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Implementation of ISO19650 based framework for asset management in logistics centres for a major food retailer

Ibironke Regina Adegun

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Universidade do Minho
Escola de Engenharia

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Master Dissertation
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Work conducted under supervision of:
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STATEMENT OF INTEGRITY

I declare hereby to have conducted this academic work with integrity. I confirm that I have not used plagiarism or any form of undue use of information or falsification of results during the process leading to its elaboration.

I further declare that I have fully acknowledged the Code of Ethical Conduct of the University of Minho.

Ibironke Regina Adegun

RESUMO

A relevância da informação tem acelerado a par da importância das profissões que envolvem dados, com a gestão da informação a assumir um papel central. Para a indústria AECO (Arquitectura, Engenharia, Construção e Operações) BIM representa dados (geométricos e não geométricos) e verifica-se, em muitos casos, que os dados originados na construção são pouco ou nada utilizados durante as fases de exploração dos edificios e na manutenção dos mesmos. Com base nesta realidade é de grande importância investigar a gestão de ativos e sua integração com BIM.

Esta pesquisa aborda o tema através de pesquisa estruturada quanto á utilização passada e presente da metodologia BIM na gestão de ativos e manutenção. A pesquisa também aponta a questões em torno da implementação da norma ISO-19650 para as indústrias de operações e manutenção, pelo desenvolvimento duma estruturação que identifica e lista os requisitos de informação relevantes aplicáveis (OIR, AIR e EIR), bem como o nível de informação necessário. A revisão de literatura aponta a que há poucos casos de implementação na área da gestão de ativos com recurso a BIM. Verifica-se que os gestores de manutenção e ativos procuram casos de sucesso verificáveis para convencer proprietários e/ou investidores nas vantagens da adoção de BIM. Ao definir os requisitos de informação para a operação e manutenção de ativos utilizando os dados recolhidos no caso estudado, esta dissertação contribuiu para o aprofundar de conhecimento na implementação da referida gestão.

Uma vez que a gestão com recurso à integração BIM é ainda nova nas operações e manutenção, há pouca pesquisa verificável no tema, como já apontado. Para melhor percebermos o nível de implementação BIM em operações e manutenção, o autor estudou sistematicamente o processo de gestão de ativos da logística do maior retalhista alimentar em Portugal, SONAE MC. O objetivo desta pesquisa é criar uma estrutura de trabalho para a implementação dum sistema de gestão de ativos baseado na norma ISO-16950 e que será aplicável a um ‘site’ real da empresa. Esta dissertação também procura utilizar a capacidade de visualização e exploração isométrica BIM, dando à equipa de gestão uma nova ferramenta que garante informação geométrica e que permite melhorias no planeamento das intervenções de manutenção, resolução de problemas e uma intervenção que se prevê mais rápida e produtiva.

Como parte da implementação da norma ISO-19650 esta dissertação explorou ainda a modelação direcionada à gestão de ativos, pelo estudo da importação e exportação de dados COBie no sistema (CMMS) da empresa (IBM MAXIMO), em paralelo com a integração desses dados COBie num ‘plugin’ de visualização BIM (Autodesk Forge), que foi instalado no ambiente de gestão existente. Este processo permitiu a reengenharia do sistema de gestão de ativos na logística SONAEMC, permitindo um processo único, sequencial, poupando tempo e garantindo uma organização mais eficaz dos dados e exploração dos mesmos no processo de gestão.

Palavras chave: Autodesk forge, COBie, Gestão de activos, ISO 19650, Nível de necessidade de informação

ABSTRACT

In recent times, the relevance of information has grown in prominence with roles involving data or information management taking centre stage. For the AECO (Architecture, Engineering, Construction and Operations) industry BIM represents data (geometric and non-geometric). The data from construction has been put to little or no use in the operation and maintenance stage. Based on this proposition it is of great value to investigate BIM-asset management integration.

This research approaches the subject by carrying out structured research into the past and present use of BIM methodology in asset management. It also highlights issues around ISO-19650 implementation for the operations and maintenance industry, by developing a framework that promotes the creation of relevant ISO 19650 information requirements documents (OIR, AIR and EIR) and level of information need. The literature review reveals that there is a lack of case study implementations in the area of BIM-asset management. Asset managers generally require verifiable data from case studies to convince building owners and investors to adopt BIM. By defining the information requirements for operation and maintenance using the data collected from the case study, this dissertation has contributed to increased knowledge in BIM- asset management implementation.

Since BIM- asset management integration is still new in the operations and maintenance areas, there is little verifiable research on this topic. To understand the status of BIM implementation in the operations and maintenance fields, the author systematically studied the logistics operations asset management process of the largest food and consumer goods company in Portugal, Sonae MC. The objective of this research is to create a framework for the implementation of an ISO 19650 compliant BIM based asset management system, for the case study in which such system will be applicable for a chosen existing facility. This dissertation also aims to use BIM visualization capabilities to provide the asset management team with tools containing both geometric and other asset relevant information and that will allow for improved maintenance planning, better problem solving and faster reactive maintenance response times.

As a part of the ISO 19650 implementation process, this dissertation explored subjects on modelling for asset management purposes, importing and exporting COBie data in a Computerized Maintenance Management Systems (CMMS) IBM Maximo. Alongside COBie data integration, a BIM viewer plugin (Autodesk Forge) was installed within Maximo asset management environment. This implementation process allowed the reengineering of the asset management system in Sonae MC, namely simplifying the existing workflow, saving time spent uploading individual asset information and improving the overall information storage and management process.

Keywords: Asset management, Autodesk forge, COBie, ISO 19650, Level of information need

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1. INTRODUCTION

During the classic building handover stage from the construction stage to the operations and maintenance stage the construction and installation history information is given to the asset management team in form of drawings, operation, and maintenance (O&M) manuals and in recent times COBie files. This information is often not fully utilised because it is not easily integrated on the asset management software. This disconnection leads to re-work for the asset management team in trying to get building data to create maintenance schedules and uploading them to the Computerized Maintenance Management System (CMMS) software.

With the use of building information modelling (BIM), one of the most important technology developments in the construction industry, the outlook of the handover process has significantly improved. The implementation of BIM in the operations and maintenance phase is still limited because despite its many benefits there is inadequate BIM knowledge in the asset management industry (Heaton et al., 2019b). Though BIM adoption is on the rise, it is obviously not very strong in the asset management industry due to the reason mentioned. To increase BIM adoption rates in the asset management industry stakeholders, need to push for BIM adoption and implementation.

The cost of a building's lifecycle is mostly driven by its operational phase. According to estimates, the lifecycle cost is five to seven times greater than the costs of the initial investment cost (Talebi, 2014a). Despite these benefits in cost savings, traditional asset management systems will not fully use BIM data until the transfer of BIM data to CMMS becomes automated or user-friendly (Heaton et al., 2019a). Although, asset managers can get some of the information needed for Operation & Maintenance (O&M) through the Construction-Operation Building Information Exchange (COBIE) format and BIM models Industry Foundation Classes (IFC) these interoperable formats need to be improved to store the relevant asset management parameters (Becerik-Gerber et al., 2012).

As a recent and expanding research area, BIM for asset management aims to meet the informational requirements of the operational phase of assets within increasingly digital maintenance workflows. The requirement to manage both new and existing facilities effectively on an environmental and economic level has increased significantly for building owners which makes BIM and the data it provides much more relevant to integrated asset management (Motamedi et al., 2014). The asset management industry stakeholders also have to take strategics steps in making their systems and software interoperable with the construction industry open formats (Teicholz, 2013). One of the research gaps identified and explored during this project is lack of a standard framework or guidelines for BIM- asset management implementation.

There is also some knowledge gap on the best ways to set up a BIM model for effective operation and maintenance use. Additionally, it is unclear how to transfer data from a BIM model into an Asset Information Model (AIM). The technology described in this research enables the direct extraction of BIM-related data from a model into a relational database for integration with current asset management systems. The requirements for the BIM model, the creation of the extraction platform, and the framework and database architecture are all covered in the dissertation. To better present and validate the process, a case study is presented.

1.1. Objectives

The main objectives of the dissertation are to create a framework for implementation of the ISO19650-3 and setting the practical approach for the connection of IBM Maximo software to the BIM models available. To achieve these global objectives, a set of more specific objectives can be considered:

- Define the organisational information requirement (OIR) and asset information requirement (AIR) for owners of existing buildings and in the specific case of SonaeMC the logistics centres. On the AIR, consider both the creation of the as-is models, but also the relevant trigger events and the underlying information needs.

- Define the Exchange information requirement (EIR) using client informed requirement. This objective involves gathering relevant data about asset management process for the update/creation of information for the models, including the provisions of EN17412 for the Level of Information Need. The level of information need for asset management process covers creating asset property/attributes data templates, specifying geometric information needs and data template.
- Master the operation of client used CMMS (IBM Maximo), as well as integrating Maximo with BIM Viewers. For this specific objective, several distinct viewers can be considered and implemented, such as Autodesk Forge, or others.

- Correctly map all the information of BIM models (geometric and non-geometric) using recommended interoperable formats COBie and IFC to transfer information into IBM Maximo Database. Take records of CMMS complaint COBie files making multi-import session to ensure proper synchronicity and data mapping for BIM- Asset management interoperability.

1.2. Dissertation structure

This dissertation is divided into six chapters, The first chapter being the introduction and it is organised systematically all the way to the sixth chapter on the dissertation conclusions. It is important to mention that some of the work done in this research like the comprehensive OIR, AIR and EIR is not included in the dissertation due to the Case study's (Sonae MC) data protection policies. The first chapter introduces the subject of asset management from a construction industry perspective. It also clearly states the motivation behind the dissertation topic and strategic objectives.

The second chapter *"BIM- Asset management integration"* takes a look at current and past research and literature on the dissertation subject. It discusses concepts of BIM implementation, ISO 19650 standards, industry trends and research on BIM- asset management interoperability. This chapter also highlights the potential benefit of BIM for the operation and maintenance sector.

Chapter three *"Implementing ISO19650-3 framework"* explains the methodology or research approach that was taken in this dissertation. The first section explains the ISO documents that relate to asset management and the process involved in creating this information requirement. The very important topic of level of information need development as it relates to asset management under this section topics on geometric, non-geometric information BIM uses.

Due to the implementation process involved of this dissertation, chapter four discusses the other part of methodology used to define the geometric models according to the level of information explained in the previous chapter. The fourth chapter "Modelling for asset management purposes" further discusses the relevance of asset-space association to the asset management team, manufacturer supplied BIM-objects and best modelling practices for the dissertation subject.

Chapter five "Roadmap to BIM compliance for existing buildings" describes results and discussions from the implementation process. In the context of the presented dissertation, the case study Sonae MC uses IBM Maximo for their enterprise asset management which was discussed in this chapter. This chapter further explores topics on software integration, data mapping, COBie file and re-engineered TO-BE asset management process after implementation.

The final chapter, chapter six gives a short recap of the dissertation objectives achieved and the identified gaps in the literature identified. It states in the conclusions drawn from the framework developed and the BIM asset management integration. Section 6.2 *"Recommendation for future developments"* discusses future development for BIM- asset management pointing out the areas in need of improvement and further research.

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2. BIM – ASSET MANAGEMENT INTEGRATION

Asset Management is a process in which a management system is bi-directionally linked to a record model to efficiently aid in the maintenance and operation of a facility and its assets. These assets, consisting of the physical building, systems, and equipment, must be maintained, upgraded, and operated efficiently to be of better value to the owner and the end users (Farghaly et al., 2017).

The asset management profession is an old one that has long been isolated from the construction industry. Traditionally the construction team often meets with the asset management team at the handover stage after construction. In some cases, the project is handed over to the client/appointing party then the client (acts as a middleman) appoints the asset management team. Globally buildings are becoming more complex than they have ever been, with multiple operational systems and monitoring. This complexity means more information is being generated and this needs to be managed (Wong et al., 2018).

