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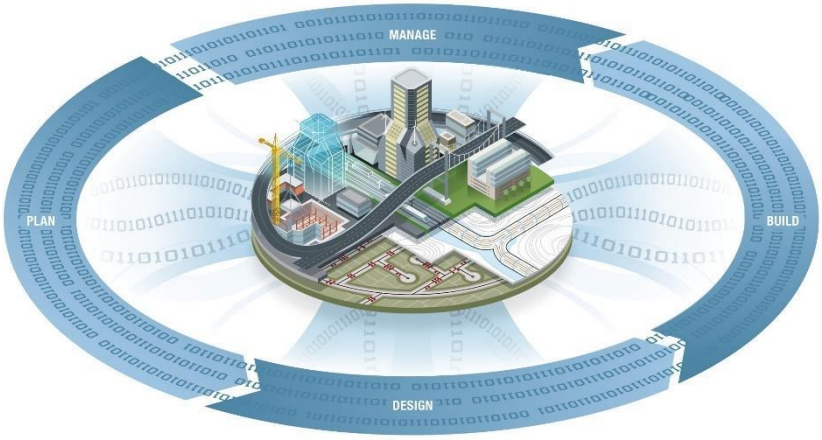


# Research on Bridging the Information Gap of BIM of interoperability and integration in Facilities Management

*Master of Science thesis in the master's Program Design and Construction Project Management*

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CHALMERS UNIVERSITY OF TECHNOLOGY
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## Summary

Building Information Modeling (BIM) is a combination of technologies and human work practice in handling geometric and non-geometric information management over the whole life cycle of the construction project. BIM has already matured for implementation in the design and construction phase of a construction project. However, there is still a low rate of utilization of BIM in asset operation and maintenance in the industry. Even though there has been a lot of academic research to study how asset information in BIM can leverage the workflow and performance of Facilities management (FM), there is still only 10% of companies/projects that recognize the benefit of the usage of BIM in Facilities management. There is less research to study the challenges of information integration from BIM to operation and maintenance. So, the purpose of this report is to investigate 1.) What information is required for FM, 2.) What hindrances are there in terms of information integration from BIM to FM and, 3.) What improvements can be done to the integration process.

This report is a qualitative study and is based on a literature review and interviews. The interviews, which were semi-structured, were deployed in order to explore the different perspectives regarding the issues about the BIM-FM information transfer and integration process. The interviewees were acting as architects, engineering consultants, and facilities managers from different construction companies in Sweden and Hong Kong. Their experience and opinions from the interview provide findings to form the base of the conclusion. The main findings of this study are discussed. One cause of the problem of information integration from the BIM model to FM is because there is a lack of standard information requirements and format in facilities management. Each practitioner provides asset specification and construction detail in BIM with the format under their preference and perception. Furthermore, the insufficient collaboration between each party, inactive engagement from facilities managers at earlier stages, and different levels of knowledge toward BIM usage in FM and benefit recognition are also hindrances to drive further development of information integration from BIM to FM. BIM enabled FM benefits cannot be fully recognized due to many challenges mentioned above.
This study concludes by calling upon a holistic integration of people, processes, and technical change in order to reach better performance of information integration from BIM to FM

Keywords: BIM, Information gap, Facility management, operational stage, information integration.

# Contents

# 1 Introduction

Facility management (FM) is defined as a set of disciplines, methods, procedures, and tools to integrate people, place, and process within the built environment, as a result, to provide a safe and healthy life to people and improve the productivity of the core business (Becerik, 2011). Facilities management can also allow future changes; enhance the organization's image and culture (Haider, 2013; Atkin, 2015). Authors suggest that the objective of the facilities management process is to preserve the asset operating condition at good performance close to the original condition as long as it achieves cost-effectiveness during operation, boost energy efficiency, support sustainability, and enhance the quality of the facilities (Haider, 2013; Sklar, 2004; Too, 2010). Meanwhile, Becerik-Gerber (2011) states that one of the important factors to affect the quality of performance in operation and maintenance is dependent on the completeness and quality of the information involving design and installation detail of facility components received by building operators and facilities managers. They rely on the information obtained from various teams including consultants, subcontractors, building contractors, and suppliers to make decisions on maintenance schedules and activities.

Adeline, Lai and Deng (2018) identify what information should be presented in facilities management including constructed drawings and schedules, the product datasheet and

manufacturer pamphlets, asbestos material assessments, hazardous material reports, fire performance and containments details, actual versus planned project costs and schedule, operation, and maintenance (O&M) manuals, product warranty information, and spare parts lists. However, Hooper (2012) summarized the traditional information flow in construction projects is not effective enough no matter which project stages such as design, construction and operation stages. They defined there is an efficient path through the life cycle of the project in term of time expense in information transmission. It is used to determine the efficiency of information transmission by measuring the deviation between actual information flow and the efficient path in each project stage. The flow meanders up and down an efficient path which results in frustration, loss of momentum behind value-adding processes, and often considerable time wasted.

Building Information Modelling (BIM) is an information center to store geomatics and non-geomatics building information in digital format and providing the platform to share on a single repository throughout the building's life cycle (Succar 2009). Motawa (2019) and Matarneh (2019) point out BIM is applied in facility management which helps to specify the information needed to be passed from design, and construction to operation and maintenance (O&M). It can provide a unified platform for various data sources needed for daily O&M activities, data regarding technical specification, planned activities, and building performances. It can also visualize the building model with detail of asset information for asset managers to assess the relationship of building system and equipment for decision making in maintenance schedule and activities detail.

However, Lai and Deng (2018) also state that asset managers cannot directly use the data extracted from BIM. The data from BIM should coordinate with the original existing data in the FM system in order to form a whole picture of facilities management planning. This is called information integration. The performance of integration can determine whether facilities managers can carry out facilities management successfully or not.

Moreover, Jang (2020) claims that there is still less penetration in using BIM for facilities management and less research to investigate what challenges are faced. One of the main problems is that facilities managers are unable to identify information from the BIM database. Each party in the project team comes from a different background and they also act in different roles withholding specific interest and responsibility within the project team. It will develop their own perception toward what, how, and when information is needed to be shared into BIM. Neda (2016) studies the problem of information integration from BIM to FM based on the project owner perspective. He emphasizes the data in BIM with various semantic formats toward element decomposition, naming, and coding of asset specification from the FM system. The information in BIM should be gone through semantics synchronization but it is normally less focused by project owner in the work practice. It leads to information quality issues such as misrepresentation, data loss, and data inconsistency.

Golparvar-Fard (2011) focusses on the designer and also reflects the view toward the information quality issue such as misrepresentation, data loss, and data inconsistency which is caused by lack of communication and cooperation between designer and facilities manager. The designers are not able to well know the detail of need and requirement of information from the facilities manager at the earlier stage of the project. There even are far fewer studies to investigate the perspective from the third-party consultancy toward how organizational management and technical problem influence the information integration requirement and quality in the project operation stages

This paper summarizes the literature and collects empirical data from interviews with engineering consultants and facilities management firms to explore three research questions described below in order to reflect their perspective toward the performance of the information integration from BIM to FM and the problems existing during project handover. The main reason to conduct this research to further investigate how organizational management and technical issues influence the integration process (Jang, 2020) can provide a distillation of the problems surrounding BIM/FM asset integration and its resolution from a consultant perspective.

## 1.1 Purpose

The purpose of the thesis is to identify different challenges in information integration from the Consultants' point of view and investigate how the gap can be improved in terms of technical implementation, organization structure, practitioner knowledge in the process, and communication itself. The thesis can also help to initiate a further study to identify whether there is a gap between the improvement strategies in driving the standardization process of information requirement to reduce the knowledge gap toward BIM information handling in asset operation and maintenance and exactly implement progress within the organization. In addition , it can encourage an further analysis to study the reason for this gap existing in the industry and find out possible solutions.

## 1.2 Objective

The primary objective of this research was to investigate how the consultant thinks about the problem existing in information integration from BIM to FM and recognize what hindrance prevents the integration process. It can help management within organization to refresh the understanding that not only the introduction of a new technology is enough to solve the information integration problem, it initiates the project team to establish a breakthrough in future development not only in digitalization technology but also including working procedures,

project team structure, knowledge, and communication enhancement. It can serve as a reflection to identify technology itself as hardware is not enough to improve information integration.

## 1.3 Research questions

In this report, there are three research questions defined below which will be used throughout the report:

- **What information in BIM would be important for facilities managers to carry out their work?** It can help to summarize different kind of asset information into systematic clarification and identify what kind of asset information is actually critical for proceeding the facilities management
- **What are the hindrances to perform BIM information integration from the other stages to the operational stage?** The challenges will be discussed not only covering technical aspects such as requirements or standardization issues. There is also a focus on management aspects such as project team structure, people knowledge gap, and communication to find out how they affect information integration from BIM to FM in reality
- **How to improve the information integration from BIM to FM?**

## 1.4 Limitations

In this report, the primary focus is on data integration from BIM to FM in the operation phase. It mainly focuses to research how third-party consultants perceive the data integration from BIM. When the master's thesis starts to study the consultant perspective, it induces the limitation of only focusing on the operation phase. It assumes that the design phase and construction phase have been well developed in terms of data integration and are therefore not included in the study.

However, it actually should consider the information flow and integration from the designing phase to the construction phase in order to identify any pre-existed problems related to information quality because those pre-existed problems will bring along to cause the chain reaction of negative effect to the operation phase.

Another reason for focusing on the operation phase due to the framework of data recognition and information integration from designing a model to construction work has been well developed and creates a comprehensive database in most architecture consultant firms and contractors. Reversely, there is less standardization on data formalization in semantic presentation and information requirements to assist data recognition and information integration in the operation phase. It results in fewer facilities management consultancy companies directly using BIM in operation work. It is more valuable to conduct further

investigation of what are the real reasons to cause the problem as mentioned in the operation phase.

## 1.5 Disposition

The report begins with an introduction followed by a theoretical framework. The theoretical framework begins with a short description of BIM and is then divided into four different parts. The first parts describe the benefits of using BIM in the operation phase. Secondly, it identify the items from asset information to be critical for the operation phase. The continuing part is presented as the problem of the integration and reason from a different angle with the detail of the explanation. The last part is to collect ideas on how to improve the situation.

Thereafter the methodology chapter describes the work process applied in this report to achieve the goal of this report and to reach answers to the research questions.

After the methodology section, there are interviews with the case companies how they apply BIM to transfer the proper information as required in operation and work with another individual of the project team. The analysis results of information collected from the interviews are presented in the result and analysis chapter. In the discussion chapter, the result and analyses are discussed and compared with the theory. Finally, the report is finalized to conclude, containing the main key points and a few suggestions for further studies.

# 2 Literature overview

Facilities Management can be defined as a scope of the process to be applied during the lifecycle of the asset in order to ensure the performance of the asset fulfilling its expectation and sustain its condition as long as it can to provide safety and a healthy work environment to the user or owner. It can be divided into three levels (Haider, 2013): operational, tactical or management, and strategic.

- The operational level includes activities to ensure expected asset performance.
- The tactical or management level is to plan and determine what activities are necessary at the operational level and schedule them during the life cycle.
- The last strategic level is classified as a long-term vision of facilities management to create new value propositions for the stakeholders and organization.

FM processes are often segregated from the design/construction phases to result in costly inefficient information management of an asset over its whole life cycle (Vanlande, 2008). The application of BIM in FM can allow asset managers to participate in an earlier stage of design and

construction of assets by exchanging information such as warranty data, administrative characteristics, life expectancy, maintenance recommendations, and renovation documentation. It can let all team members get well to understand what difficulty in the FM at the earlier stages (Alexiadi and Potsioy, 2012). It means that BIM can help to link FM into the whole lifecycle of the project by its function as a single information storage platform (Azhar, 2012).

