture an object, space or a whole building. Point Clouds can be transformed into meshes, surfaces and even 3D objects using specialised tools. Point cloud files can be typically imported into most BIM Software Tools to generate As-Built Models or model parts.
Design Tools	Digital tools generate, modify, analyse, or optimise an object or a space. CAD represents all pre-BIM digital tools and their 2D/3D deliverables
Model checkers	Design Model (D Model) is an object-based 3D model generated by the Design Team (individually or as a group) for the purposes of design analysis, Clash Detection and documentation.
Cost estimation	The use of specialized calculations to identify and analyse projected construction costs. Cost Estimation can be a manual or a fully automated process.
BIM Integration tools: For Construction model	Construction Model (C Model) is an object-based 3D model generated by the Contractor or Construction Team for the purposes of construction analysis, Construction Scheduling and plant design.
BIM Integration tools: Construction model	A Model Use representing how 3D models and related databases are accessed in the field (i.e. on the construction site). Through a tablet, laptop, smart phone or wearable equipment, the user would inspect designs, send requests for clarifications, mark drawings/models, complete a checklist, report an issue, or conduct information-rich, site-based activities.
BIM Integration tools: For Demolition planning	A Model Use where 3D models are used to plan or monitor demolition activities of existing structures (or parts of existing structures).
BIM Integration tools: For Record model	Using BIM Software Tools to generate an accurate representation of an existing Facility; its spaces, assets, physical condition and surrounding environment. The Record Model may link to other records (documents, drawings, images, etc.) and include equipment manufacturer data, maintenance schedules, warranties and space conditions/damages.
Planning and control	Operation competencies and topics cover the daily, hands-on individual efforts required to deliver a project or part/aspect of a project. Operation topics do not typically cover the specifics of software tools or equipment used to generate Project Deliverables but focus on the deliverables themselves and the workflows enabling them.
Surveying site condition	A Model Use where 3D models are used to establish the dimensional relationships, including horizontal distances, elevations, directions, and angles, on the earth's surface. surveying is typically used to locate property boundaries, generating maps and establishing construction layout.
4D capabilities	The fourth modelling dimension (4D) refers to 3D + time. That is, a model or a modelling workflow is considered to be 4d when the time is added to model objects to allow Construction Scheduling.
BIM Software Tool	The software applications which can author an object-based, data-rich, 3D model. These software applications often link to other Specialized Software Tools to generate a variety of Model-based Deliverables.