BIM as described by National Institute of Building Science (NIBS) is a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decisions during its lifecycle from inception onward.(NBS-US). The information collected through a BIM process and stored in a BIM-compliant database could be beneficial for a variety of FM practices, such as commissioning and closeout, quality control and assurance, energy management, maintenance and repair, and space management. However, the building information needs to be integrated or compatible with asset management information systems, such as computerized maintenance management systems (CMMS), electronic document management systems (EDMS), energy management systems (EMS), and building automation systems (Becerik-Gerber et al., 2012).

Some of the major issues BIM- asset management integration faces are the differences in naming conventions, standard, software interoperability to name a few. Information from the design and construction phases is equally crucial for asset management. However, the fragmented structure in the construction industry leads to information loss (Farias et al., 2014). Large volumes of data are produced during the life of a building. Typically, hard printed and kept in boxes, these data cover topics pertaining to building design, construction, use, and upkeep. Throughout the entire life cycle of both buildings and public infrastructure assets, BIM is a strategic facilitator for better decision-making. It is applicable to new construction projects and, more importantly, encourages rehabilitation, refurbishment, and upkeep of the built environment, which accounts for the vast majority of the AECO industry (Abab, 2018).

2.1. Asset management and Facility management

Asset management is defined in (ISO 55000:2013) as "coordinated activities of an organization to realise value from assets" throughout the entire lifecycle of an asset. Assets in the built environment go through the stages of their lifecycle, which include strategic planning, initial design, engineering, development, documentation, and construction, daily operation, maintenance, refurbishment, and end-of-life or recycle(BS EN ISO 19650-1:2018). Facility management is defined as the integration of procedures within an organization to maintain and enhance the agreed-upon services which support and increase the efficacy of its principal activities (EN 15221-1, 2006).

The disciplines of asset management and facility management intersect as shown in (Figure 1) with operations and maintenance being a subset of facility management. In contrast to asset management, which has a wider range of applications, Facility management is concentrated on the building and infrastructure industries (Guillen et al., 2016). Although facility management, operations, and facility maintenance have certain variations, these three parts of "asset management" are generally used interchangeably in the construction industry. Based on the specific methods used by the building owners/client representatives to allocate organisational goals and expenditures to facilities, asset management will have distinct requirements (Nisbet, 2008). Facility management is seen as a firmly established profession, particularly in the building sector(IFMA, 2013).

Figure 1 - Relation between AM, FM and O&M (Guillen et al., 2016)

Even though both asset management and facility management are focused on overseeing an organization's physical assets and services, they have evolved into separate management disciplines. Figure 1 shows that the asset management encompasses facility management and operation and maintenance is under asset management. The fields of asset management and facility management have created their own standards and naming conventions (ISO 19650-3, 2020). The global concept of facility management is in general misunderstood, and its importance underestimated. Traditionally, the facilities management function has been widely described as involving clients, real estate, architecture, engineering, and construction teams (Alexander, 2003).

One of the crucial components of the asset management that is defined in (ISO 55000:2013) is the information system. The purpose of an asset management system is to develop the asset management policy, the asset management objectives, and the processes necessary to achieve those objectives. An asset management system is a collection of interconnected and interacting aspects of an organisation.

2.2. AEC- Asset Management Software Interoperability

In recent times, building information modelling (BIM) have gained popularity in the construction industry due to their numerous advantages and resource savings throughout the design, planning, and construction of new buildings (Lee Y. C. et al., 2015). Despite 3D modelling began to evolve in the 1970s, BIM modelling was not implemented in pilot projects until the early 2000s to aid architects and engineers in the design of buildings (Volk et al., 2014).

The Open formats such as IFC, COBie and IDMs are now being used across different software platforms. There has been recent effort by asset management software providers to make their software adaptable to this open format (Guillen et al., 2016). Some of the popular asset management software platforms in the industry are IBM Maximo, Oracle EAM, IFS cloud etc. are deigned from a non-AEC perspective with information management an task tracking the major goals. There is little literature discussing these subjects (Xu, 2011). This difference in work culture is one the reasons for the slow adoption of BIM in adoption is asset management(Heaton et al., 2019a).

In recent times some new software has been developed for asset management from AEC perspective, examples are Bexel FM, Bentley AssetWise, YouBIM etc. This software types are expanding to accommodate the large data base needed to store asset management data. Several BIM and CAFM systems in fact offer functions to export/import information to/from the COBIE data. To facilitate the process of generating the COBIE data out of Building Information Model, some add-in applications, such as BIM Interoperability Toolkit for Revit, also have been developed.

From an application point-of-view, there are several attempts to utilise BIM within the O&M phase. (Pärn & Edwards, 2017) developed an Application Program Interface (API) that acts as a plug-in within BIM modelling software and a customer database to integrate O&M data directly within the BIM model. Xu (2011), explains that the interoperability between BIM-related data (such 3D models) and O&M information management systems like Enterprise Resource Management (ERM) is constrained from a technological standpoint.

Interoperability is the capacity of two or more systems or components to share information and make use of that information, according to the ISO/IEC 33001:2015 Standard. Creating a common ground for semantics and data structure for construction and asset management stakeholders is necessary to address the interoperability issues (Arayici et al., 2017). It is important to take other elements impacting interoperability into account because there are bounds to interoperability both inside and outside of a specific BIM environment. Elements such as legal and organizational factors which is very prominent on AEC and Asset management industry (Tommasi & Achille, 2017). Nevertheless, technological interoperability, such as data validation with Industry Foundation Class (IFC) has been the main emphasis of interoperability of most research (Y. C. Lee et al., 2015).

According to the National Institute of Standards and Technology (NIST) report, the cost of inadequate interoperability amounts to approximately 57.8 % percent of the total project cost to owners and operators during facility operation and maintenance (Pishdad-Bozorgi et al., 2018). There is a growing need to address interoperability issues for integrated BIM- Asset management practices. BIM- Asset management integration is achieved with a properly defined interoperability plan for data exchange between BIM tools and the CMMS software (Shehzad et al., 2021).

Hence, one of the reasons for slow BIM adoption in the AM industry is the rigid options for interoperability in the form of static spreadsheet formats such as COBie (M. T. Farias et al., 2015). Figure 16 illustrates BIM interoperability maturity levels from manual to unified. BIM software is at integrated interoperability maturity level.

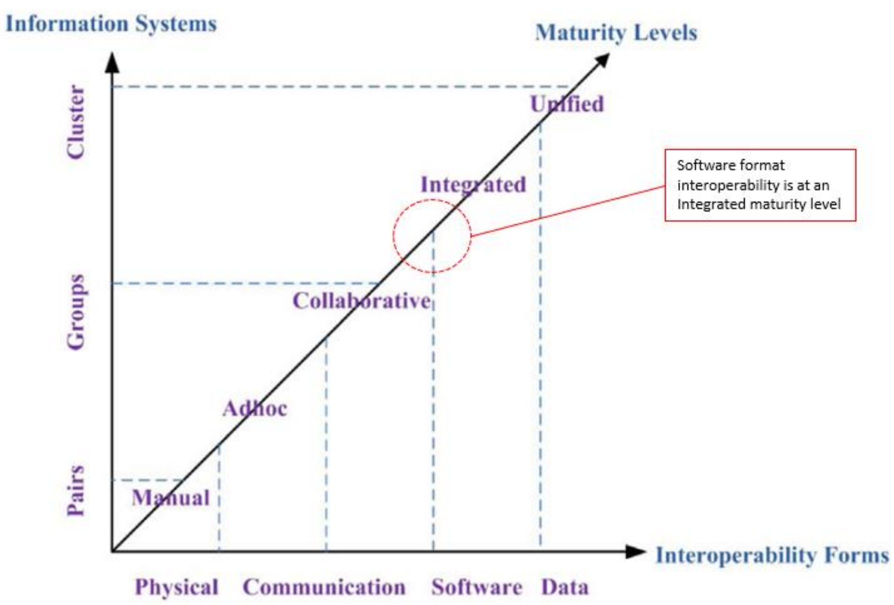


Figure 2 - Information Systems Interoperability Model (Shehzad et al., 2021)

In addition, from the perspective of information management, the built environment is essentially divided into silos within individual lifecycle stages and between stakeholders. Data is frequently stored in EAM software solutions with poor interoperability, leading to manual and frequently ad-hoc information exchange. This amplifies the demand for cross-disciplinary and all-encompassing applications (Akcamete et al., 2011).

2.3. ISO 19650-3 Framework for Information Management

There has been an increase in research into requirements validation and compliance checking approaches as a result of the expanding availability of metadata rich building information models and the ability to express project needs in machine-computable formats (A. Motamedi et al., 2018). The standard to guarantee the accuracy of information in the creation of BIM for AM applications is found in ISO19650-3. It states the standard for information management for the operational phase of an asset. It establishes the requirements for information management in the form of a management process (ISO19650-3, 2018). The client's/appointing party demands for the quality of the models delivered can be determined based on the information requirements. Information requirements can be categorized into different categories, as stated in ISO19650. Figure 2 illustrates the progression of information requirement in ISO 19650-3 standard.

The standard is defined for a scenario where the asset management team was present during construction, and it explains the transition and handover procedures. This transition though possible is usually not the case. An expedited remodelling procedure for existing facilities taking into account the facility management approach was suggested by (Carbonari et al., 2015). Building information models including FM data needed for FM activities like space analysis, retrofitting, and preventative maintenance were proposed by(Pishdad-Bozorgi et al., 2018), who also applied their method to an existing building in the higher education sector.

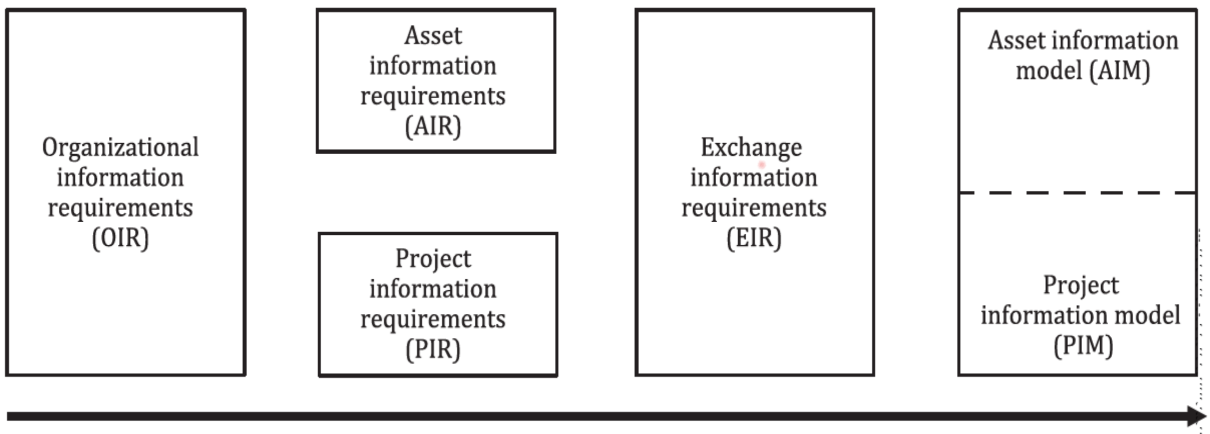


Figure 3 - Simplified illustration of the progression of information requirements (ISO 19650-3, 2020)

2.4. Benefits of BIM Asset management Integration

Currently, research projects have shown the benefit of BIM implementation in supporting many activities across the full building lifespan as a rich data base for building facilities; nonetheless, a new debate have been growing(Gouda Mohamed et al., 2020). Facility management professionals rarely adopt BIM database schemas, mostly because they do not understand how data is transferred from BIM models to facility management systems. This makes the data flow between the AEC-BIM and facility management processes laborious and time-consuming. It is always necessary to address technical issues, notably by standardizing the data sharing procedure and resolving interoperability issues between construction industry and facility management schemes (Shalabi & Turkan, 2017a).