However, Patacas et al (2020) states that the industry is still facing several challenges in how to apply BIM for the data integration process from other phases to the FM stage. The literature overview of this report is mainly based on published scientific articles, books, and conference papers. It is divided into five sections as follows in order to go deeply around the issue related to the problem of data integration from BIM to FM.

1. What is BIM?
2. Identification regarding different recognition of BIM benefits from various perspectives of shareholders in the project team.
3. What asset specific information items are critically required for FM?
4. The origin problems in information integration from BIM to FM.
5. The way of improvement in information integration performance.

## 2.1 What is BIM

Eastman et al (2011) define BIM as a modeling technology and the associated set of processes to produce building models with parametric digital databases. The building model also consisted of components in computable graphic and data attributes. Those geomatics and non-geomatics data can be used for visualization, facilities management, cost estimating, construction sequencing and spatial relationships collision detection

There are commonly two terminologies towards BIM as interpreted into technology and process. As under technology terminology, BIM is used in 3D model simulation for an asset and its components. It is created by combination of different information and documents from project planning, design, construction, operation and facility management separately (Azhar et al., 2012). As under process terminology, the building model is developed by well-integrated and cooperation within project teams including designers, builders, owners and other stakeholders in the life cycle of buildings or facilities. It requires effective communication, trust, transparency, information sharing, shared risk and reward (Azhar et al., 2012).

IFC is an open standardized data model for BIM. It is developed to address information interoperability during information exchange and transmission as different IT technologies are used by corresponding members within project teams. It contains definitions for hundreds of objects and links up relationships of these objects regarding their respective properties. (Patacas et al. 2015) . According to Froese (2003), the IFC include all types of project information such as

parts of a building, the geometry and material properties of building products, project costs, schedules, and organizations, no matter geometrical and non-geometrical data which can be mapped into single IFC data file in order to effectively shared and exchange information in different phase through BIM (Froese, 2003).

However, Naghshbandi (2016) and Cavka (2017) claim there is normally a different information classification and presentation format applied in the facilities management. Construction Operation Building information exchange (COBie) is introduced as a non-proprietary format for the asset information presentation by exchanging with BIM which is commonly focused on delivering non-geometric asset specific information for facilities management purposes. It is capable of storing and sharing the specification of assets from the various operation and maintenance documents into digital spreadsheet data format. Before COBie was established, the asset information was normally saved in different documentary formats as well as the preference of corresponding project team members. It is difficult for the client to read and use throughout the life cycle of the project.

## 2.2 The benefit of using BIM in Facilities Management

Cavka (2017), applied a study which revealed that most of the current project handover to facilities managers is done without using BIM. There are few problems induced related to BIM not to be applied, such as lag behind schedule. Moreover, the project documentation is often unstructured, uncompleted, nor reusable, and information has inconsistencies. Furthermore, Clayton (1999) recognizes that there is often the problem of missing or irrelevant information included in the closeout documentation. Some of the closeout documentation is found in an inappropriate format and a mismatch in terms of structure and content. Under this circumstance, the facilities managers often do not have a clear picture of what exact equipment and systems are responsible to undergo their operation and maintenance process depending on how the detail of information is handled by manually entered into FM systems themselves after the handover (Cavka, 2017). Clayton (1999) emphasizes that there is no compromise to the information requirement standardization between different parties within the organization. It causes facilities managers who always chase back information from designers or contractors to perform their tasks. In addition, most of them do not have clear requirements for handover that are sufficient to ensure the usefulness of delivered information.

Studies show significant evidence of the great improvement in project management by using BIM 3-D graphics integrated with the activity schedule and collection of resource components to generate a 4-D view of critical path method plan (Mohandesa, 2014). It can visualize the layout

of the workplace space in order to simulate how each asset is located in the right place without a crash. Moreover, it can also simulate the asset construction process component installation sequence which is carried out by the contractor onsite. In addition, BIM can use its 3D model feature to visualize the detail of material used in components of assets. So, using BIM visualization features can enhance the communication between designer, contractor, and facilities manager. It can help to avoid the discrepancy in onsite facilities construction process and installation sequence. It can help facilities managers to build up concepts on how to determine the schedule of regular maintenance and reflect the difficulty they will face during operation at the earlier stage.

There is a lot of research investigating how BIM data can save time and expense in the facilities management process by creating an exchangeable database (Patacas et al., 2020). The BIM components are able to show the detail of different types of maintenance-related information, for example, scheduling the maintenance, replacing the parts ordering, installation and maintenance instructions, and past records of maintenance (NaghshbandiS, 2016). Other data in control definition may include energy usage data, furniture inventories, allocating the space, schedules of space utilization, locations of personnel, and so on.

Moreover, Garrigos (2018) claims that BIM implementation can standardize and codify those information regarding the operation and maintenance. It will further help to centralize information and flexibly store all changes for obtaining an As-built model, adapting the building logbook into a real updated document in a single file, reliable and exportable. Mayo,G, & Issa, R.R (2016) also emphasizes the advantage of BIM in project operation after handover allows the database in relational format. Morton (2011). Skripac (2013) suggest that BIM can help to reduce the time and effort to generate FM database by 98% by automating the process of data transfer and update

Naghshbandi (2016) claims BIM can Improve Space Management through visualization of spaces and assets with the location. Additionally, when space requirements or purposes change, BIM can assist to reduce conflict in identification. Furthermore, all service history and specification and contract information can be found in BIM which can assist to set up maintenance activities. The last is BIM can compare various energy alternatives which can effectively diminish environmental impacts and operating costs.

Jang (2020) claims if it is perfectly allowed the information in BIM to be directly used by the facilities manager transplanting into the FM system in order to proceed their work due to BIM with high information accuracy and sizable database . It can help to alleviate complicated data transfer from design and construction to operation and maintenance by providing reliable BIM-based data and accurate as-built information to facility managers. However, the actual situation is reflected by facilities managers who are facing the difficulties in capturing asset information directly from BIM to FM (Jang, 2020).

Patacas et al (2020) also proposes the other integration approaches are specific to mechanical, electrical, and plumbing (MEP) maintenance data from BIM to be extracted for routine operation and maintenance (O&M) tasks and emergency planning. This approach enables the automatic scheduling of facility maintenance work orders which can reduce operating costs and time in workflow. However, they show there is still only 10% of companies/projects that can recognize the FM phase benefits by adopting BIM.

## 2.3 The asset information items request for Facilities Management.

Love (2015) iterates that it is still unable to perform a good information transmission due to stakeholders without a clear understanding of what specific asset information is necessary for conducting FM. Sometimes, the misleading of asset information identification is due to various semantic interpretations toward certain asset components (Burkett 2002). It is essential to gather useful information about the asset throughout their lifecycle for facilities managers to make effective decisions in management and control of asset utilization. McArthur (2015) states that information required in FM will vary enormously from project to project, based on specific user systems, organizational structure, and scope of the model but it still stick to three rough areas: space planning, maintenance activities, and front-of-house In addition, Ouertani (2005) claims that a set of information is necessary in facilities management enabling the facilities managers to make effective decisions on maintenance activities throughout the lifecycle of assets. It includes spatial information, design specification, component installation, material data and environmental condition.

it is very important to have clear spatial arrangement for different facilities (Asen et al. 2012). Akcamete et al. (2010), Becerik-Gerber et al. (2011), and Nepal et al. (2012) suggest the spatial information should be included in two things. One is the accurate space definition and the other is accurate facilities placement as well. The main function of them can help facilities managers not only identify in which space for particular facilities are located but also it can help to determine whether the facilities are placed as the original assigned location. Providing relevant, timely and useful location information to facilities managers can help to make quick and informed decisions on what, how and when to conduct the maintenance events. It can help to avoid extra cost associated with searching for misplaced or lost assets and improving overall productivity and throughout.

Ouertani (2005) states the other important information to be physical component lifecycle information. It includes the design, material acquisition, manufacturing, construction flow and relevant operation and maintenance record. The detail of material for each component during acquisition can let the facilities manager have a clear picture about their properties and usage life span in order to arrange proper maintenance activities later on. Moreover, once all components are ready onsite which will be installed by following the schematic design from architect or

engineer. The different component installation flow and method may influence the performance and duration of the whole facilities in operation after the project handover. Therefore, the information related to the facilities construction sequence and procedure is also important to the facilities manager.

Kulusjärvi (2012) claims the information toward Mechanical, Electrical and Plumbing engineering systems is especially significant for intelligent troubleshooting processes where facilities manager is without knowledge to know all equipment within the MPE systems and able to identify which one is not working properly as well as for better understanding the consequences when the facility is broken.

In fact, Broadbent (2016) claims that there should be much more information items requested for FM. They identify 72 critical items to be captured for asset and maintenance management. Within these 72 critical items, there are 62 items which can be captured from the BIM model and can be categorized into eight main classifications as shown in below Table 1:

- Purchase Information
- Facility Information
- Asset Specification
- System Specifications
- Maintenance Procedures
- Manufacturer
- Vendor
- Extended Warranty.

*Table 1* The Eight main information categories definition for FM usage *(Broadbent, 2016)*

Generally, in the current ongoing BIM projects, the required information is identified based on plain language questions, educated experience, and sometimes on assumptions of data that might be needed for better facilities management.

Farghaly (2018) based on the finding of (Broadbent, 2016), conducted interviews with asset managers in order to develop a domain taxonomy to facilitate the successful implementation of BIM in AM. They made an advanced development in taxonomy for BIM information which is critical to Facilities management by identifying 60 asset specification information and classified under six main information categories under table 2 below 1. The detail of 60 asset specification information is shown under figure 1 below2:

| | |
|---|---|
| ● Space/Location | ● Warranty |
| ● Classifications | ● Asset Capex |
| ● Specifications | ● Maintenance |

*Table 2* The Six main information categories definition for FM usage *(Farghaly, 2018)*