BIM data and information gathered throughout the building lifespan will decrease the cost and time needed to gather and create asset management systems, notwithstanding the present interoperability problems (Teicholz, 2013). For instance, information on spaces, systems, finishes, etc. can be recorded in digital format BIM models and need not be entered again in enterprise asset management systems (Y. C. Lee et al., 2015). More significantly, data quality and reliability will grow, leading to greater worker efficiency (Teicholz, 2013).

One of the major benefits of BIM in asset management is the smooth flow of information from the construction stage to the operation lifecycle of a building which can last up to 50-100 years. (Shalabi & Turkan, 2017b)discusses in his paper that building owners at the handover stage should get a data rich BIM Model at the post-construction handover stage. In most cases, building owners are already have defined operation process as defined by ISO 55000, however without the context of BIM. The integration of BIM and asset data within these tasks allow for improved and often more cost-effective processes.

2.5. Prevalent Structures for Information transfer (Handover)

The results of the research carried out by Cavka et al., (2017a) reveal that the building owner’s expectations, generally with minimal codified structure, are expressed in a large number of different papers as well as in the brains of facility management specialists. In this regard, requirements are frequently not specified in a way that corresponds to the content and structure required for the implementation of BIM-enabled projects. Cavka et. al (2017) argues that national and international guidelines frequently fall short of providing a full set of BIM requirements for asset managers. This expresses the lack of structure for information transfer.

As suggested by Crotty. R (2012) a general practice shift that must occur across all sectors engaged in the design, construction, and operation of a facility, as well as throughout its entire existence, contributes to the difficulty of implementation. The change in practice primarily affects how people produce, use, manage, and exchange facility information throughout its existence.

The as-built BIM model that is handed over after construction is a goldmine of information that can be useful during FM operations, but not all the information is relevant within the scope of an FM practice, where data retrieval, change management, and keeping track of costs and work activity are crucial (Araszkiewicz, 2017).

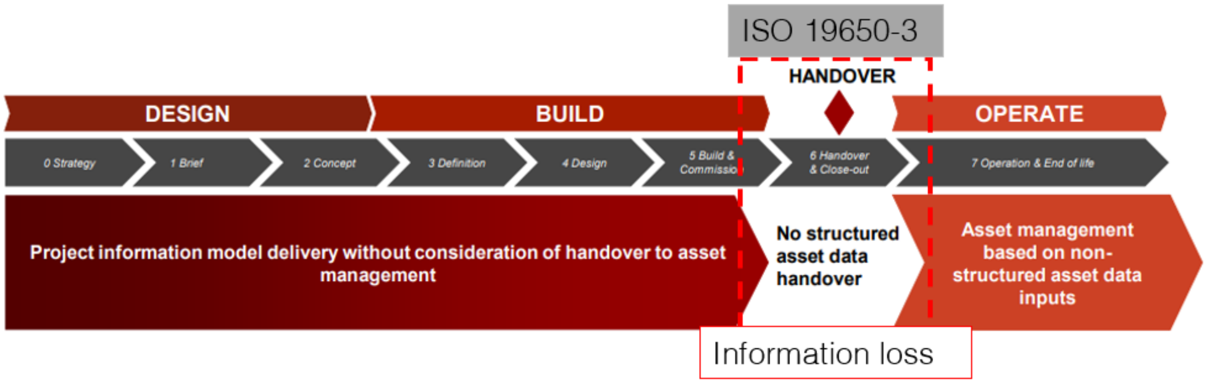


Figure 4 - Asset information transfer without BIM (PwC BMM, 2020)

Interoperability of BIM in different life cycle stages and functionalities still is limited due to incomplete, differently, or ambiguously used IFC attributes, denotations, or content (Venugopal et al., 2012). Figure 3 illustrate information transfer in the stages of building's lifecycle. It also shows that there is information loss at the hand over stage due to a lack of structure for asset information transfer.

The IFCs serve as the foundation of a building description from the perspective of collaboration. This foundation is strengthened during a building's lifecycle with information about on facilities management, including financial information, maintenance guidelines, evacuation protocols, and more. As information volume grows exponentially, it becomes increasingly difficult to organize it in a meaningful way (Nicolle & Cruz, 2011).

Talebi (2014) concludes that BIM software tools are currently not yet appropriate or 'readily-applicable' to meet the asset management processes. In other words, there are significantly fewer BIM technologies supporting asset management operations than there are for the design stage. Additionally, attempts to supplement 3D models with facilities data in existing BIM platforms can be difficult since it leads to a conflict between the facility data structure, such as asset management inventory, and the conventional built-in classification systems.

The available methods building information transfer are COBie an open standard for post-construction information and BIM/CAD model which is often not update because of the information loss during construction. Therefore, an AS-IS BIM Model is advised. However, the purpose of this research is to define recommended methods of information transfer for owners of existing buildings.

2.5.1. Non- Geometric COBie Development

For the transfer of non-geometric date, COBie format is recommended. The US Army Corps of Engineers created COBie originally to convey O&M-specific data in a standardized format that could be delivered in spreadsheet format. COBie aids in the collection and utilization of data required to support operation and maintenance (East, 2007).

Open data formats such as COBie make data available/visible to others and can be freely used, re-used and distributed. while proprietary data is restricted to specific software solutions. BuildingSMART is committed to delivering improvement by the creation and adoption of open, international standards and solutions for infrastructure and buildings.(UK BIM Guidance, 2020.)

One of the options that would make the process of transferring information from BIM systems to CMMS software easier has been the Construction Operations Building Information Exchange (COBIE), a spreadsheet data format proposed in 2007 (East, 2007)to manipulate building information. Figure 4 illustrates the structure of COBie format, it shows the different spread sheets in COBie and the stage in the buildings lifecycle the spreadsheet can be updated. Although the COBie format is simple the structure is static and lacks logical formalism which make it restricted(Farias et al., 2015). Table 1 also specifies the 16 Cobie spreadsheet and the construction stage they are relevant to.

In actuality, a number of BIM and CMMS systems provide functionalities for information export to/import from COBIE data. Some add-on apps, such COBIE Toolkit for Revit, have also been developed to make it easier to generate COBIE data from Building Information Models.

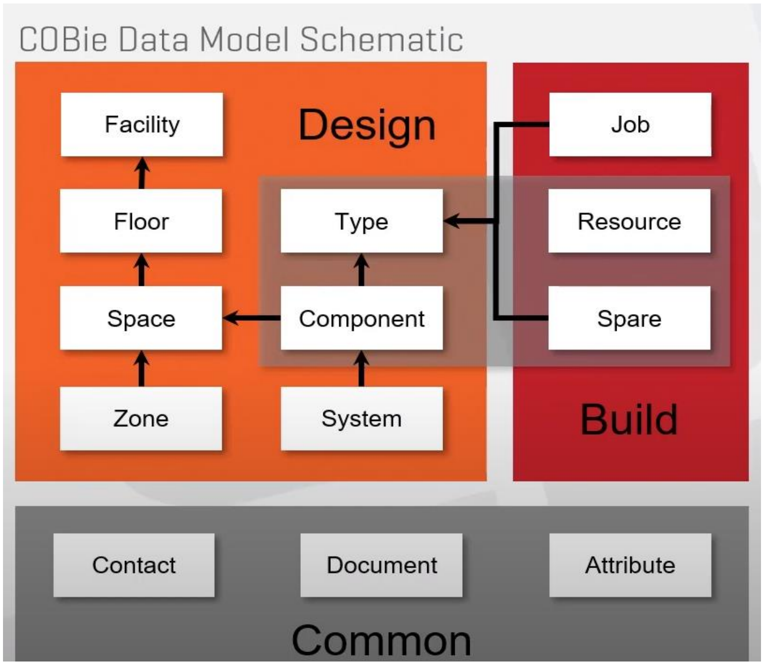


Figure 5 - COBie data structure adapted from (East, 2007)

Table 1 - The 16 Worksheets of COBie (J Lee et al., 2015)

Set	**I6 Worksheets**
Design	Facility, Floor, Space, Zone
Construction	Type, Component, System
O &M	Job, Resource, Spare
Common	Contact, Document, Issue, Coordinate, Attribute, Connection

2.5.2. Methods for Geometric Information Transfer

The prevalent methods of geometric information transfer is to receive CAD drawings and sometimes 3D models. The as-built model should be based on the design intent model and gradually integrate project information as construction advances since it reflects the situations at the end of construction (NIBS, 2017).

For the development of CBR (Case-Based Reasoning) within knowledge management, there is an attempt by (Motawa & Almarshad, 2013) to build a taxonomy of asset management keywords and link them directly to BIM objects. This technique adopts the strategy of directly attaching data to the BIM object (such as a window), but is constrained in how it addresses the asset hierarchy and how asset systems can influence O&M requirements To integrate O&M data directly into the BIM model, (Pärn & Edwards, 2017) created an Application Program Interface (API) that functions as a plug-in within BIM modelling software and a customer database.

This covers the definition and specifications of an AIM, structured information exchange, and the repurposing of BIM-related data during the O&M phase. It is suggested that the BIM model be set up from the beginning of the design process for O&M purposes. This is done by building in custom parameters to the BIM model that let you categorize different BIM items based on how they work. An extraction platform is created using the categorization to enable the export and grouping of BIM objects according to their functional output (Heaton & Parlikad, 2019).

The Asset Information Model AIM serves as a central data repository to support organizational needs, such as planning and budgeting, operational and maintenance choices, capital investment and life cycle costing, and contingency/emergency planning, among others. The Electronic Document Management System (EDMS) and a Data Store are the two separate components that make up an AIM. Documentation in the form of 3D models, PDFs, Excel, and Word files is stored in the EDMS (Heaton et al., 2019b).There aren't many examples in the literature that show the AIM's full evolution because it's so wide.

By exporting a 3D model from an authoring software Revit into a gaming engine software Unity (Patacas, Dawood, Greenwood, et al., 2016) showed how to visualize an AIM. They also connect maintenance data to the 3D objects, such as walls, doors, or windows.

From the perspective of live data integration, (Dave et al., 2018) presents an open-source standards-based framework for integrating IoT sensors and a BIM model hosted on a web server, delivering a live platform for visualizing the 3D model and real-time data analytics. To build the information required for an AIM from an operational and maintenance management perspective, (D. Navendren et al., 2015) examine how clients and project teams might collaborate.

3. IMPLEMENTING ISO 19650-3 FRAMEWORK

There's no clear pathway for BIM-AM integration for existing assets (Heaton et al., 2019a). Fundamentally, compared to traditional approaches that are used to generate built assets, BIM improves coordination, increases information accuracy, decreases waste, and enables better-informed decision making (Love et al., 2013).

The standards in the series ISO 19650 provide information management guidance for assets in their operational phase (ISO19650-3, 2018). For the purpose of this project the implementation of the ISO 19650 framework is to cover a case of an existing asset belonging to Sonae MC the largest food distribution company in Portugal. For the implementation process the company considered has an existing asset management software and process, as shown in Figure 5. In the current asset management process information is fragmented and stored in isolated files with the implementation of ISO 1950 standards information will be specifies according to the asset management team's there by avoiding duplication and irrelevant information. Maintenance planning will also be improved because the process of uploading or updating asset information will be automated with the use of EIR (Exchange Information Requirement) compliant COBie file.

Depending on the organisation's goals, size, and financial commitment the level of BIM expertise, and resources available, the implementation process will differ from one organization to the next (PSU-CIC, 2013). In this case, the use of the relevant and available industry standards to achieve the best method for BIM integration. The first step for this approach is to adequately define the information requirement for future appointed parties, using information gathered by the appointing party.