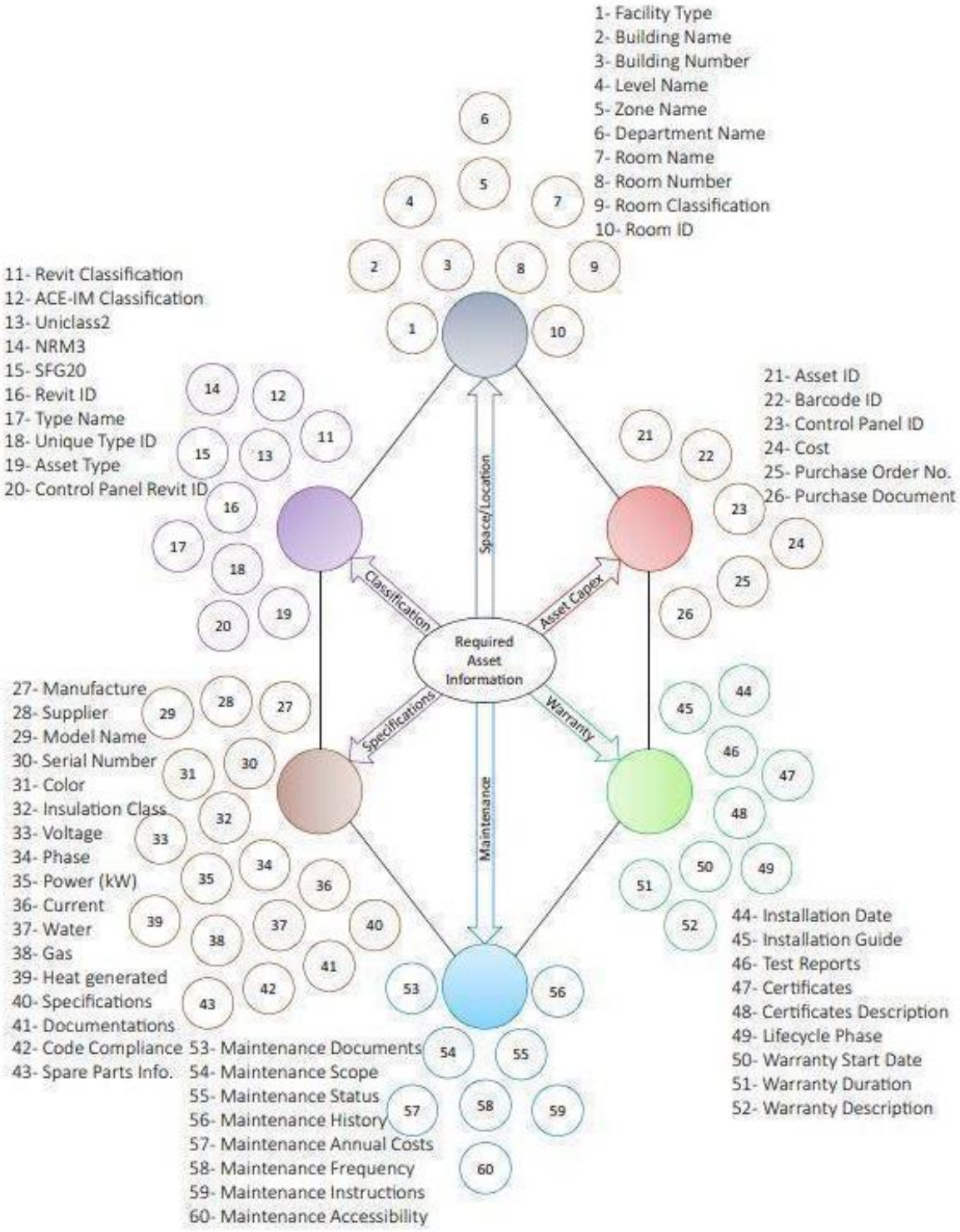


*Figure 1 ACE-IM taxonomy for the required information for AM (Farghaly, 2018), page4)*

Usman (2017) also proposes the reason to list out detail of information items to standardize information items definition for facilities management, it can allow the practitioners no matter architect, contractor, supplier and facilities manager to follow what information needs to

contribute for project operation purpose in order to reduce the risk of data inconsistency problem passing from designing stage or construction stage to operational stage because of different data acquisition requirements. Also, this taxonomy can help the data integration in a BIM environment has issues related to the establishment of an effective process to extract, store, manage, integrate, and distribute data to ensure interoperability.

## 2.4 The origin of the information integration problem from BIM to FM

Patacas et al. (2020) emphasizes the problem of information flow from BIM to FM during the integration process to be much more serious than the other project phases. Jang (2020) research shows the operation cost is still occupying a very high proportion of project lifecycle cost and amounts to 85%. Facilities managers normally spend 80% of their working hours on seeking accurate information under an unclear information requirement and data formulization environment. Neda (2016) identifies these are one of the major factors to affect the efficiency of asset management processes. It results in a higher total project cost. Besides that, there are a number of barriers to data integration from BIM to FM as discussed below.

### 2.4.1 Unclear Information requirement and project scope

Jang (2020) summarizes that the less use of BIM in FM, in reality, is due to the problem of BIM information integration into FM systems. They summarized the hindrance of implementation of BIM into two areas. One is the incompatible information and software interoperability. The incompatible information is caused by unclear scope of operational work to state the standard of information requirement. This is a problem due to clients without sufficient competence to understand the details of operation and maintenance activities and the relationship between design and construction work and facilities management (Jang, 2020). They are unable to understand what the prerequisite information is required for corresponding operation work and how to arrange the activities into proper sequence order. Without the full concept, it is difficult for them to make the scope and schedule of work even under the assistance of designers or consultants. it is still very difficult for them to fully understand what level of detail in asset specification is needed to be shared in BIM. It may cause too much information or insufficient information to influence the operation and maintenance coordination (Miettinen, 2018).

Furthermore, clients normally delegate the liability to the contractor for developing operation scope of work and information requirements. However, the work practice of the contractor on site normally leads to a lot of changing work during the construction stage under site uncertainties and non-finalized designing. The asset information in BIM is also needed to change to align with the construction method and sequence (Pishdad-Bozorgi, 2018). Simultaneously the information in the FM system is also needed to be revised frequently. It may easily cause the error of information transmission from BIM to FM systems as the high frequency of changing

because it is difficult to follow the client's requirement to specify the data from BIM. The quality of BIM asset integration is affected.

The other cause of the problem of incompatible information is the clients who have difficulty getting the full picture of each operation and maintenance management requirement in order to translate into an executable rule to restrict the format and level of detail of asset information required for operation work in terms of making Asset Information Requirement (AIR). Without AIR working as a fundamental specification of information standard, it is challenging to transform into a BIM Execution Plan (BEP). The BEP can help to assess project-conditions and work processes in order to build up a clear picture of what information is necessary to proceed with the facilities management. In addition, it can clearly define the role and responsibility of each party within the project team toward what, when, and how to share the specific asset information in BIM. Therefore, It can assist asset managers to monitor the information received in a timely and cost-effective way to ensure that the asset manager receives the facility management information timely, and cost-effectively (Yu-Cheng, 2016).

In the end, a facilities manager or client cannot follow Asset Information Management to identify what kind of information they need and determine the level of detail of asset information in BIM. Poirier (2020) claims that It results in rework and manual data entry which are usually required to lead to duplication of efforts and high chances of errors. It affects the time of workflow and waste of resources. There is also a lack of knowledge to manage data through digital systems such as BIM for clients and contractors which is quite common (Poirier, 2020). Considering this, lacking those understanding and experience can cause missing or misaligned information requirements which hinder or negate the potential value of asset information during the operations phase. The last problem is the lack of stakeholders' involvement in the BIM transitioning process which will affect their understanding of the requirements of the FM team (Poirier, 2020). The stakeholders such as designer, contractor, or client without a clear concept of how the FM team manages the resulting AIM after facility handover in order to prepare a well-organized and comprehensive information required for making an execution plan to the FM team.

### 2.4.2 Different level of understanding of BIM.

Matějkaa (2017) discusses that project team individuals have different levels of understanding the benefit of BIM in data handover to operation, they have different perspectives toward the information required and what specific asset data from the specification is critical in the operation stage. Under this circumstance, it may lead to an excess amount of data in the BIM database which results in more difficulty for facilities managers to extract exact data as they need from BIM. This becomes an obstacle to bridge the gap in data integration. Matějkaa (2017) introduces three levels of understanding to benefit BIM from shareholders participating in the operation phase.

- The first level is using 3D model features from BIM to assist daily work only. The facilities manager and owner use the geometric data from BIM to perform space management during maintenance and operation.
- The second level is using BIM as a process. It is not limited only to software or equipment. The facilities manager and owner have good knowledge of BIM extracting non-geometric asset information and collaboration with geometric information applying in a specific operation activity. They know how to get the benefit by applying that specific information from BIM.
- The last level views BIM as a methodology. It develops a construction project in the whole life cycle by linking the different phases with specific information communication platforms. Individuals with this perception should have a wider vision to apply this logic in the whole construction project life cycle.

Facilities manager and owner are able to identify the context of information and route of flow from one project stage to another in a proper sequential workflow in order to finalize information requirements to connect different project activities. Under a comprehensive information flow network, it can give out a better project integration in the life cycle. According to Matějkaa (2017) if the understanding of facilities managers stays at the first level, which implies that the organization is unable to effectively apply BIM for information integration between different project stages properly.

### 2.4.3 Different level of information

According to Hooper (2012), the individuals within the project team have different perceptions on the level of detail subject to information toward the different project phases which prevents facilities managers with a higher level of clarity, specifying the content and reliability of BIM deliverables. Level of information (LOI) declares how detailed different elements are in the model. It is found difficult for them to collaborate and contribute toward the same level of information requirement. It can be related to their different background and knowledge of BIM functionality and how they recognize the benefit of BIM in each stage of the project.

For the operational stage of the project, (Eastman, 2008) emphasizes that lack of a standardized level of detail on the same object is unable to ensure effective communication in order to enable the unequivocal exchange of information from designer and contractor to the facilities manager. There are 5 levels of detail in construction projects from 100 to 500 (Bedrick, 2008). When it is applied in the operation of a project, the lowest level is mainly used to present the conceptual level of an asset such as size and function and the highest level presents the detail of an asset with more specific and precise detail from specification such as cost and warranty detail or even

with extra than that. Different levels of asset presentation are critical to facilities managers for how they plan their facilities management and workflow.

The individual parties during the project have their own idea of determination on the level of detail to the same object which will lead to the problem of perception of information standardization. The contractor or designer cannot facilitate and clarify the demand specification of BIM deliverables in order to assist them, assist to clarify what information and details that need to be provided at the operation stages during project handover.

### 2.4.4 Interoperability

The software interoperability is caused by different system usage between designers and facilities managers (Jang, 2020). It is found that facilities managers are most likely not familiar with using BIM in asset management. Chen (2018) points out that facilities managers in the UK and US mostly prefer to use COBie spreadsheet which is normally used to store operational data since it can provide more information such as spatial data, asset details, documentations, and graphical information. Additionally, it can support processes during the operation of buildings like space management, asset management, maintenance planning, energy management, and reconstruction projects during the life cycle (Chen, 2018). The data from the designer and contractor cannot be directly transmitted to the facilities manager. Due to the data format difference, it will cause the problem of information interoperability and data sharing problems in the architecture/Engineering/Construction (AEC) and Facilities Management (FM) industry.

Begg (2018) claimed that the main challenge to achieve interoperability is the difficulty in identification of which data are required, relevant, reliable, useful, and can add value to the AM processes. The common problem of Interoperability existing right now includes inconsistent naming conventions, a myriad of bespoken FM information requirements, inadequate data categorization in BIM and Computer-aided facility management (CAFM) systems, poor information synchronization, and lack of a measurement to formulize data related to existing facilities and assets (Teicholz, 2013).

### 2.4.5 Surfeit information

According to Bozorgia, et al (2018) it is normally for information collection continuously in BIM from different project stages for different purposes. However, due to different interpretations of the asset specification from shareholders cause information duplication and excess. It typically does not fully contain the necessary information for FM task execution. Although BIM models could support facilities managers in FM-related tasks, they still need to spend extra time and cost to ask for the asset information from the designer or contractor (Mayo and Issa, 2016). The lack

of standardization to recognize what information is required contributing by a particular project team member as a result of too much information eventually. Under this circumstance, it costs extra time for the facilities managers to understand the information structure and processing of information management such as filing, storage, and sorting (Hietanen, 2006). Too much information will invariably create data (observations) and not information (purpose) for the organization (Davenport, 1997) which means too much data without presentable and meaningful implication cannot assist to work out the facilities management plan.

### 2.4.6 Lack of communication

Golparvar-Fard (2011) claims that there is usually very little collaboration between designer and facility managers in design phase works. Pärn (2017) claims that COBie is normally used in the US and or UK to retrieve BIM data for the improvement of data hand-over to facilities managers and building owners. It is found problematic when Facilities managers request semantic information which means the information with interpretive and descriptive context. It is originally formed by the non-geometric data extracted from the source of the asset's specification and contributed from different shareholders in order to fit for a certain purpose of asset management. But they were unable to directly get it from BIM during the handover from the design and construction stage due to different semantic interpretations among shareholders. Even the client's O&M requirements have already been defined at the project's outset in the exchange information requirements (EIR) to let facilities managers follow but it is still difficult for them to understand what information exactly stands for. Jang (2020) claims that the reason is due to a communication gap between the facilities management team and designer and contractor. The designers always use their own interpretation of the asset property and specification to apply in their design model. They have their own meaning of semantic data.

On the other hand, Jang (2020) also points out the miscommunication between tier 2 contractors such as M&E engineering contractors and clients is also very serious due to low engagement from subcontractors in the project team. Normally, under the project team structure where subcontractors just follow the requirement in the BIM execution plan and depend on the information received from the main contractor to proceed with their work. They always have a passive role with less opportunity to reflect their perspective toward the requirement in the BIM execution plan and their upstream contact point is the main contractor. For those M&E engineering contractors, their data is very important for facilities managers to work out their operation schedule and determine what method of management is used (Pham, 2014).

### 2.4.7 Different perspectives toward data requirement

There is a found variance of information requirement of facilities' operation and maintenance because FM teams and designers have various knowledge and perspectives towards data related to asset property and specification as required in asset operation (Jang, 2020). Without collaboration with designers in the design phase work, FM teams cannot reflect their information requirements to designers such as requirements in space management and operating conditions. Moreover, designers normally lack operational experience. Under this circumstance, designers cannot consider the perspective and knowledge from the FM team toward the asset properties to coordinate with their design model. In the end, Designers normally create models for construction purposes rather than producing as-built drawings for FM teams. According to Pärn (2017) designers normally have no idea what the semantic data from their design model in BIM is required by Facilities managers which will result in the Facilities management team often linking additional external databases to the BIM to create an enormous integrated multi-dimensional model. It makes data integration more difficult. It causes that information required by FM teams is always missed during project handover.

## 2.5 Improvement to information integration problems

### 2.5.1 Communication enhancement

Jang (2020) suggests that improving the communication between facilities manager and other individuals from project teams such as designer and contractor is so critical since it can allow the designer and contractor to know what kind of asset information in BIM as facilities manager is highly concerned. They agree that it should be better to bring facilities managers into project discussion at an earlier stage. They introduce the earlier engagement arrangement should be included into the procurement contractual document between owner and designer or contractor such as mutually beneficial memorandums of understanding or letter of intent to clearly declare the necessity of this arrangement. In addition, Patacas et al. (2016) supports facilities manager contribution from the beginning stages of project development and throughout the lifecycle of the building. It can enhance the closer cooperation between designers and facilities managers. Due to their closed cooperation, they can help determine:

- What is the asset information requirement?
- What is the intended use of handover data?

Jang (2020) also emphasizes that it is important for the Mechanical and electrical engineering consultants in the information integration process as they can bridge the communication gap between the main contractor and supplier to make asset information accurate and precise. They can help the main contractor in screening the right suppliers with the ability in using BIM. In addition, they can screen out what critical asset specification database is provided by suppliers according to their profession in project M&E requirements and should be shared with the main contractor. It will help to avoid too much information stored in BIM for project operation handover.

### 2.5.2 Benefit realization Management

Peter et al (2014) suggests that the asset owner should process BIM benefit realization management within project groups in order to materialize the benefit of using BIM for information integration into FM. Peppard et al (2007) describes the benefit realization management is a method to materialize the intangible benefit of technology implementation into quantitative economic value. It can make it easier for all individuals within the project team to recognize the benefit of the new technology to their work.

Peter et al (2014) suggest that asset owners should firstly help to build up the conception for every team member to the benefit of BIM for FM regarding information integration issues. Secondly, they should standardize and centralize the perception of this suggested issue from different roles within the project. The benefits realization management will not give out expected results if asset owners do not carefully plan and manage. It is dynamic as asset owners should consistently question the BIM integration process in order to ensure that BIM benefit is materializing at the right time. At the same time, owning the competency in handling BIM information integration can help to drive the benefit recognition from individuals within the project team and facilities manager (Barney, 1991; Ashurst et al., 2008) One way to do so is to underpin their skills, knowledge, and experiences by providing workshops or training.

Barney (1991) and Ashurst et al. (2008) also propose to employ external bodies such as a specialist BIM manager who can provide special domain knowledge regarding the execution, and integration of an FM building information model into existing systems.

### 2.5.3 Asset Information Requirement (AIR) & Asset Information Management (AIM)

Poirier (2020) points out that unclear asset information requirements to be established at the beginning stage of the project cause a gap between digital and physical assets. They explain that BIM originally is designed to tackle information transfer problems between design, construction, and operations. Moreover, it enables stakeholders to add and acquire information during their period of contribution to the project. It results in the date of asset specification in BIM that can be easily shared and reused by each stakeholder. It can help facilities managers to plan the maintenance workflow based on the asset requirement in AIM and eliminate the risk of data re-

entered into downstream information systems. This potentially reduces the cost of generating high-quality facility data (Poirier, 2020).

However, (Pärn, 2017) points out that the real situation happening right now is normally without clear asset information requirements to be established at the beginning stage of the project. It causes the gap between digital and physical assets. Furthermore, the lack of a standardized information format requirement in different systems induce difficulty in data transmission automatically and recognition from one system to the other during a handover of each project phase. Even when the documents are available digitally, heterogeneous data formats and interoperability issues hinder the usefulness of this information. Rework and manual data entry are usually required.

Cavka (2017) emphasizes the success of information integration is depending on whether it contains clear and concise asset information requirements (AIR). It is better to secure the information commissioning process if there is a development of exchange information requirements (EIR) to agree on how to transfer the information in what format, what level of information and establishing an agreement amongst stakeholders on how and with what features they need to exchange their digital information. Moreover, the FM team needs to have confidence that the model is complete, verified, and accurate to be useful. Equally important aspects, model maintenance, and updating are also critical to reflect the as-built situation and effectively transmit to the FM team for preparing updated workflow (Cavka, 2017). Otherwise, the model will become outdated and lose its value down the road. Heaton (2019) suggests a framework in order to Identify what asset information can be computable to store in BIM by following computable BIM guidelines and deliverable requirements. Moreover, validating that asset information with client requirements so that information from the model can be exchanged with the organization's FM applications.

Patacas et al. (2016) gives more detail by introducing information management methodology to formalize and structure the definition of Asset Information Requirements (AIR). Then there is applied validation of data deliverables from BIM in open standard against AIR in order to proceed with the development of Asset Information Models (AIM). The last step is to visualize and use the required data from AIM which are stored in distributed databases for specific facilities management applications. It can improve the efficiencies of data handover at the end of the construction phase and support maintenance and other FM tasks during the operational phase of the building by enhancing the data renewal and accuracy.

For the first step in setting Asset Information Requirements (AIR), it is important to specify the owner's data requirements for the Asset Information Model. AIR is defined based on the owner's Organizational Information Requirements (OIRs). They are the data and information requirements required to achieve the owner's and/or FM provider's organizational objectives (BSI, 2014). There are five key areas of AIR: legal, commercial, financial, technical, and managerial.

The clear definition of AIR can be used to control the information-centric tasks of processes across the lifecycle of building projects due to its requirement specification.

After the retrieved required data from digitalization format such as BIM is validated, it can be used by the owner for asset management purposes by following the AIM based on those validated data against AIR.

### 2.5.4 Ontology approach in data recognition

Chen (2018) presents an ontology approach built with the web ontology language (OWL) based to define and reform the relations of each COBie data entities with corresponding attributes in order to help retrieve information from an IFC model, transfer data into COBie data standard, and finally deliver BIM data into FM systems. They introduce using Ontology methodology to match the corresponding data in IFC in order to solve the problem of interoperability to result in data mismatch or inaccuracy. The whole process includes a number of steps in orderly.

1. Identify the facility information requirement.
2. Transfer geometric and semantic information from IFC to COBie.
3. Use the ontology approach to represent COBie data to match the corresponding. data in IFC.
4. Import COBie data into the FM system based on ontology approach.

Before proceeding to map IFC data into COBie and FM systems, the first step is to identify what kind of information is necessary in FM activities. The information requirements of various facility activities can be different. However, they summarize some of the common facility information requirements as follows:

1. Information on warranties, spare/replacement parts, preventive maintenance tasks and resources, etc.
2. The operation about equipment and machines for buildings, start-up/ shut-down procedures, and troubleshooting procedures.
3. Space measurement fixed or movable properties, and space-function capabilities.

Secondly, it develops a class hierarchy of entities, which correspondingly means the data structure. Later on, as mentioned above involves the relationship building of product type with other entities and also includes the properties clarification. It would be better if there can be shown an overview of ontology graphs to show the detail of the class hierarchy with different layers of entities level for easier tracking the data location and matching process later on. After the reformation of COBie data is completed by using the ontology management tool, extracting

the IFC format data from BIM can be proceeded for integration into related attributes under the corresponding class of hierarchy for data location identification.

The last step is to import COBie data by matching the corresponding attributes in the FM system. the attributes of COBie data and attributes of data stored in FM databases should be mapped one by one.

### 2.5.5 Data verification

Patacas et al. (2020) suggests it is highly required to develop a common language of communication and framework for data verification against the owner information requirement at the same time in order to eliminate the problem of data inaccurate and irrelevant to the need for proceeding the operation work during the project handover.

As a contribution the designer and contractor provide the structured (i.e. graphical and non-graphical) and unstructured (i.e. documents) data in BIM.There is necessary to ensure the quality of information extraction from BIM for FM applications to meet the AIR as prescribed even the information has already been formalized by using BIM (Arayici, 2005; Kiviniemi, 2005; Teicholz, 2013). However, the current information stored format in BIM using IFC does not include all the required properties and relationships related to the operation and maintenance (Motamedi et al., 2014). Patacas et al. (2020) it is highly demanded to develop a framework to conduct information verification against the owner's AIR for the BIM and FM system in order to align the information in these systems and ensure to fulfil the AIR before carrying out transmission during the information integration process. The definition and verification of maintenance requirements is a prerequisite for the development of an AIM. Firstly, they emphasize the AIR should be formed in a rule executable format. Later on, they propose two verification methods.

- One is using semantic web query approaches for checking the execution of rules in AIR against structured and unstructured data sources exporting from BIM.
- The other one is the development of Exchange Requirement Models with exchange requirements defined by Business rule.

This model is particularly designed for the verification of IFC and COBie deliverables against the execution rule of AIR. The verification should be performed starting from project development to the operational stage.

### 2.5.6 Knowledge enhancement in COBie application

According to Ahmed (2019), the good practice working with COBie in the UK and US is that the asset manager is trained with good knowledge toward COBie which enables them to iteratively conduct ad hoc asset information management along each stage of the project. They know how COBie coordinates with BIM to stream down what the information should be present in BIM. The

idea behind COBie is that the key information is transferred into one format and shared between project team members (Naghshbandi 2016; Cavka 2017). Patacas et al. (2020) The use of standard product data templates from COBie can be applied in a wide coverage of information exchange such as Life-Cycle information exchange (LCie), Specifiers' Properties information exchange (SPie), and industry initiatives such as Product Data Templates (PDTs). They can streamline the delivery of facility asset data by simplifying the 3D BIM information from the design and construction process to the facilities management databases in a spreadsheet format. Love (2014) The successful BIM model cooperated with COBie to form a 'live virtual facility' used for FM decision making and building operations troubleshooting, incorporating maintenance information, documents, and real-time data from the building automation system. Furthermore, they add how BIM models create measurable and tangible value propositions to the asset owner's organization depending on the definition of client requirements in a structured way. It can form as a practice of operation to share standards that create a basis for action, problem-solving, performance, and accountability.