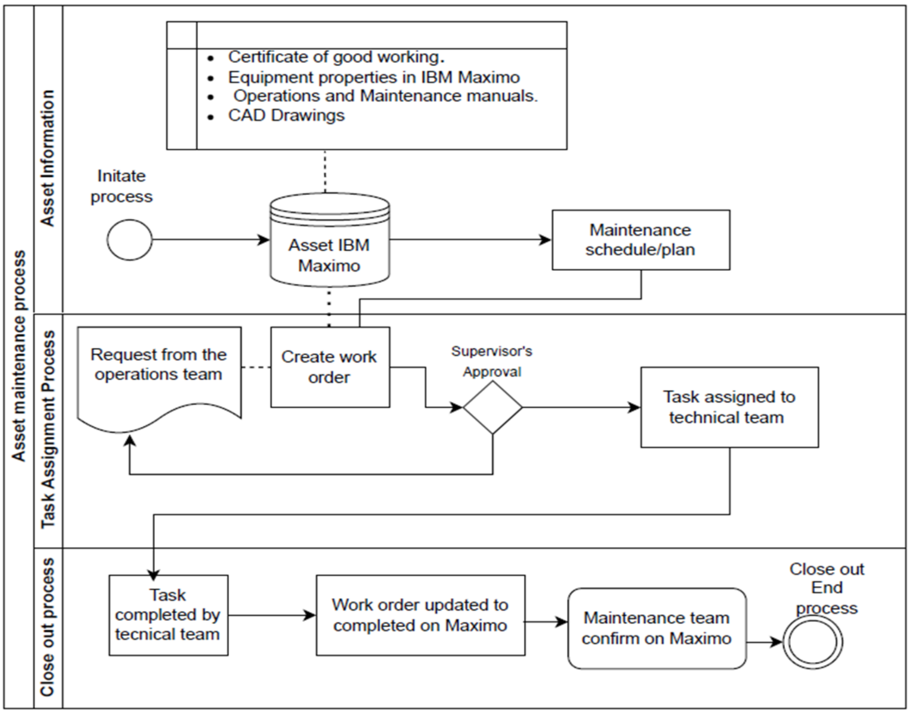


Figure 6 - Case study AS-IS macro asset management process

3.1. Research Methodology

First, a general framework as shown in Figure 6 is suggested to help owners determine their requirements for BIM-enabled asset management. A taxonomy of owner requirements was created as part of the technique using information gathered and analysed from qualitative research of available existing building information. It was necessary to understand the currently used asset management system in other to know how BIM implementation will change this process. The AS-IS asset management process of the case study SonaeMC is shown in Figure 7&8. BIM implementation will improve the way asset information is stored, record creation and task assignment process

In this research, information requirements refer to owner needs that can be modelled in and retrieved from the BIM model. Finally, through the creation of an asset information model, the connection between the digital model and the physical design solution with various information requirements and organisational frameworks is presented as the Asset information model (AIM)(Talebi, 2014a).

Figure 6 illustrates the steps taken to implement ISO 19650 for the case study Sonae MC. The first step involves gathering client data to understand the prevalent asset management process. The information from this informs the creation of the OIR, AIR and EIR and the level of information need definitions.

The company in this study has an existing maintenance system and software. It is recommended that time should be taken to analyse existing asset records, naming convention and other information requirement. The proceeding from this research defines an effective approach to improved information management methods for small and large existing buildings.

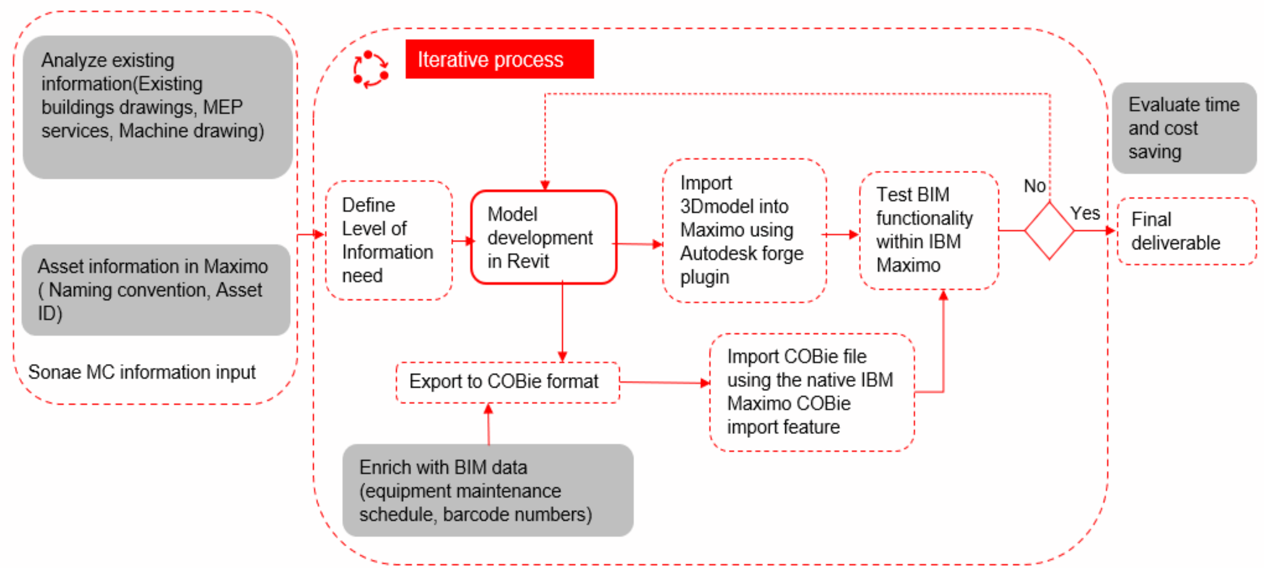


Figure 7 - Proposed process for BIM implementation for the dissertation

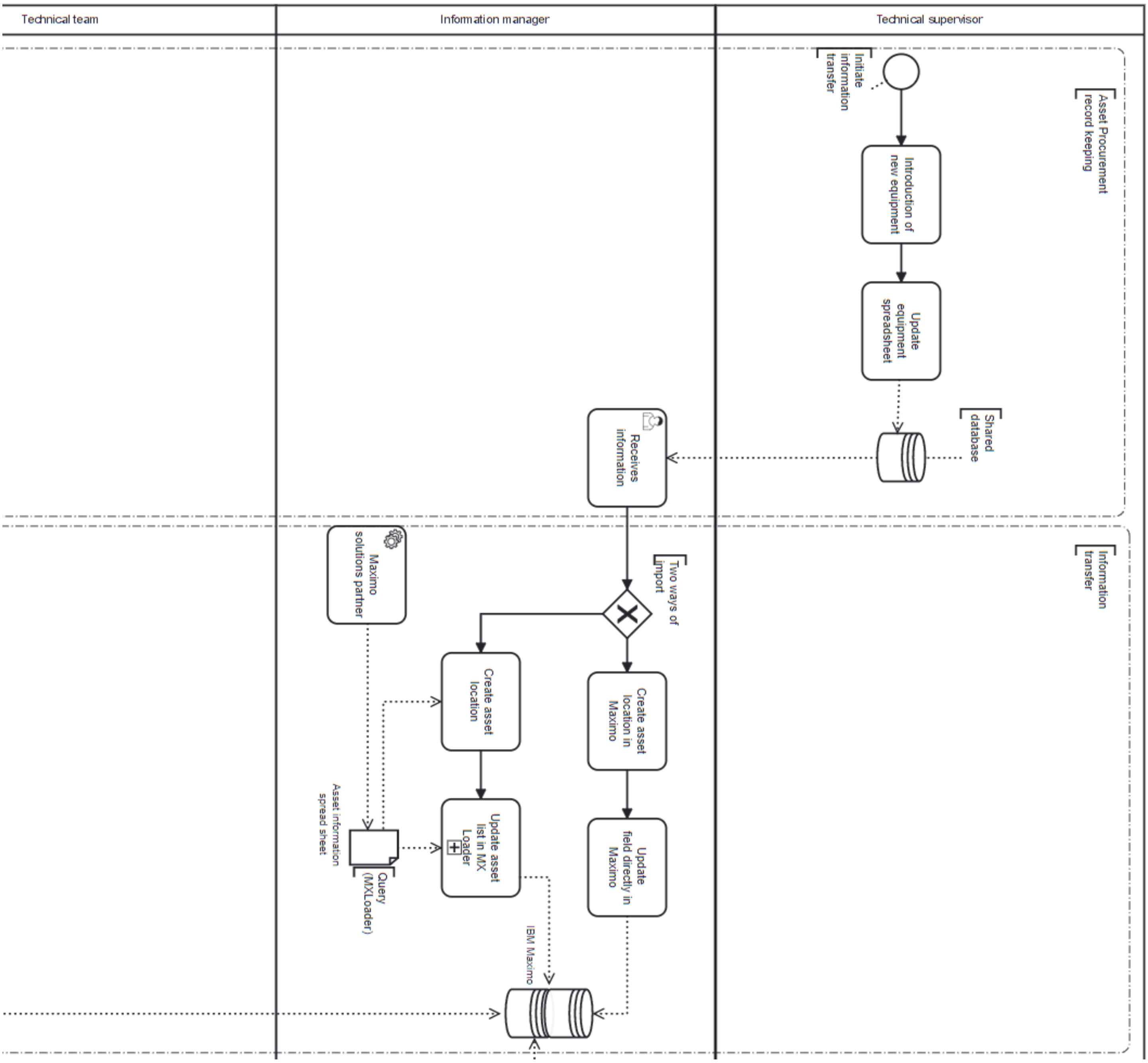


Figure 8: AS-IS asset management operation process map (Part 1)

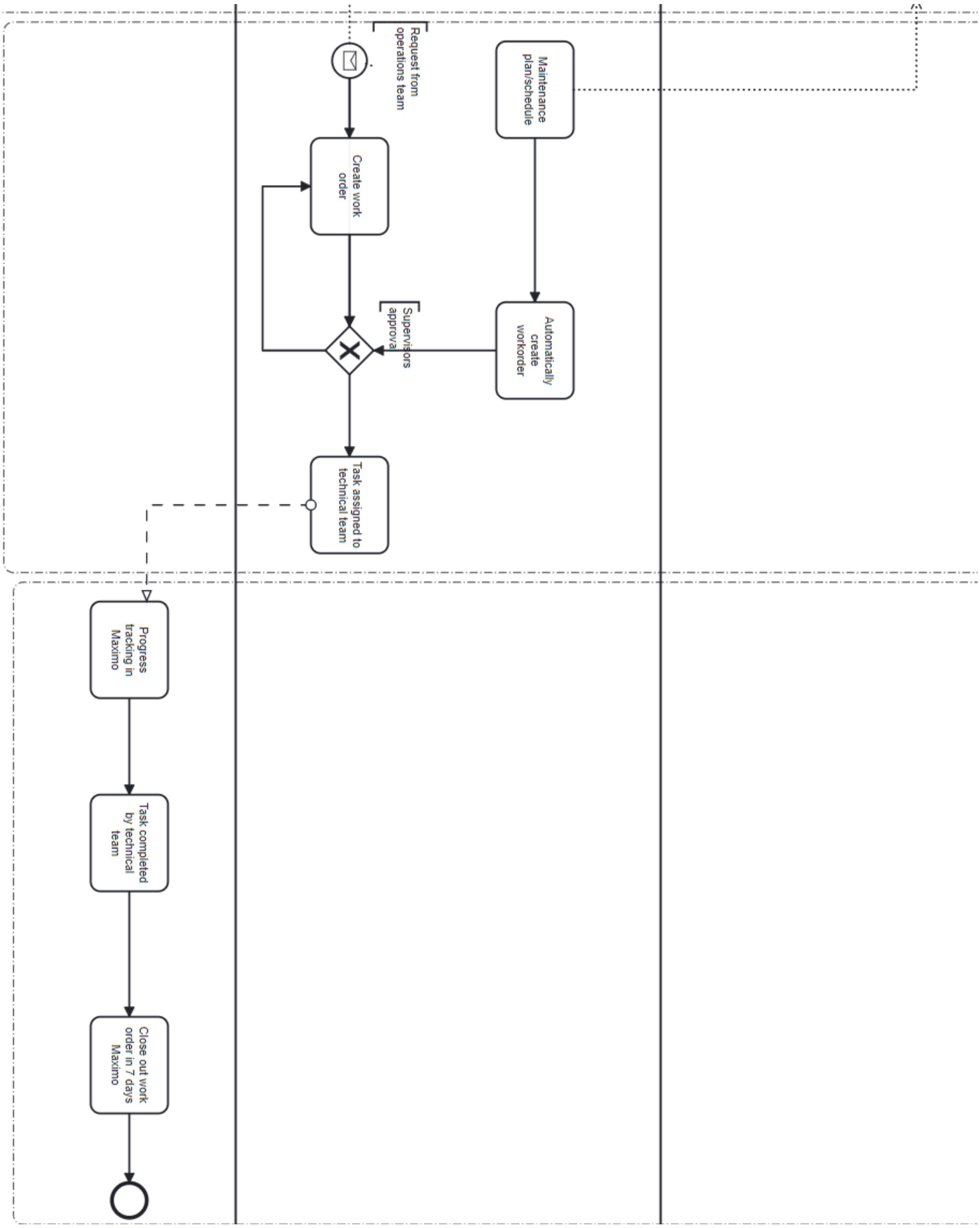


Figure 9 - AS-IS asset management operation process map (Part 2)

3.2. ISO Documents

The idea behind ISO19650 document information requirements is that they will change and evolve during the course of a project, with the knowledge gained from each phase being used to improve the needs for the following project or phase (CIC-BIM, 2021). The information requirement is defined in a way to facilitate BIM-asset management integration. It serves to guide the lead appointed party/appointed party on how information should be transferred in other to match the organisation's objectives.