COBie is intended to simplify the work required to capture and record project handover data but there are found with many limitations (Abdirad, 2019), including the limited scope, the lack of the format in which information is exchanged, and the limited process through which information is entered and controlled. It is still unable to offer any specific guidance on who is responsible for providing this information between the architect, main contractor, and subcontractors, when it is provided, and at what stage of the building lifecycle. Therefore, Ahmed (2019) also advises there is needed further investigation into how COBie can be coordinated in BIM execution plan identify roles and responsibilities between different project parties who provide what and when concerning COBie throughout the project lifecycle, such as mechanical, electrical, and plumbing (MEP), architecture and landscape.

### 2.5.7 Information assessment

Yu (2001), Becerik-Gerber (2012), and Shen (2012) propose to conduct an information-needs assessment in order to produce the reduced list by classifying and grouping deliverables based on the owner's intended use of information to solve the problem of Surfeit information. It is started by collecting the perspectives of both the best practices and proposed use from a group of experienced facilities management (FM) personnel. The standardized reduced list of deliverables can be used by the owner or the contractor as a starting point for carrying out better data handover from the building information modeling (BIM) model and closeout documentation during the operational stage of the project. Moreover, a streamline of information requirement from this reduced list of deliverables can act as a starting point for owners to formalize the workflow of operation.

The process of assessment addresses the perceptions from experienced facilities management (FM) personnel in order to identify what owners need in terms of components or attribute

information in both graphic and non-graphic form (Mayo and Issa, 2016). It can act as the object-oriented standard for BIM data with higher interoperability in data-exchange by using construction-operations building information exchange (COBie). Secondly, this assessment can also help to address the required format of information. For example, the information for the decking material may require a warranty, a cut sheet, and a test report.

# 3 Methodology

The methodology that has been used in this thesis is qualitative which focuses on the evaluation of idea reflection and theory explanation rather on modeling validation and development (Dawson, 2007). The qualitative methodology is most likely used when there is no solid framework of data analysis to finalize the correlation of numeric data to present the theory properly. Some criticisms of the result of the qualitative methodology are that they can be too subjective and may be controlled by the evaluator (Toro, 2013). For that previous research with relevant topics as few of them apply to a quantitative data analysis method to make a validated model formulation as research purpose. Moreover, there is also less research to investigate the correlation between the performance of information flow from BIM in project operation and its determinant factors and calculate correlation coefficient between each independent factor.

For this reason, there is no quantitative model that can be used for validation in this research. So, it is better to use the qualitative method to discuss the main reasons for mismatching flow information in the project life cycle. By collecting the idea from the target group of interviewees the master thesis applies and undergoes an inductive data analysis approach in order to develop a set of theories to explain the phenomenon happening during the information integration process.

All interviewees are selected from the corresponding role in the project as described above which is based on purposive sampling. It means that the rule of interviewees selection is not random but also according to their experience and knowledge in a particular area and are capable to reflect their knowledge answering research questions (Bryman, 2008; Remenyi, 1998) They have well knowledge and experience how to work with BIM in their respective organization. Furthermore, the selection criteria in this research are mainly based on the variety of the role and responsibility of interviewees under particular stages of the project not only selecting from those who work in facilities management. The main reason is to widen the range of ideas regarding the asset information requirement issue during integration from BIM to FM and the hindrance of this process. Burkett (2002) claims that the effective decision making in facilities management planning and execution is partially dependent on how asset information can be transferred in completeness and accuracy from the other project stages. It means that each party within the project bears their own responsibility to the asset information sharing in BIM. Using these selection criteria can help to collect data from different particular roles of the project in order to

identify whether their background and professional has already affected their judgement in information exchanging to induce a gap on the specific asset information recognition and standardization requirement. Later on, It can effectively help to justify whether the problem of information transfer has already existed at the earlier stage of the project and seems like a chain reaction to roll over along the life cycle of the project becoming more and more serious until handed over to project owner to proceed the operation and maintenance. At the end, It can help to decide the right improvement strategies toward the exact problem.

## 3.1 Empirical data collection

Empirical data have been collected through documents and interviews. To collect data from interviewed companies, who worked as third-party consultants in the project, we summarize how they comment on BIM information integration from construction to operation phase and investigate what substantiated factor influences the performance of integration, pre-interviews were conducted with Chief Technology Officer (CTO), BIM coordinator and facilities manager. Furthermore, there is some data collected from the interviewee on behalf of the client-side located in Hong Kong.

### 3.1.1 Secondary data

The documents have been used in this report to be the internal documents from the studied company. These documents, such as BIM guidelines, BIM-model, and BIM execution plan, were used to understand how the company works with BIM in operation and be useful to formulate the interview questions.

### 3.1.2 Interview

Data has been collected through conducting interviews for reaching the goal of this report. The interviews conducted were qualitative and semi-structured. The reason for choosing semi-structured interviews is to allow more flexibility for the interviewer to think out of the box and ask further questions (Bryman, 2011). At the same time, it still maintains questions in a well-organized structure, and with the sequential order of questions arrangement. It forms a basis for the development of new ideas and theories (Bryman, 2011).

A semi-structured interview is also specified by short questions and longer, spontaneous, and relevant answers (Kvale, 2009). The critical factor to determine the success of a qualitative interview is whether the new ideas and theories are produced through the interaction between the interviewer and the interviewee (Kvale, 2009). However, the main problem of qualitative

interviews is the difficulty to eliminate the biased result from specific interviewees which should affect the final theory reliability.

There are three interviews conducted by Conference Call in Swedish as shown in Table1. All of them took around 60 minutes. The other interview was sent out an interview questionnaire for Hong Kong's engineering consultants and received back after one week. Hong Kong already has solid experience in how to apply BIM in the design and construction of projects. However, the Property and Facility Management Division of the Hong Kong Institution of Surveyors (HKIS-PFMD) still also finds certain challenges in information integration from BIM to FM. By collecting data from Hong Kong, But the study of Hong Kong can be used for investigation in this research to find out whether some of their experience of handling information integration from BIM to FM can be used as a lesson learned by applying in Sweden.

First of all, the purpose of the interview was explained, and interviewees were asked for their permission to record the interview. The first questions concerned the interviewee's background, to get the interviewee started and then the questions concerning the subject were asked, most of the information related to BIM was gathered from their point of view as a consultant role in the project.

***Table 1:*** *Interviewees*

| *Respondents role* | *Location* |
|---|---|
| BIM Coordinator | Sweden |
| Head of Virtual design and construction (VDC) | Sweden |
| Architect SAR/MSA Member of the Swedish Association of Architects | Sweden |
| Project manager in FM | Hong Kong |

### 3.1.3 Data analysis

The quality of the data interview is critical for performing qualified data analysis. There are different ways to process data analysis after collecting all relevant information from interviews (Kvale, 2009). The method used in this report was firstly to summarize all point forms of notes dropping during the interview with detailed elaboration. Later on, a numerical number was given to each of points for easy identification and grouping under corresponding research questions. The next step grouped them into different subdivisions regarding their connection on their similarity of concept interpretation (Bryman, 2011). The next step was to group the concepts under the name of subtitle and compare with the existing ideas from previous research in order to develop new ideas to explain the real situation of the information gap of data integration from BIM to FM.

### 3.1.4 Data quality

The trustworthiness of data is interpreted in terms of credibility, transferability, dependability, confirmability to justify the data quality level in the research (Lincoln, 1995; Lincoln, 2011) The credibility is based on whether the research findings represent reasonable information from respondents' original data to correctly interpret their original views. Transferability means the results of qualitative research can be transferred to other contexts or settings when collecting data from other respondents. Dependability means all evaluation of the finding, interpretation, and recommendations of the study should be supported by the data as received from respondents. Confirmability means whether the findings of the research can also be confirmed by the other researchers and the degree to which the findings of the research study could be confirmed by other researchers. The confirmation is also required data supporting. In addition, reflexivity is an integral part of ensuring the transparency and quality of qualitative research which involves the process of critical self-reflection regarding any own biases and the development of any relationship to the respondent. Since the relationship built up during the research may affect the respondent's answers to questions.

For Credibility, the respondents are encouraged to give more examples to support their ground and ask them follow up questions to get the solid idea with comprehensive data provided. Moreover, all transcripts of the interview were sent back to respondents for feedback enabling them to correct the interpretation. The interviews include questions to get more detail about the respondents' experience and current duty. In addition, trying to collect more information about the background of the respondent can help to make judgement whether the context can be applied to other cases in order to maintain the transferability of research. For Dependability, checking is requested to make sure whether the analysis process is in line with the accepted academic research standards. In addition, it should also be ensured the interpretation should not

be based on own particular preferences and viewpoints but needs to be grounded in the data inter-subjectivity of the data to align with research confirmability.

### 3.1.5 Ethics

According to Bryman (2007) ten ethical principles that should be considered during conducting a research study. Firstly, it should ensure respondents are safe while carrying out the research. Secondly, full informed consent should be obtained from respondents prior to the study. The informed consent should include sufficient information from researchers and allow respondents to understand the implication of participation to freely make decisions on whether to go ahead or not with the exercise of any pressure or coercion. Furthermore, the protection of the privacy of respondents and the confidentiality of research data should be ensured. It should avoid any deception or exaggeration about the aims and objective of the research. In addition, it should not allow any dishonesty and non-transparency by interfering with respondents' reply to the research. The last is to avoid the biased way of data representation which results in misleading information. It should maintain the highest level of objectivity in discussions and analysis throughout the research. findings in a biased way must be avoided. It can be done by going through the proper training toward the subject issue. In addition, there can be a checklist to let third parties monitor and conduct checking purposes.

# 4 Result

The primary objective of this research was to investigate how engineering consultants think about the problem existing in information integration from BIM to FM and recognize what hindrance prevents the integration process. There has been quite a lot of research to focus on the challenges of information in BIM flowing from the design to the construction stage. Even though there is little research to study information integration problems in the operational stage but mostly only what the technical problem happening during the integration. For this report, it is not only to find out how technical issues hinder the development of information integration but also initiate to establish a breakthrough of organizational management such as the change of working procedure, organization structure, knowledge, and communication how to tackle the information integration from BIM to FM.

The findings are hereby presented in three main aspects; The specific Information that is required from BIM for the FM stage, the challenges of information integration from BIM to the FM stage, Different respondents come from engineering consultants, facility management, and architecture who are interviewed to explore the above objectives.

## 4.1 The specific Information needed from BIM for the FM stage

It is found that most of the respondents from the interview, no matter as an architect, engineering consultant, and facilities manager, had similar ideas to the asset information in BIM for facilitating FM operations should be started to prepare from the early design stage. There is consensus among both Architects and consultants/facilities managers who acknowledge the potential benefits of BIM to facilitate FM operations. Architect, engineering consultant and facilities manager also agree to use BIM which can simplify the working process in data storage, retrieval, and modification. The major motivational triggers at the FM stage are simplicity to put, retrieve, use, and modify information in their FM systems.

Architect:
The architect emphasized that most architects also ignore what information is needed to proceed with some of the non-core support services in FM such as security, cleaning, and maintenance. In fact, it should be better that they are able to consider during the early design stage in order to enhance facility management operations. However, He expressed with the challenge as stated below:

*"We don't have the knowledge to know what exact information facilities managers need, moreover when the information should be handed over that is what problem the industry is facing right now. Probably, because we lack the knowledge to make a judgment on information requirements and priority for FM operation. So, Even BIM is a good tool, but we do not fill the right information at the early design stage."*

Moreover, he also emphasized that most of them have no idea how to align the information from BIM compatible with facilities management format. such as the format like COBie or CoFM parameters for FM which are commonly used in the UK and US. But most of them are not familiar with and even they know most of the facilities managers in Sweden who don't use these kinds of information format for integrating the information in BIM.