The information requirements as specified in ISO 19650 includes the project information requirements (PIR) and the project information model (PIM) which is excluded in this case because project definitions have to be achieved with in a specific time frame i.e. pre-construction, construction stage. For situation with existing asset only three documents Organisation Information requirement (OIR), Asset information requirement (AIR) and Exchange information requirement (EIR) will be used to specify the Asset Information Model (AIM) as illustrated in Figure 8.

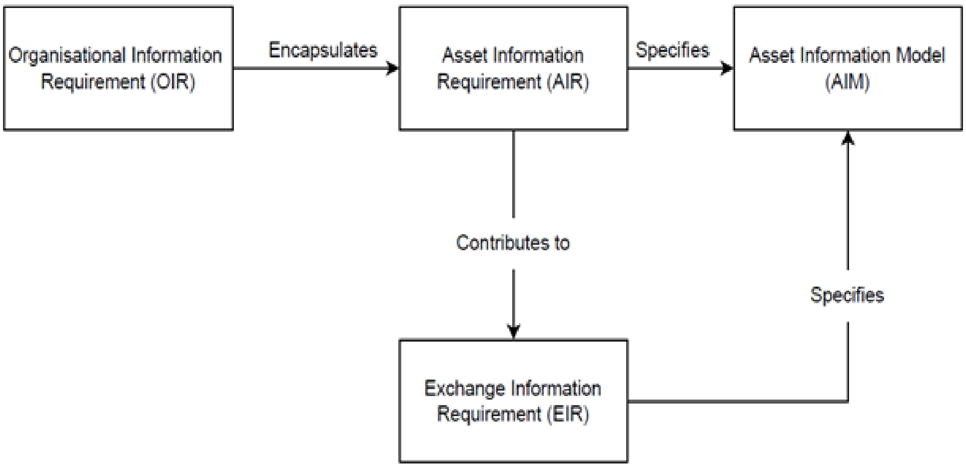


Figure 10 - Extracted from (Hierarchy of information requirements ISO 19650–1:2018

3.2.1. Organization Information Requirements (OIR)

The OIR is the first document to be considered because it encompasses all the organizations objectives and the strategies to be used to achieve them. The OIR is considered first because it links the information requirements to the overall organisational goals. It is of advantage if the appointed party understands the OIR because it facilitates comprehension of the high-level information required regarding assets throughout their existence. In addition to understanding the information requirements of the appointing party the OIR also aids the appointing party to conduct business in an informed and efficient manner(UK BIM Framework, 2021).

The effectiveness of many organizations is dependent on the way its facilities are managed. There are various ways to evaluate effectiveness, and in general, these measurements are strongly correlated with the organization's mission, goals, and objectives as well as the relative influence of its stakeholders. They also relate to one of the main goals of the majority of the organisations, which is to turn a profit from its operations (Alexander, 2003).

Table 2 shows some organisational goals and associated BIM use. This table is an important part of the OIR as not all the BIM uses are relevant to the appointing party’s goals or objectives with this, the OIR becomes strategic to achieving organisational goals.

Table 2 - Organizational goals and associated BIM uses

Organizational Goals	Associated BIM Use
To reduce maintenance time through visualization in BIM	Design Review, 3D Coordination
Reduce company carbon footprint	Energy Analysis, Performance Monitoring
Improve information management system	Record Modelling, Existing conditions Modelling

3.2.2. Asset Information Requirements (AIR)

Asset Information Requirements (AIR) provides the basis for the commercial, managerial, and technological aspects of producing and managing asset information and includes the standards, methods, and procedures to be implemented by the deployment team (BS EN ISO 19650-1:2018). The AIR is necessary to meet the goals stated in the OIR. The AIR will facilitate the cascading of requirements across multiple appointments and the amalgamation of data deliverables to provide a consolidated response to the OIR.

One of the identified key needs was to assist building owners in the creation of requirements, as well as the management and validation of information deliverables against these requirements. This had to be considered because of the inadequacy of BIM knowledge in the asset management industry. AIR set out the asset related information which the asset owner/operator needs, either for themselves or for their stakeholders. The AIR is used closely with the Exchange information requirement (EIR). The client specific AIR defined following the steps in the process map bellow (Figure 9).

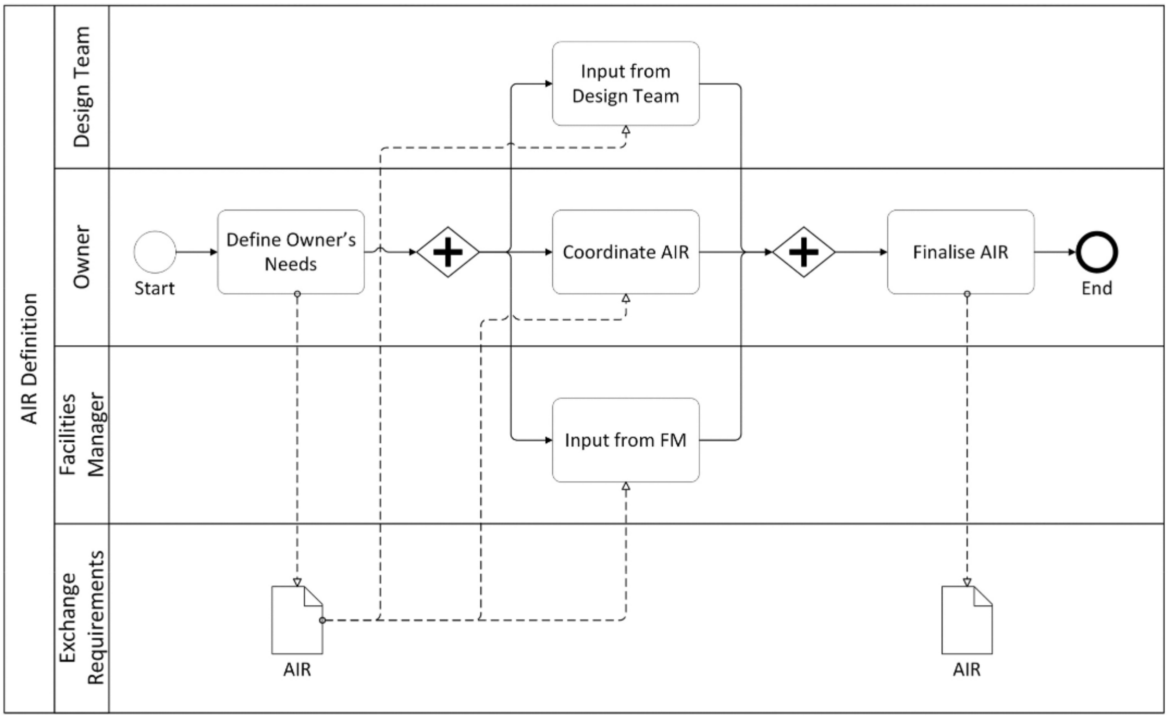


Figure 11 - Collaborative steps to define of AIR process map (Patacas et al., 2020)

In other to properly structure the asset information model for an existing asset the scope of the AIR should be clearly defined. There is a huge mass of data as it regards asset information ranging from asset properties to models and schedules. The information in the OIR states the overview of the appointing party goal and information requirement.

The asset information structure was defined as shown in Figure 10 This structure divides the BIM model into systems (water supply, HVAC) with elements relevant to the asset management team. The structure is also used to define the asset property sets as shown in the appendix The asset property templates are asset properties selected by the appointing party relevant to operation and maintenance properties. It is also of importance to map the AIR parameters/attributes to IFC property sets so that they can be seen in an IFC export in order to facilitate the open-source interchange of a BIM model.

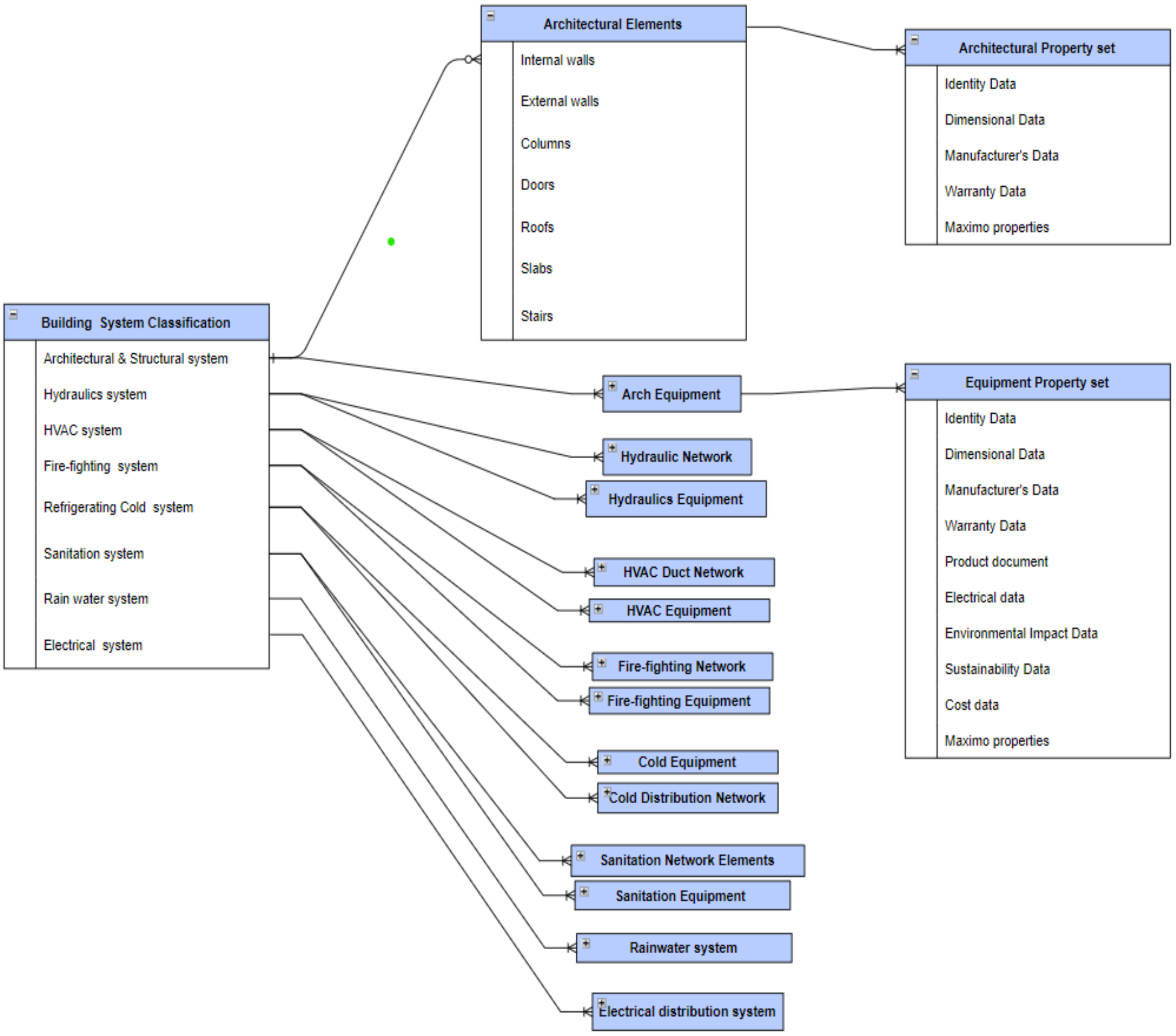


Figure 12 - Asset property structure for case study

3.3. Exchange Information Requirements (EIR)

The Exchange information requirements (EIR) specifies the mode and form of data required to be delivered by an appointed party at the post-construction stage of information exchange. One of the most important ISO documents is the exchange information requirement because it contains specific guidelines for information delivery some of which are the level of information need, specified file formats, naming conventions. The definition of EIR provides a structured approach that is particularly suited for the validation of IFC and COBie deliverable.