They usually own the perception toward information related to space planning and management to be the most important to asset managers for proceeding with the operation and maintenance process. They also think that this information can be directly provided by BIM. Therefore, they think of their main duty to provide accurate geometrical information during design to fit the client's need for the FM stage. They focus on using BIM to provide building 3D elevation which can visualize the function of different building components, for example, wall types and it is essential to the operation and maintenance.

Consultant and facilities manager:

Due to explore different perspectives toward the information for facilities management from BIM., engineering consultants and facilities managers are also interviewed. As referred to the information provided by architects above, there is a gap in the idea regarding awareness of necessary information to be put in the BIM model from the early design stage between designers and consultants/facility managers.

Architects do not have a full concept about all necessary information for FM, but consultants and facilities managers have a clear picture of what information should be put in a BIM model from an early design stage. The consultant and facilities manager reflect that they put lots of resources to follow and search for some useful information in the BIM model contributed by the designer or contractor for their operation and maintenance proposal. Compared to a few years before, now they find that architects are becoming more mature and knowledgeable to know how to handle the BIM in data transformation into asset management systems. Through in-depth discussions with consultants/facilities managers, the following information possesses a great hope to result in better performance in facilitating FM operations if applying a BIM 3D model.

However, both consultants and facilities managers reflect that there is still too much information in BIM as they need to spend more time and money to ask for clarification from designers and contractors in order to sort out the essential information. Moreover, consultants and facilities managers emphasize the information in BIM is normally incompatible to integrate into their system directly.

Regarding the critical information for asset management identification, Consultant and facilities managers hold the same idea that the spatial data is a piece of necessary information used so much at the FM stage especially for planned maintenance and renovations and should be developed from the early design stage. The Spatial Areas information is commonly used at the FM stage for different purposes during operations. The consultant said that.

*"We commonly request for spatial areas information which can be changeable due to how the client determines the type of use for a specific area, but it is the most basic information that is required to conduct the regular maintenance activities."*

They know the benefit of using the data from the BIM model to be applied in spatial management by directly analyzing the existing use of space, proposing changes, flexibility, or effective plans for future needs.

Besides spatial area information, they also express that physical asset information for planned maintenance information, such as walls, doors, windows, and ceiling, etc. is also a very important consideration during the design stage. In many cases, the consultant thinks that it should result in better performance in information handover during the operation stage if they can engage to work with the designer at the earlier stage of the project. They are able to inform the designer about their information requirement. In addition, they claim to closely cooperate with owners to

make clear the scope of work at the preliminary stage. It can act as a foundation to form Asset Information Management. As refer to consultants' point of view as shown below:

*"It is of great importance for us to know owner's expectation of their asset information required in order to make a clear scope of work including necessary information such as the purpose of works and need in operation and maintenance, its budget and time allowed for completion of works, limitation of the site during operation period, latest approved floor plan, licensing plans, as-built E&M drawing, and maintenance history, etc."*

Simultaneously, the Consultants and the facilities managers also agree to elaborate on what is necessary at the FM stage because, in the end, they are the ones to maintain the building. Furthermore, they also claim that suppliers' information regarding materials and product information in a BIM model from an early design stage is normally ignored in practical situations. One example is how to determine the schedule of regular maintenance regarding specific building elements such as every 3 years or every 1 year. It is common with the idea of the information contribution that architects should be responsible for it. But in reality, it is most probably the supplier or manufacturers who have that information. So, they see the importance of including supplier information.

More specifically, information related to energy consumption, installation information, elevators, cooling systems, ventilation, fire protection, etc. they also think to be necessary to put in the BIM model to transfer to their asset management system for future large-scale refurbishment usage. Furthermore, it was emphasized that with BIM several pieces of information are developed from early design stages to help management and decision making. This information includes Life cycle cost estimation, scheduling and inventories information, and repair information including what should be changed and when.

## 4.2 The challenge of information integration from BIM to FM stage

Regarding the challenge existing of the information integration from BIM to FM, both architects, consultants and facility managers have nearly similar ideas on this issue. Some of these challenges are as follows.

### 4.2.1 Unclear Information requirement and project scope

All of them also claim that in normal practice is common without the clear scope of work for operation and maintenance to define asset information requirements as guidance to the designer, contractor, and supplier to provide all as-built product data such as warranty information, maintenance schedules, and operations data for the building equipment inventory within the BIM Model deliverables at the earlier stage of a project. Subsequently, it is very difficult to develop a BIM Execution Plan (BEP) to define the responsibilities for designers, contractors,

and suppliers using BIM to provide the information required in Facilities management. There are reflections from consultant as following:

*"Under unclear information requirements and scope of maintenance and operation work, we need more time to carry out the on-site measurement to produce the basic information to proceed the operation work by themselves or they need to spend extra time and cost to ask for further clarification of data in BIM from designer, contractor or supplier. Hence, the project handover time will be delayed."*

*"Furthermore, it is usually found discrepancies between the tender drawings and the actual site condition due to the lack of information provided in BIM during the design stage. One of the reasons is due to the unclear scope of work and information requirements at the early stage of the project. It induces too many changes at the end of the handover. It is difficult for us to finalize our operation and maintenance work by only relying on the information from BIM."*

### 4.2.2 Lack of communication

The architect, consultant and facilities manager also reveal their observation from practical project running as asset managers who always play a passive role in the project team. They are normally ignored and without a chance to take part in the project at the earlier stage for reflecting their idea and requirement asset information toward the project owner and designer. It will result in a communication gap between the facilities management team and designer and contractor. Upon tackling the site uncertainties or updated requirements issued by the owner, there is always lots of change in the spatial design and asset type implementation during running the project, architects reflect that sometimes they receive complaints from asset managers as they are difficult to track change. Those changes are normally not reported to them until handover. It will totally interrupt their original planning in their maintenance scope of work and propose a schedule.

One of the consultants expresses the following:

*"We think that it makes a successful digital information flow from BIM to FM in the projects. everyone to come up consensuses of acknowledgment to decision within the whole project by inviting different parties on board even asset manager, and everyone needs to communicate a lot no matter using BIM in order to consolidate the idea."*

### 4.2.3 Different recognition of BIM benefit in FM

Architects and consultants/facilities managers also express their thought that they find even nowadays still individuals with different levels of perception toward the benefit of BIM in data transformation from different stages to operation. Despite people working in the same project team, it is still difficult to align within the same recognition among architect, contractor, supplier, and asset manager. Some of them narrowly define the usage of BIM as a 3D tool on specific

project tasks only. Some of them extensively use BIM as modeling to classify and organize geometric and non-geometric building information regarding specific project phases. But all of them also feel that there are very few practitioners who are able to link the information from one phase to another in order to form the life cycle of information flow in the project. Normally, asset managers can only receive asset information at the end of project completion. Before the handover, different parties have already contributed their own information using BIM according to different levels of recognition to the usage and benefit of BIM. It will result in different information requirements and interpretation of the same attributes of asset specification. For example, architects mostly focus on providing geometric design and always ignore to cooperate with suppliers to obtain the right asset specification information. Lacking linkage with their spatial design will affect contractors to carry out the construction process later on. It is a chain reaction to cause poor performance of the asset under improper construction methods and insufficient information passed over to the asset manager when project handover to the operation stage. That is what the interviewees call an information gap during integration from BIM to FM.
One of the consultants describes the situation as following:

*"It's hard to get everyone with the same recognition of benefits from BIM using FM by integrating the substantial asset information from other phases of the project to the FM system. Some of them still strictly stick to their own thinking to use BIM as a digital tool in each separated task. It will result in various interpretations of the same asset. However, due to pressure of time and normally not all project members are well educated with competence. so, there is limited action that they can take to come out with the same recognition to all project members."*

### 4.2.4 Incompatible / Interoperability

All of the respondents also point out that facilities managers commonly use different information-keeping systems from BIM to proceed with their work practically. Asset managers own their information presentation format and semantic interpretation toward the same parameter of the asset. It is different from the data in BIM contributed by designer, contractor, or supplier. The asset manager cannot directly abstractly transfer information from BIM to their system and the problem is to find that in the industry right now.
Without standard information format, it will lead to miscommunication between asset managers and the others among the project team. The other parties are challenging to understand what data is required by the asset manager and fit their format used in the asset management process. Difficulty in the identification of which data are required, relevant, reliable, useful, and can add value to the FM processes. Under poor information synchronization, the asset managers also face a challenge to capture the data from BIM and spend extra time and cost to ask for further clarification from the designer and contractor.
According to one consultant reflection:

*"We think if we work with standardized information format and interpretation, everything can be machine-readable, and then we can work with linked data integrated from BIM to FM systems*

*instead of setting up intermediate interfaces to search required information and transform it into a compatible format."*

### 4.2.5 Lack of BIM expertise in the company

Another big challenge reported by consultants was the lack of BIM professionals in Asset management. They all emphasize the importance of BIM experts inside facilities management organizations who have knowledge of how to use BIM for asset information transformation into Facilities management purposes and are able to insist on a clear asset information requirement through promoting better collaboration between facilities managers and other stakeholders within the project team. They can also help to provide the formulation of information requirements to make up the asset information management at the earlier stage of the project. The reason for deployment of a BIM expert is used to coordinate different concepts about the asset information requirement from stakeholders as they are coming from different knowledge backgrounds and role interests. It will lead to various interpretations toward what the components of asset information and presentation format is required to be shared and exchanged from BIM to FM. With the BIM expert can let the whole integration process smoothly and efficiently by transforming information from BIM into a compatible FM system under the frame requirement from asset information management. One consultant said.

*"This is the kind of new competency in the industry, who in the industry should obtain and develop all this knowledge. In a normal case, the Owner or asset manager has to develop new competency to develop and manage BIM in information integration for the operation phase. Some people with the concept of this responsibility should be barred by the architects. However, when the project is completed and handed over back to the owner or assigned asset manager who heads the project operation and maintenance."*

The other respondent from consultancy said.
*"BIM is viewed as a new competency supplying new knowledge at FM stage. But if the organization is lacking skilled employees and less encouragement to employees in learning new technology due to high cost and time expense concerns. it will easily cause inadequate coordination for multi-discipline to integrate different information."*

The other comments are as following:

*"There is a lack of knowledge within the whole industry and we can see that a lot of consultant doesn't have the right competence creating those models and the information in the way that we require, so we always need to start the project in educating the consultants what they supposed to do and how to deliver to us from BIM to an FM system."*

### 4.2.6 Easy loss of information due to multi-access of change

The consultants recognize the other challenge of BIM information integration is to ensure the required asset information in BIM is kept until project handover. Most of the parties are striving

to keep the digital format of geometric or non-geometric information into BIM. Nevertheless, during the project running, it has been difficult to keep the original information in the database by frequently changing from parties with access right into the database. It was indicated that once the information is lost it becomes expensive for the asset manager to get the same information extracted from BIM after the project completion. One of the consultants said the following.

*"There is normally a big concern for us to ensure that the building information is still in BIM for our integration process. A lot of other stakeholders do not care how to keep the information consistency from one stage to another. They will just focus on whether they have contributed as they can. So, they need to pay extra time and cost to chase back information required after handover."*

The consultants also reflect this problem as follows:

*"We thought this information should stay in BIM as they can gather it from and transform into FM system but actually at the end, they found out the information is missing."*

The respondent indicated that there is also possible information lost in the BIM due to bad handover between parties itself because individuals leave the organization.

## 4.3 Improving the information flow and integration

### 4.3.1 Invite asset manager in earlier engagement to the project team

Architect and consultant/facilities managers suggest that one effective way to improve the information integration from BIM to FM is to invite asset managers to join the project team at the early stage. They think that it can allow asset managers to reflect what information requirement is fit for information transitional flow and what specific asset information is critical in operation. It can let architects, contractors, and suppliers have a clearer concept on the detail of information that they need to contribute during running the project for operation and maintenance at the end. It can help to avoid the problem of information missing. In addition, they know the semantic interpretation regarding data entities of asset specification from asset managers and standardize into a single presentation in order to avoid miscommunication. The asset manager also can be eliminated from putting extra time or cost in data clarification with them.

One of the architects has the following reflection:

*"We need to have a clear concept of what information we need to pass for operation and maintenance at the early stage of the project. We know that we don't need to contribute all information from the beginning, but we need to be aware when is the right moment to transmit the information without being overloaded with information at the beginning."*

One consultant states the following idea:

*"We should go for a discussion with asset managers at the early Stages around what information needs to be delivered to them by going through the details of the design. It does not mean all should happen at one point in time. But we believe that you should go for different construction elements and demand what information we need to contribute at a specific time after getting a consensus with the asset manager."*

### 4.3.2 Request for standardization format

Architect and consultant/facilities managers also request for the standardization data format by aligning the geometric and non-geometric data from designer, contractor, or supplier with a requirement from the asset manager. Because they also know that it is quite common for asset managers not to use BIM as a system for proceeding operation and maintenance work. There is no other alternative as they think by using a standard format to solve the problem of interoperability

One of architects states the following idea:

*"We should start to talk about standards in all that digital Solutions also, like standard APIS and how to exchange information, the common language of communication is the most critical part right now. "*

In addition, one consultant also has the following comment as below:

*"It shouldn't be Sweden wise, because we don't have that many suppliers. Our project is not only focusing on Sweden and our members inside the project team are normally international companies. So, it should be at least required to achieve European Standard in all data formats. Because if you look, we have European Standard than we are able to work together with the US or China or whatever."*

### 4.3.3 Prepare documentation in information requirement.

Architect and consultant/facilities managers reflect that the other improvements should be made by every project team member to prepare completed documentation in the information requirement of the operation and maintenance. They reflect that they always face the problem of a lack of asset requirement management. They cannot follow to identify what information needs to be contributed to BIM and standardize the semantic presentation to asset information due to different interpretations from specific roles within the project team. With a clear statement of requirement, it can be also used to validate the data contributed from different stages of the project against prescriptive requirements agreed by the owner before extracting from BIM to an FM system.

*"In each project, we need a custom-made requirement regarding information from the owner or asset manager. This requirement is critical to validate against data in BIM for the information integration process."*

### 4.3.4 Set up new coordinator position.

The consultants propose one effective way to improve the situation is to set up a new position among the project team. The individual is good at knowledge in both BIM and FM systems who know how to coordinate the information transplantation from BIM to FM as required by the asset manager. This position works as a manual interface between the two systems above to locate subscripted specific asset information under certain attribute items in BIM. Then the individual will manually input in the FM system by changing into a readable and compatible format.

Moreover, this role is also needed to coordinate with different stakeholders before the operation stage on the data interpretation and requirement trying to align into a single form. it can reduce the risk of data duplication. It can also be easier to audit any change in data before it transfers into the FM system.

### 4.3.5 Implement education and training activities in the system of information management.

The consultants also insist that education and training to employees improve their understanding regarding the use of the data format of BIM and open standards in FM. Actually, they don't know what kind of open standards such as COBie, which has been commonly used in asset management from the UK and America. They think it is a good chance by introducing education and training to collect different opinions from employees regarding how to standardize the open standard usage in Sweden. The other directive advantage is to improve their working performance and efficiency as achieving enhancement incompetency in the proper data format and system usage.

One of them express the following:

*"We are educating as many as we can in this way of working and also implementing stepwise part so that our colleagues can feel the efficiency and benefit from working this way."*

# 5 Discussion

The research aims not only to explain gaps in information integration from consultants but also how to improve the technical implementation gap, the structure of the organization, practitioner knowledge, and the communication process itself. It may also help to launch a further analysis of why and how difficulties for BIM enforce the company's strategic progress in driving standardization and reducing the knowledge gap in the handling of BIM assets and maintenance information. Furthermore, this study was aimed to see how the consultant sees the issue of BIM-FM integration and what hindrance the integration process avoids. It allows corporate management to understand how new technology is not just good enough to solve the problem, and it leads the project team to gain an overview of the potential growth of emerging technology as well as of working processes, project team structure, expertise, and communication enhancement.

The results indicate that there is common perspective from the consultants, facilities managers, and architects about the potential benefits of BIM to facilitate FM operations, also about how implementing BIM in the project will let the work process become more manageable in data storage, retrieval, and modification and make it simpler (Garrigos, 2018). The main focus at the FM stage is to receive, extract, adjust the information in a simple way to stepping inside their system. The data that been collected from the interviewers for the consultant, facilities managers, and architects has a comparable about the asset information in BIM for facilitating FM operations to receive the best result by starting the preparation at the initiation design stage, this will improve the facility management operation by thoughtful in advance in the initiation design stage. The responsibility at the design stage is to provide the FM stage and the client's precise geometrical information to secure their needs.

## 5.1 Benefit of using BIM in FM.

Cavka (2017) revealed that most of the current project handover to facilities managers happens without using BIM. The analysis showed that there are few challenges, such as delays. The paperwork of the project is frequently unstructured, incomplete, or reusable and information inconsistencies. It causes asset managers to always chase back information from designers or contractors to perform their tasks. Most of them do not have clear requirements for handover that are sufficient to ensure the usefulness of delivered information. Jang (2020) claims BIM implementation in FM is expected to alleviate complicated data transfer. It can store geometric or non-geometric information for the specific purpose of usage.

According to empirical data, from the architect's point of view they think that their main duty is to provide accurate geometrical information during design. They focus on using BIM to provide building 3D elevation which can visualize the function of different building components. As is

also mentioned by Eastman et al (2011) the significant evidence of the great improvement in project management by using BIM 3-D graphics. It can help to avoid the discrepancy in the onsite facilities' construction process and installation sequence. BIM can use its 3D model feature to visualize the detail of the material used in components of assets. This tool can help facilities managers to build up concepts on how to determine the schedule of regular maintenance. and more specifically, information related to energy consumption, installation information, elevators, cooling systems, ventilation, fire protection, etc. From the empirical data it is also found that it is necessary to put in the BIM model to transfer to their asset management system for future large-scale refurbishment. The architects emphasized that most of them have no idea how to align the information from BIM with the facilities management format. Lai and Deng (2018) Indicate that asset managers cannot use data from BIM directly. In order to form an outline of the preparation for asset management, the BIM data should be in coordination with the original existing data in the FM system, this called information integration (Lai and Deng 2018). Most of the architects are not familiar with the requirement for asset information integration and understand the facilities managers in Sweden what exact information format as they use.

Architects have found out that most do not know how BIM knowledge can be matched to the facility management format. In Sweden, the majority of facility managers are not aware of COBie or CoFM criteria for FM, usually implemented in the UK and in the U.S. Both consultants and facilities managers consider that there is a large base of information in BIM to cause difficulty in information searching and matching. Spatial data is a piece of necessary information used to a large extent at the FM stage especially for planned maintenance and renovations. This information is normally incompatible to integrate into the FM system directly. Patacas et al. (2020) described how BIM data can be integrated into FM in order to save time and expense. The BIM components are able to show the detail of different types of maintenance-related information. Garrigos (2018) claims that BIM implementation can standardize and codify that information regarding operation and maintenance. It will further help to centralize information and flexibly store all changes for obtaining an As-built model. Naghshbandi (2016) claims BIM can improve space management through visualization of spaces and assets with the location. When space requirements or purposes change, BIM can assist in conflict identification. Patacas et al. (2020) also proposes the other integration approaches are specific to mechanical, electrical, and plumbing (MEP) maintenance data from BIM. This approach enables the automatic scheduling of facility maintenance work orders which can reduce operating costs. From the reflection of respondents, there is no doubt that all of them acknowledge the benefit of using BIM in FM can help to release their workload by the feature of BIM as it is easier to share and change asset information in a single platform. They do not spend extra time to ask for further clarification due to some information being missing or incompleteness. But there is critical prerequisite for achieving this outcome which it is required with clear standard asset requirement to declare what specific asset information should be shared and what responsibility for each stakeholder should bare in the asset information flow between each phase.

## 5.2 Challenges

### 5.2.1 Unclear Information requirement and project scope

The empirical material mentioned that an asset manager or client cannot follow Asset Information requirements to identify what kind of information they need. It results in rework and manual data entry which are usually required and leads to duplication of efforts and high chances of errors. There is also a lack of knowledge and experience to manage data in BIM for contractors and clients the last problem is the lack of stakeholders' involvement in the BIM transitioning process which will affect their understanding of the requirements of the FM team. While previous research Jang (2020) has focused on the little use of BIM in FM, in reality, this is due to the problem of BIM information integration into FM systems. They summarized the hindrance of implementation of BIM into two areas. One is the incompatible information and software interoperability. The incompatible information is caused by the unclear scope of operational work to state the standard of information requirement.
Moreover, the empirical material claims that in normal practice for defining asset information requirements it is common that there is no clear scope of work for operation and maintenance.

### 5.2.2 Different level of understanding of BIM.

Architects, consultants and facilities managers from the interview find it difficult to align the same understanding to the benefit of BIM enabled in facilities management among architect, contractor, supplier, and asset manager. They reflect that very few practitioners are able to link the information from one phase to another in order to form the life cycle of information flow in the project. Most of them still stay with the concept of using BIM as a tool to assist their work individually with less interaction on the information exchanging, Matějkaa (2017) discusses that project team individuals have different levels of understanding the benefit of BIM in data handover to operation. They have different perspectives toward the information required and what specific asset data from the specification is critical. The first level is using 3D model features from BIM to assist daily work only, the second is using BIM as a process.
The last level views BIM as a methodology. It develops a construction project in the whole life cycle by linking the different phases into the single platform where asset information can be shared and exchanged properly. Moreover, architects, consultants and facilities manager's emphasis on keeping changing of spatial design from designer in the same platform inducing extra amount of information which will affect contractors to carry out the construction process later on. It is a chain reaction to cause poor performance of the asset under improper construction methods and insufficient information passed over to the asset manager when project handover to the operation stage.

### 5.2.3 Different level of Information

As reflected by all respondents, they claim there is a challenge to align each practitioner within the project with the same requirement on the level of detail toward asset information. According to Hooper (2012), the individuals within the project team have different perceptions on the level of detail subject to information. It is found difficult for them to collaborate and contribute toward the same level of information requirement.

Since respondents are coming from different backgrounds to induce various understanding toward the function and benefit of BIM. Some of them protect their interest regarding their position in the hierarchy within the organization. They will not easily compromise into a standard level for bridging the information flow between different phases and create better communication for each stakeholder, as has been mentioned in empirical data. Eastman et al., (2011) added that the absence of a uniform standard of detail cannot ensure effective communication. During the project, the individual parties have their own definition of detail determination for the same reason. The contractor or designer cannot simplify and explain the BIM deliverables demand specification.

### 5.2.4 Interoperability

The interoperability of software is induced by various system implementations between designers and facility managers (Jang, 2020). All of the respondents point out that asset managers commonly use different information-management systems from BIM. As explained in Chen (2018) software interoperability is caused by different system usage between designers and facilities managers. It is found that facilities managers are most likely not familiar with using BIM in asset management. The data from the designer and contractor cannot be directly transmitted to the facilities manager. This causes problems of information interoperability and data sharing problems. As outlined from the empirical data the data in BIM contributed by designer, contractor, or supplier is different. The other parties are challenging to understand what data is required by the asset manager. Under poor information synchronization, the asset managers also face a challenge to capture the data from BIM. It can take extra time and cost to ask for further clarification from the designer and contractor.