3.3.1. Level of Information Need Definitions

In recent times discussions around level of information need has been somewhat controversial because of the mix up with level of detail and level of information definitions. To set a precedence on this discussion the UK BIM forum as defined level of information need as general definitions of information requirements from the client or appointing party to the leader appointed party. One of the major reasons of defining level of information need is avoid the supply of irrelevant information and the associated time-wasted in information sorting.(EFCA, 2017)

The level of detail gives definition only the geometric information, but the level of information need caters before both geometric and non-geometric information. In the ISO standards the non-geometric information is referred to as alphanumerical information and documentation. For this research the level of information need has been divided to these two broad categories. An appropriate structure for the level of information need definitions is illustrated in Figure 11. Information specification related to geometry or BIM object behaviour is called geometric information. Non geometric information is broadly divided into **two groups the alphanumeric information and documentation.**

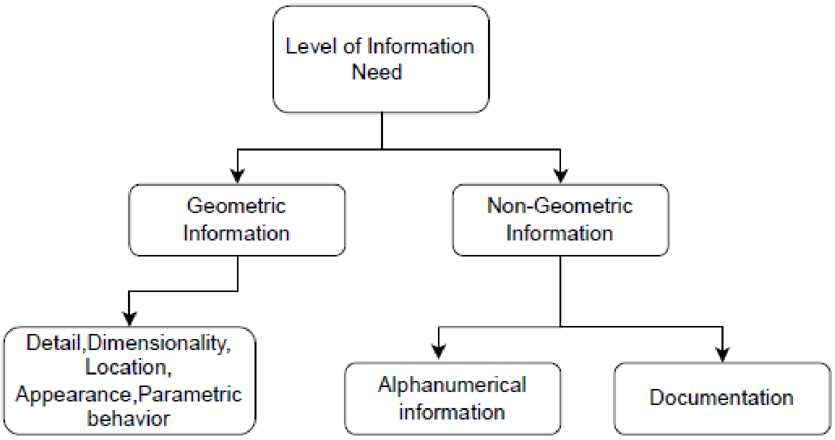


Figure 13 - Level of Information Need Structure

3.3.2. Geometric Information

The geometric level of information required by building elements demonstrates which aspects of the element can be omitted or simplified while still maintaining the element's functionality for specific BIM purposes like asset management. (EFCA, 2017.)

Information that can be conveyed in detail and to a certain extent utilising shape, size, dimension, and location is referred to as geometric information. The geometric information of a BIM object is often defined in the Level of detail (LOD).

The model requirements of each building element should be established when the organisation has chosen a model element breakdown structure. This can be done by going through each component of the facility data and deciding whether a visualisation of that component would be useful to the working group.

Table 3 - Sample definition of geometric information requirement (Extracted from Appendix 1)

Architectural and Structural Elements		
Information Delivery Milestone:	Handover of BIM Model	
Purposes/Uses:	Asset Management	
Asset:	Architectural and Structural Elements	Format
Structured Information		
Geometrical Information		
Detail	Wall assembly is represented with overall thickness that accounts for framing and finish specified for the wall system. Wall elements are modelled to specific layouts, locations, heights, and elevation profiles. Penetrations are modelled to nominal dimensions for major wall openings such as windows, doors, and large mechanical elements.	n/a
Dimensionality	3D	
Location	Location defined by space function	
Appearance	Object must have representative colours close to the reality but there is no need for textures.	
Alphanumerical Information		
Identification	Columns	IFC
	Doors	IFC
	Slabs	IFC
	Roofs	IFC
	Stairs	IFC
	Internal walls	IFC
	External walls	IFC
	Insulations	IFC
	Ceilings	IFC
	Windows	IFC

3.3.3. Non- Geometric Information

Non-Geometric Information is information not associated to a building element geometry. It is the alpha-numerical data or associated documents. The concept of information containers or metadata is described as an information set retrievable from within a file, system, or application storage hierarchy which is linked to a particular element. In this dissertation, the metadata are the associated asset properties relevant to the asset management team's requirement for operations and maintenance. The property data templates for architectural elements are shown in Table 4 which groups the properties into property sets. The property data template also describes the properties data type, units and notes this information is to be provided to the appointed party to ensure the alphanumerical information are as specified in the EIR. The property data template for the other building system can be found in the Appendix.

Table 4 - Sample product data template with AM defined property sets (Extracted from Appendix 2)

ARCHITECTURAL ELEMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Name/Description	Properties Identity Data	IBM Maximo Asset. Description	Text	n/a	Free text to describe product
Material		-	Text	n/a	General material assignment
Omniclass Classification		-	Character	n/a	Construction classification system
Finish		-	Text	n/a	If available (outer coat material)
Category		-	Character	n/a	
Gross Weight	Dimensional data		Integer	Kg	Suggested weight supplied by manufacturer
Height			Integer	m	Height from FFL (manufacturer supplied)
Area			Integer	m^2	Contact surface area
Volume			Integer	m^3	Volume supplied by manufacturer (space requirement)
Model Reference/Number	Manufacturer's data	IBM Maximo Asset.EQ1	Character	n/a	Manufacturer equipment identity number
Model Label			Character	n/a	If available Manufacturer model class
Manufacturer		IBM Maximo Asset. Vendor	Text	n/a	Manufacturer name
Manufacturer URL			URL	n/a	URL to technical details, e.g., system flow rates, pressure drop curves
Serial Number		IBM Maximo Asset. Serialnum	Integer	n/a	Serial number manufacturer provided (if available)
Service Life Duration	Warranty Data		Integer	Yrs.	Expected service life (manufacturer supplied)
Installation Date		IBM Maximo Asset. Install Date	Character	n/a	Date of installation/first use
Mean Time Between Failure			Integer	Min	Maximum time before maintenance (manufacturer supplied)
Warranty ID			Character	n/a	Warranty identity number (manufacturer supplied)
Warranty Start Date			Character	n/a	Warranty starts date (manufacturer supplied)
Warranty End Date			Character	n/a	Warranty end date (manufacturer supplied)
Is Extended Warranty			Boolean	n/a	Information on if warranty is extendible Y/N (manufacturer supplied)
Warranty Period			Integer	Yrs.	Warranty validity period (manufacturer supplied)

The methodology for this research suggests creating a spreadsheet with asset management team input clearly defining the property sets and associated properties using naming conventions defined by the appointing party. This spread sheet should be given to the design team at the start of the project. The spreadsheet should be used to create property set and properties in the BIM authoring software by the design team.

3.4. BIM Use

The project's objectives and requirements must be taken into consideration while choosing the BIM uses, and these applications must bring significant value to the design and construction processes. This directly impacts which BIM uses can be applied at each project stage as well as the outcomes anticipated. The amount of information required to execute the uses correctly is closely tied to how they are stated.

Each single BIM use must be specified with a clear objective in terms of cost, time, quality, or risk, and it must be connected to the project or another secondary use. Defining the BIM use is necessary for creating the required data templates and asset information model. Asset management is an all-encompassing BIM use which covers the following BIM uses:

Record Modelling: Record Modelling is the process used to depict an accurate representation of the physical conditions, environment, and assets of a facility. The record model should, at a minimum, contain information relating to the main architectural, structural, and MEP elements. It is the culmination of all the BIM Modelling throughout the project, including linking Operation, Maintenance, and Asset data to the As-Built model (created from the Design, Construction, 4D Coordination Models, and Subcontractor Fabrication Models) to deliver a record model to the owner or facility manager. Space Management & Tracking: Space Management & Tracking is a process in which BIM is utilized to effectively distribute, manage, and track appropriate spaces and related resources within a facility.

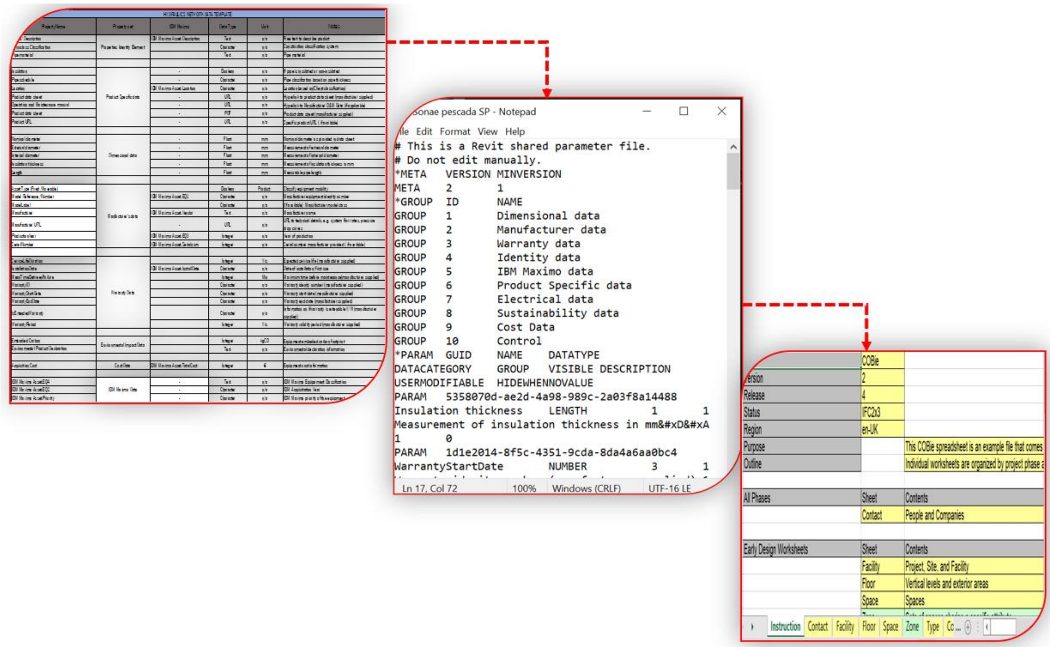
3.5. Asset Property Data template

Throughout the lifecycle of a facility, it is essential that the building information is accurate and readily available for a variety of functions. As a result of the disparity between the AEC industry and the asset management industry there is a need to create the asset property data template for the properties stored in the 3D model. This is because the properties relevant for construction are different from the ones needed during operation and maintenance phase. There are disparities in naming conventions and assets metadata relevance. This brings about the need to filter out relevant properties for asset management purposes. In order to achieve this and assets property data templates should be created to meet the requirement of the asset management team.