### 5.2.5 Lack of communication

Pärn (2017) claims that the designers always use their own interpretation of the asset property and specification to apply in their design model. They have their own meaning of semantic data. Even the client's O&M requirements have already been defined at the project's outset in the exchange information requirements (EIR) for facilities managers to follow the requirements, but it is still difficult for them to understand what the information exactly stands for.

In addition, architect, contractor and facility management show their expertise into realistic ventures that run as asset managers that still play a passive part in the project team. facility management are normally ignored and without a chance to take part in the project at the earlier stage for reflecting their idea and requirement asset information. It will result in a communication gap between the facilities management team and designer and contractor. Jang (2020) has indicated that the misunderstanding among Tier 2 contractors, such as M&E engineering contractors and customers, is also very serious as subcontractors are not engaged in the project team. Subcontractors often play a passive role with less chance to reflect on the requirements of the BIM execution plan. Their data are important in developing their schedule for facilities managers.

### 5.2.6 Different perspectives toward data requirement

FM teams and designers have various knowledge and perspectives towards data related to asset property and specification (Jang, 2020). An additional big challenge announced by consultants was the lack of BIM professionals in facilities management like BIM experts inside asset management organizations who have well recognized knowledge of BIM information transformation into FM purpose. In addition, they know how to coordinate with different stakeholders by acting as linkage to enhance the collaboration which can help to insist on the same level and clear asset information requirements starting from the earlier stage of the project in order to keep the information consistent until handover to Facilities managers . It can let the whole integration process run smoothly and efficiently. Without collaboration with designers in the earlier stage of the project such as the design phase, FM teams cannot reflect their information requirements to designers, designers normally create models for construction purposes rather than producing as-built drawings for FM teams (Jang, 2020). Pärn (2017) says designers typically don't know what semantic data are appropriate for facilities managers from their design in BIM due to their different background in result of withholding various perspective toward asset information requirement.

## 5.3 Improvements

There had been several future recommendations of how to improve the flow of information by a practical implementation or further research. Jang (2020) proposed that it is important to improve communication with facility managers and other people from project teams, such as designers and contractors, as the planner and contractor may benefit from the asset management knowledge that is extremely significant in BIM as facilities managers. Jang (2020) also underlines how important it is for the engineering consultants in mechanical engineering in the information integration process as they can fill the contact gap between the main contractor and the supplier in order to provide reliable and exact asset details. The data that has been extracted from the empirical result contributes a clearer understanding from architects and consultants with better awareness of the passive role played by FM in the project team. In order to illustrate the FM perspective and need for information on assets, the interviewees agree to engage Facilities managers earlier in the project. This would add to a communication disconnect between the asset management team and the designer.

The suggestion from Love (2014) that the owner of the asset should process the management of BIM in project groups to materialize the use of BIM for FM, Love add that, according to a formal description of consumer requirements, the BIM models generate calculated and tangible value proposals for the organisation of the asset owner. It may be used to share standards, which provide a framework for action, problem solving, success and transparency. The results from the interviews also emphasize the importance of expertise integration within owners' organizations to supplement the process of information management from BIM to FM by their skills, knowledge, and experiences and, ideally, external bodies such as an expert BIM management firm which can provide particular field knowledge toward better performance in system interoperability.

Essentially, it is important to take into account how to synchronize the different manners of working with Building information models from different practitioners, since the development of a building information model is the collective expertise and experience of individuals and teams (Neda, 2016). The problem of perception of information standardization with the different levels of knowledge to BIM usage and misunderstanding to the information standard and requirement in FM for each individual member within the project team are unavoidable. The synchronization of the knowledge and ability between asset managers and the other members of the project team toward BIM usage and benefit recognition will help to drive a better performance in information management and transformation from BIM to FM. This can be achieved by seminars or through training, which can support their abilities, skills, and experience. The consultants from Neda (2016) also strongly insist on input more knowledge enhancement in Data Formulation in BIM and open standards in FM by providing on job training.

The asset information requirements as Poirier (2020) points out that uncertain asset information requirements to be defined at the outset of the project lead to the digital information gap. In addition, the absence of a standardized information format requirement in various systems automatically contributes to difficulties in data transfer and to identification between systems during each project process. Cavka (2017) highlights the success of information incorporation based on whether it has straightforward and succinct criteria for asset information (AIR). They recommend a structure that defines what asset data should be stored in BIM by computable BIM criteria and deliverables. In order to share information from the model with organizational FM applications, the validation of the asset information with consumer requirements is necessary.

Patacas et al. (2016), provide comprehensive details by incorporating methodology for information management to formalize and organize the Asset Information Requirements (AIR) description. They propose the need to create a shared communication language and data authentication process in order to avoid the issue of information that is unreliable and unrelated to the need to do operational work during the transition of the project is strongly demanded.

However, from the result of the interview, it is found that the real situation in the industry is normally different than stated from the academic research. There is in Sweden commonly no standard open data format used by architects, consultants for matching the geometric and non-geometric data from the manufacturer, contractor or supplier to the information format in FM system as required by asset managers during project handover. Therefore, the poor system interoperability is still one of main problems existing during information integration in the industry.

The studies of Yu, (2001); Becerik-Gerber, 2012; Shen, 2012) should be taken into account when considering how to examine BIM asset management processes they suggest an information-needs assessment to plan the reduced list of deliverables by classification and grouping, based on a planned use of the information by the owner, for the purpose of solving the surfing information problem. Mayo and Issa (2016) are proposing to use OmniClass as standardized graphic and non-graphic categorical information systems. It will perform as the object-oriented standard for BIM data that are more interoperable in information sharing through the construction-operations building information exchange (COBie).

The results from our interviewees do not conform to the Peter et al (2014) theory that each project team member should make more changes in order to prepare documentation on the operational and maintenance information specifications. With a consistent requirement statement, data from various stages of the project may also be validated against prescriptive requirements decided upon by the owner prior to extraction from BIM to an FM system.

In order to maximize BIM-FM information alignment, the empirical material offers a new perspective on further suggestions and encourages asset managers to join the project team at the earliest level. It helps asset management to represent what information needs are

appropriate for transitional information flow and which basic asset information is critical for operation. In some situations, it indicates that a new role should be set up among the project team in order to fix the issue. This role acts as a manual interface between these two systems for the identification of certain BIM attribute elements with subscribed unique asset information.

# 6 Conclusion

Building Information Modeling (BIM) is a combination of technologies and human work practice in handling geometric and non-geometric information management. Only 10% of companies/ projects can recognize the benefit of the usage of BIM in Facilities management. There is less research to study the challenges of information integration from BIM to operation and maintenance due to the point of view from consultants within the project team. So, the purpose of this report is to investigate.

1.) What information is required for FM,

2.) What hindrances are there in terms of information integration from BIM to FM and,

3.) What improvement can be done to the integration process.

The methodology that has been used in this thesis is qualitative which focuses on the evaluation of idea reflection and theory explanation. The Qualitative methodology is most likely used when there is no solid framework of data analysis. Few of them apply to a quantitative data analysis method to make a validated model formulation. The main objective of this research was to explore how engineering consultants interpret the issue of information integration between BIM and FM. A lot of research has been done to concentrate on the information challenges in BIM from the design to the construction.

BIM in FM application is still considered an emerging field. There has been lots of research conducted before to investigate how BIM implementation is beneficial to the operation and maintenance process. It is a digital platform to share different kinds of project information for each stakeholder extracting what they need in order to proceed their work. As referred by some of the researchers, they aim for a full scale of asset information items for each practitioner to follow in order to contribute right and suitable information in BIM for FM usage. However, by collecting the data from respondents. Most of them still have a gap in what asset information should be included in the BIM and transmit for FM purposes. Such as architects still preserve their judgement to deliver the geometric information as their main duty in the project. They mostly ignore communicating with suppliers to under asset components properties information which will affect their design of spatial toward asset placement. This is a chain reaction to cause the lack of information for contractors to carry out proper installments and let facilities managers plan a maintenance schedule and method. On the other hand, consultants and facilities managers have similar ideas toward there being too much information in BIM which is not fit to their purpose. They need to use extra time and cost to ask for further information or tract out the information as they need in BIM.

Even so, the use of BIM in FM is hampered by obstacles. The major aspects are the lack of methodologies that synchronize the recognition and perception toward tangible benefits of BIM in FM from different stakeholders. It is becoming a very complicated issue as it may be related to

their background differentiation and role of interest among the organization. This will induce a different standard of requirement in level of detail and necessity judgement toward information for FM. Secondly. The lack of clear scope of operation work is established at the beginning stage of the project which will induce the problem for stakeholders without a clear picture of information requirement to follow. In addition, it cannot give out a clear definition for each party toward particular asset information contribution liability to avoid the problem of asset information duplication, insufficiency or inaccuracy for FM process. Thirdly, there is a lack of open systems and standardized data format due to different system usage between design/construction and operation stage of project. The problem of interoperability is still not able to be tackled effectively in real situations even though there has already been quite lots of research to propose a framework or technology to link up the information between BIM and FM systems. Furthermore, there are many characteristics of the management of construction projects that lead to persistent problems affecting the journey of BIM enabled in asset information management and transmission to FM processes. These include problems of internal barrier of early engagement for facilities managers in the design stage of the project, knowledge management toward the BIM and BIM sensitization issues in the supply chain. In early project phases, there is still the need for improved cooperation and coordination between key players in the supply chain for contractors. Briefly, a BIM for FM should meet the requirements of a building owner. Clients need to understand and articulate their BIM requirements. The differing life span of technologies and buildings suggests that there is a requirement for open-source standards.

This research is also used to find out how to diminish the gap of information integration. It can be summarized that the new technology or framework in information verification and assessment is not only one way to improve the current manual processes of information handover. This study also finds out that there are three areas to improve the problem of asset information integration. First is the knowledge and perception alignment through training or coordinated by a new role establishment in the project team. Second is organization reformation by allowing the earlier engagement from facilities managers at the beginning of the project stages. Third is the clear and standard asset information requirement established at the beginning of the project by enhancing the communication between each stakeholder.

The emphasis is on data integration in the operational phase from BIM to FM. It is primarily focused on the understanding of data integration by third party consultants. The design process and development phase have been well defined and thus have not been integrated into the study. Moreover, less standardization in the field of structured data presentation and information specifications leads to fewer facilities management consulting organizations using BIM specifically in organizational activities. As the master's thesis begins to explore the consultant's point of view, its emphasis on operations will be reduced, the flow of knowledge and integration between the design and building phases should be considered. This is to detect any pre-existing information quality issues. Another justification to concentrate on the process of operation because of the information identification and integration system. Conversely, information formalization in indication presentations and knowledge specifications are less systematic. This eliminates the use of BIM directly by asset management consultants in operations.

Future studies should take into account the asset information requirements as it has been pointed out that uncertain asset information requirements to be defined at the outset of the project lead to the digital-physical gap. In addition, the absence of a standardized information format requirement in various systems automatically contributes to difficulties in data transfer and to identification between systems during each project process. Consultants also encourage staff to enhance their knowledge of the use of the Data Format of BIM and open standards of FM, recruitment and training. Consultants do not even know what kind of open standards like COBie, widely used in British and American asset management. Consultants think it is a valuable opportunity to collect diverse viewpoints on the standardization and open practices in Sweden by incorporating education and training. The other benefit of the directive is to maximize their consistency and reliability to improve incompetence with the correct data format and system use. Architects also found that most of them do not know how BIM information could relate to the management format of the facility. As in Sweden, most facilities managers do not recognize COBie or CoFM FM parameters.

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