Assets and building elements have to be grouped in order for the data template to have a structure, building elements with similar properties and similar scope under asset management should in the same group. The asset property data template can be updated from time to time whenever there is a new development or an upgrade.

To operate a facility or carry out building renovations, a variety of information is required. Detailed information on installed components and equipment is required in addition to contract and general building information. This information includes service zones, installation dates, installation types, vendor/manufacturer, geometries and exact locations, materials and compositions, physical properties, warranties, as well as maintenance records since installation (Nicolle & Cruz, 2011). As discussed in Volk et al. (2014) to ensure interoperability across various software systems without information loss, an appropriate informational structure and data exchange is required depending on the required function.

The BIM object properties are stored in data pockets called metadata (ISO19650) in the authoring software are often different from the properties required by the asset management team. One of the methodologies applied in the research is to identify the information requirement of the AM team and map them to those in the authoring software. Figure 12 illustrates the property data transfer process. The asset property data template in the EIR is used to create a shared parameter file used within the authoring software environment. It is recommended to make the properties shared parameters so they can used for similar projects. These properties are finally exported to a COBie file o the Attributes spreadsheet.



COBie

Figure 14 - Mapping information from AIR to COBie for EAM software

There are a number of international standards that complement the BIM information management processes, although not being directly tied to BIM. For items like windows, rail tracks, and ventilation systems, ISO 12006-2 offers a hierarchical classification system (BS ISO 29481-2, 2016). According to Pärn et al. (2017), BIM modelling software does not by default offer the features needed to categorise objects by functional asset output and asset systems.

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4. MODELLING FOR ASSET MANAGEMENT PURPOSES

Implementing the newly created asset classification system within a BIM model is the next step. BIM objects are classified according to certain categories their functional output, asset system, and product). As an illustration, the classification of a BIM object model of an outdoor unit would include the functional output of cooling, asset system (central heating system), and the product (outdoor unit). Directly within the BIM modelling software, this categorization must be finished. The selection of objects and simultaneous classification of numerous items can be facilitated by object filtering and the creation of specialized views inside the modelling tools.

According to Pärn et al. (2017), BIM modelling software do not currently have the features needed to categorise objects by functional asset output and asset systems. This is because classification requires the use of multiple attributes. Additionally, there is not a property set specific to asset classification in the IFC model (BuildingSMART, 2019). Figure 13 illustrates the ratio of graphic information to attribute data at different stages in a building's lifecycle this shows that for the operations and maintenance stage the attribute data is more relevant to the asset management process and the model could have less detail.

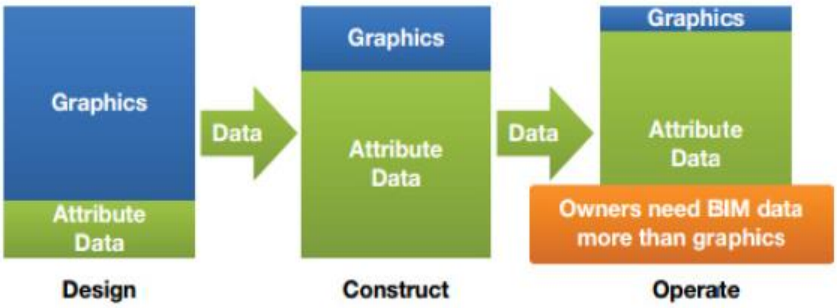

Figure 15 - Relevance of Graphical and Attribute data throughout building lifecycle (McGraw Hill Construction, 2014)

Major BIM modelling software, like Bentley MicroStation, Autodesk Revit and Graphisoft ArchiCAD offer the ability to generate user-defined requirements based on object category, type, or family. Custom parameters can be created in Revit, whereas user-defined attributes can be created in MicroStation and ArchiCAD. It is important to map the customer parameters/attributes to IFC property sets in order for them to appear in an IFC export in order to facilitate the open-source interchange of a BIM model.

While it would be ideal to have an as-built model for operations and maintenance available for every building, most existing buildings were built before the advent of BIM, and even though the number of projects using BIM today is increasing, it is still not being used for all new constructions. Technology enables the creation of as-built models that can be used during the construction phase of a building, but Patacas, Dawood, & Kassem (2016) explains that “a shortage of BIM skills and understanding by AM professional... is generating a negative cycle impeding BIM adoption in FM applications".

The process of modelling an existing building can be complicated because of (data collection, processing, and model development), it takes a lot of time and effort, and requires specialised expertise which is one of the major factors impeding BIM adoption in the FM industry. One of the research objectives is to create a modern framework for the management of geometric and non-geometric information for existing buildings.

4.1. Analysing Existing Asset Records

In the case for existing buildings, one of the first step for BIM implementation is to analyse the current asset data recorded by the operations and maintenance team. In most cases without BIM in the asset/facility management process the records kept are operation and maintenance manuals, maintenance schedules, CAD drawings etc.

It is worthy to mention that with an updated As-built BIM model all this information can be stored in the model while special documents are linked from the asset management database to specific asset. The findings of this research can help better understand the time and effort investment required by an asset manager to create an information model for existing buildings without having to resort to 3D laser scanning. The model for this case study Sonae MC warehouse was created in a proprietary software (Revit).

Information management is of immerse importance in asset management nevertheless some handover documents are still paper-based which may include operation and maintenance guidelines, manufacturer information and drawings. The information (drawings) received from the maintenance team is sorted in Table 5. It is recommended to sort out available drawings of an existing building into systems as shown in Table 5. This helps to identify missing and duplicated drawings. It also important to take note the drawing revision and the latest drawings.

Table 5 - Sample of asset record (CAD drawings) for BIM implementation

List of drawings received	Format	File names as received
Architectural drawings	CAD	ABBC_CENTRO_LEFT_02
HVAC drawings	CAD	HVAC_Distributions_Rev7
Site drawing	CAD	Topographic levels
Mechanical services drawings	CAD	HYDRO_02_11
Rainwater	CAD	RAIN_DISTRIBUTION
HVAC External drawing	CAD	EXE_HVAC_20_12
Lighting drawings	CAD	Lighting_Distribution_09
Azambuja Architectural (Reference)	RVT	ARCH_REF_22

Several research suggest that it is best to define both the geometric and non-geometric level of information need before the actual modelling begins. The modelling approach taken in this dissertation is illustrated in Figure 14. This method is recommended to avoid the re-work of changing asset or location names to match the appointing party’s existing asset records. The geometric level of information need for asset management is mostly unique and will require less detail. The building system specific level of information need can be found in can be found in Appendix 1.

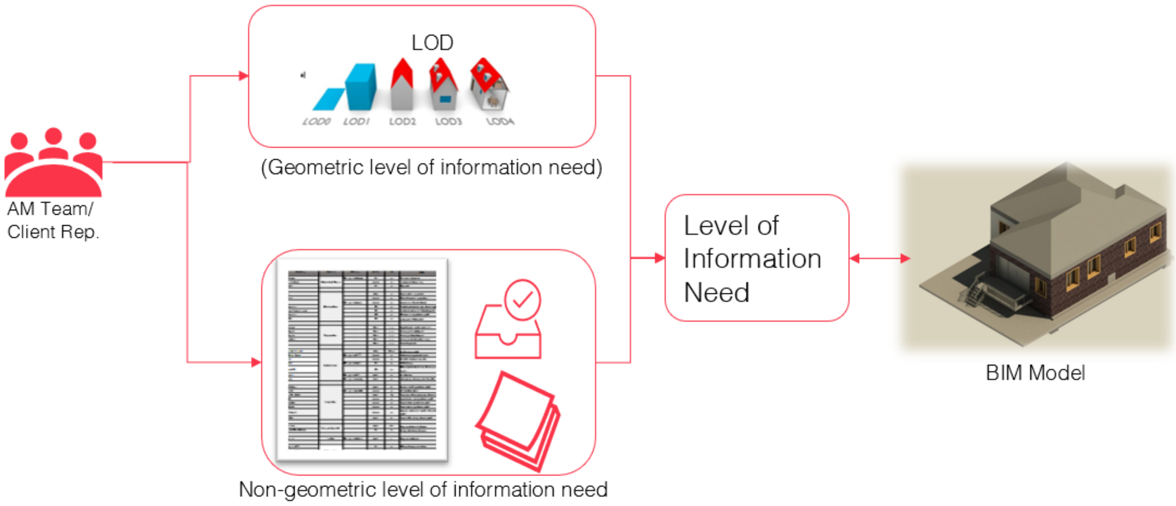

Figure 16 - Recommended Asset management modelling approach

4.2. Working with Manufacturer-Supplied BIM Objects

Technically speaking, interoperability refers to a technology's capacity to communicate, collaborate, and exchange information with other systems without significantly altering its internal design (Shirowzhan et al., 2020).

It is of common knowledge that manufacturers provide 3D or 2D models of the machines and equipment they supply. These models though some in card format or in other proprietary software format are often not used by the facility manager. This is because the FM team lacks the technical knowledge on how to make use of the models provided. One important measure added to the EIR is that this model must be provided in IFC (Industry Foundation Class) format by the manufacturer or supplier.

Some popular software often used by manufacturers to model machine and equipment parts can be Autodesk inventor, 3DMax and sometimes AutoCAD, SolidWorks, CATIA etc. Therefore, a common format that is received or accepted is the step file(.stp) format. Figure 15 shows the method used to transform manufacturer supplied BIM objects in this dissertation. It is also recommended that the BIM object be stored in IFC format in the data base

An STP file can be incorporated into the BIM model and though it is not interoperable it can be converted to common formats and imported into the selected proprietary software. One method that has proven to keep asset information is to export .stp files to CAD files and then import them in a BIM authoring software for use.

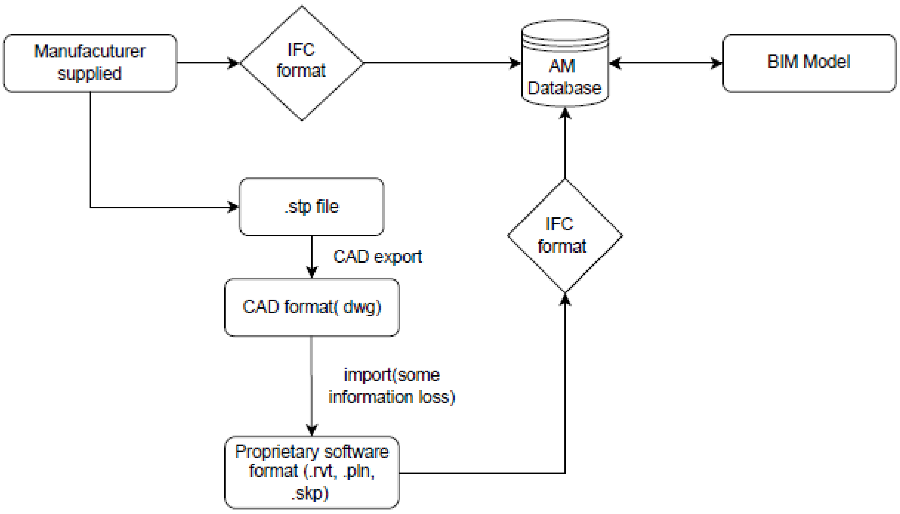

Figure 17 - Manufacturer supplied 3D model interoperability

4.3. Relevance of Space Association for Asset Location

Asset management requires a clear and smooth information transfer process for decision making to impede interruptions. Information deficits, accuracy problems and incomplete information induce more severe problems such as decreased productivity and decline in client satisfaction (Demirdöğen et al., 2021).

Assets are usually named with reference to their location in the asset management industry. Modelling for facility/asset management purposes has specific requirement, which is the BIM object space association, Due to the construction design perspective most proprietary AEC software have, conscious effort should be made by the modelling technician to associate building elements to the appropriate space. Figure 17 illustrates one of the constrains with the authoring software Revit doors between space boundaries are automatically associated to the space in front of the door. This could be a problem because the asset management team may want the door associated to a different space. For this dissertation the space association had to be manually edited before exporting the COBie to keep the space association as required by the asset management team.

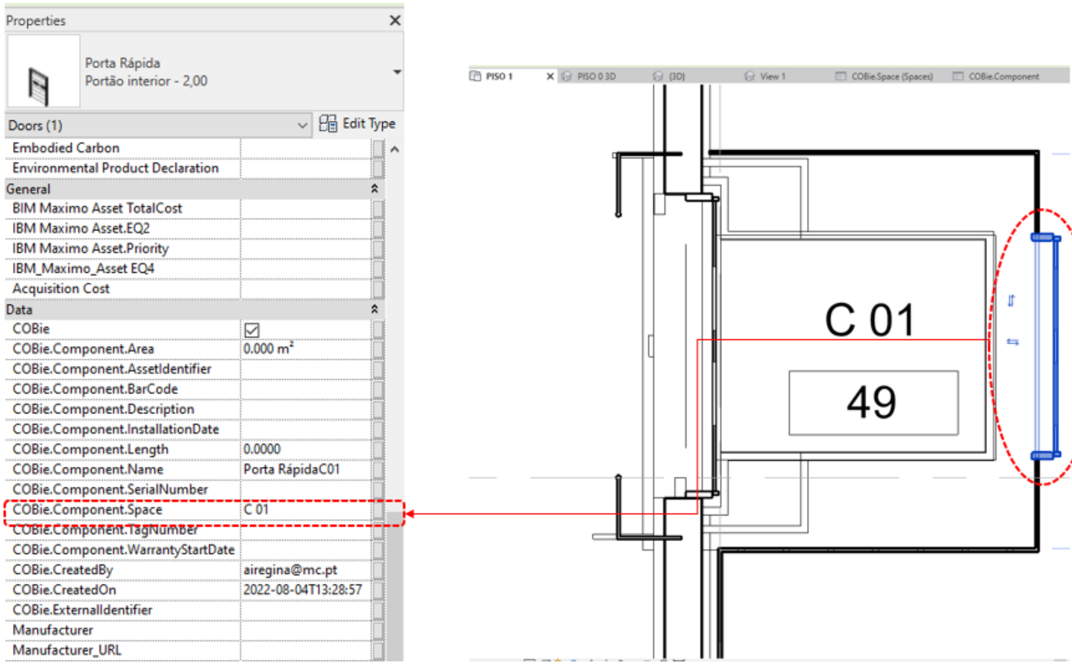

Figure 18 - Proprietary software - Space and asset location appropriation

One of the attributes of COBie format is that the Unique ID of BIM objects are linked to other spread sheets like the Space sheet. Figure 18 illustrates the space naming and external references association. This association serves as a link in the CMMS (IBM Maximo).

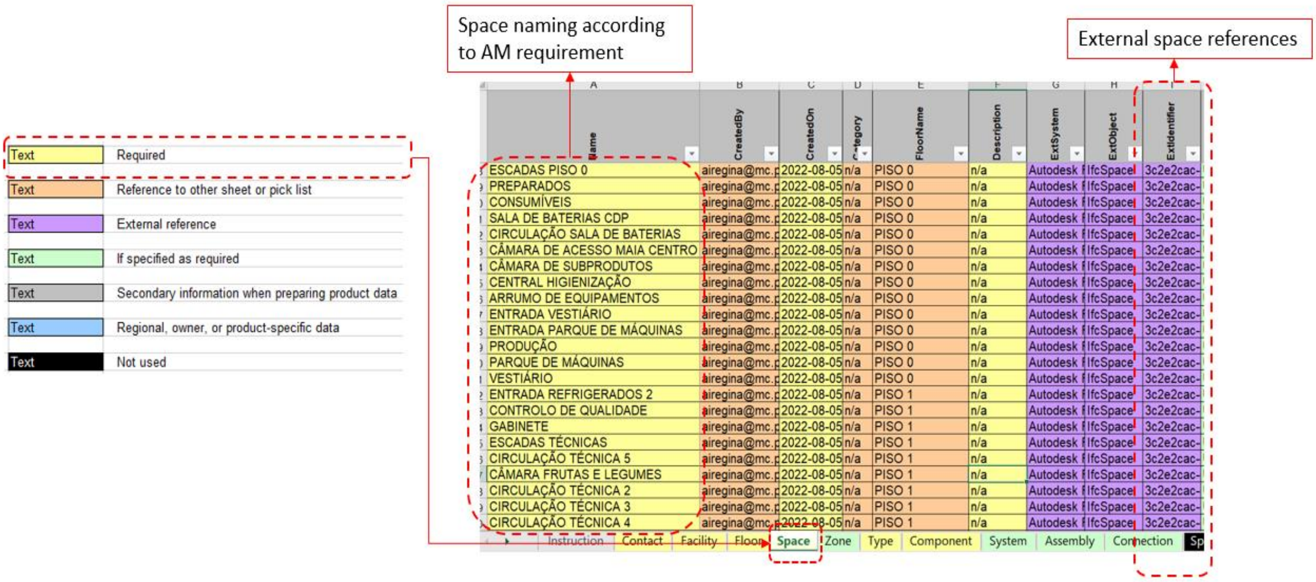

Figure 19 - Space naming in COBie as specified in the EIR

4.4. Best Modelling Practices for AIM

One of the recommended modelling approaches is to model being conscious of the BIM use. Depending on the scope of the project and the resources available, AM teams may be responsible for remodelling, renovating, or dismantling existing buildings.

The development of an asset categorization system enables a structured method for classifying BIM items within the BIM model. A structured hierarchy should be present in any classification system. Every BIM object within the model is classified as a functional of asset information requirement.

However, there is a crucial issue that should be addressed when creating a model for existing buildings: every project is unique, and each model's requirements vary depending on the building, its use, the management strategies, and the users which is why time was taken to properly define the level of information need. All of these aspects should be taken into account when developing a BIM for asset management model.

4.4.1. Create levels relevant for asset management

The asset/facility management only require a limited number of levels. The modeller often creates more levels for accurate object placing and level associations. Arbitrary levels like trusses, roof levels, Site levels are not relevant floors in the building. This floor should be deleted when handing over to the AM team or they could be excluded from the COBie export.

This also helps in the accurate space, component, and floor association floor. Creating multiple floors can make space to floor allocation complicated. Figure 19 illustrates how selected floors can be exported to the COBie. The floors is an important part of the location hierarchy in the asset management software IBM Maximo.

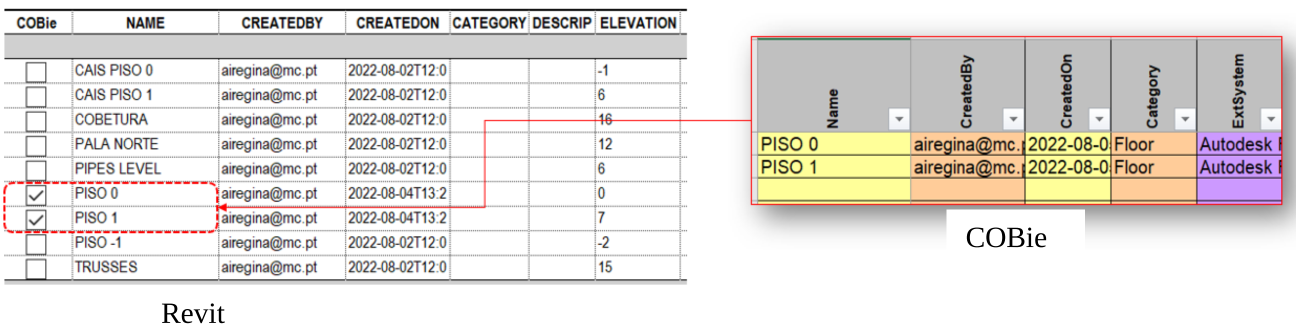

Figure 20 - Relevant levels association in COBie

4.4.2. Space or Room Consideration

It is recommended to create spaces instead of rooms in the chosen proprietary software when modelling foe asset management applications. Space allocation is important to asset management because of the need to keep a representation of facilities with the attributes of each space, such as space numbers, descriptions, boundaries, areas (gross, assignable, and non-assignable), volume, intended use, and actual status. This representation of facilities will help forecast space requirements, assign space, and streamline the move process.

The space data may be utilised for a variety of things, including the effective creation and upkeep of work schedules, the precise identification of the varied uses of places, and the ideal assignment and management of resources for events. It also gives facility managers the ability to view and track assets over a number of moves (Becerik-Gerber et al., 2012).

Figure 20 shows the space creation in Revit It is advantageous for operations and maintenance team to be able to see and recreate what their building looked like in earlier years before the remodels and additions took place for a variety of reasons, such as insurance considerations or dispute settlement.

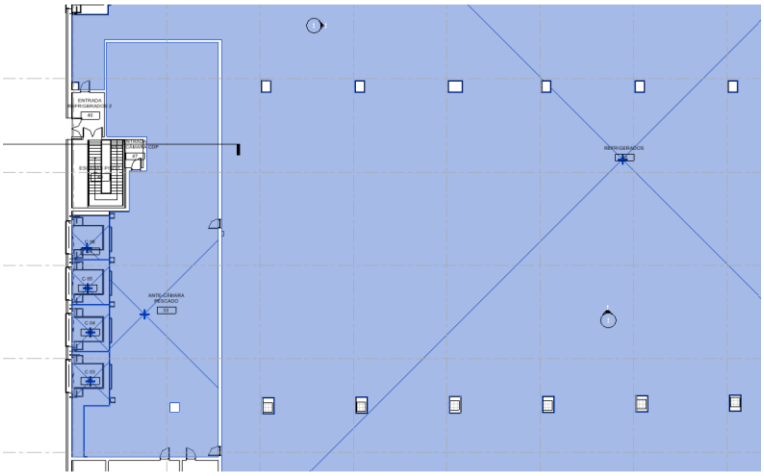

Figure 21 - Space creation in proprietary software in Revit 2022

4.4.3. Adhere to the defined Asset Information Requirement (AIR)

The level of information need defines the asset management team's naming conventions and property data template as shown in the Appendix 2 This is an important step to be carried out to avoid a re-work after developing the model and subsequently the COBie file. The asset management team also requires a certain level of detail as shown in Figure 21 with respect to certain equipment important to their facility.

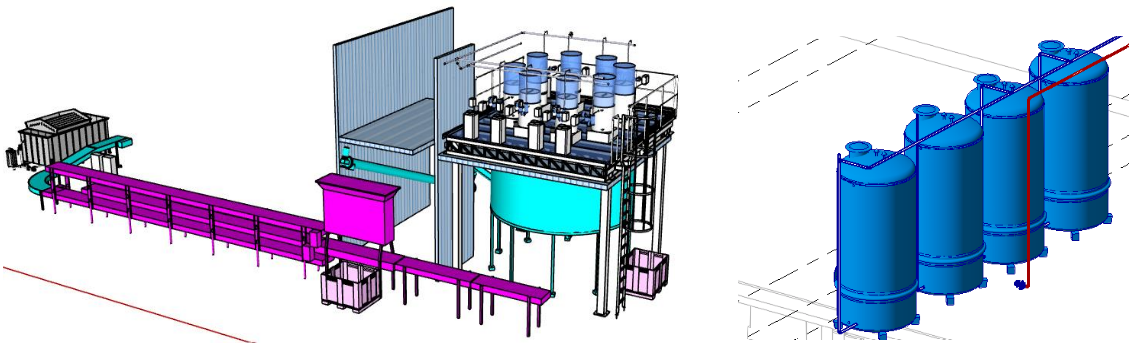

Figure 22 - Some equipment in BIM model to specified detail

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5. ROADMAP TO BIM COMPLIANCE FOR EXISTING BUILDINGS

The procedure for implementing BIM will differ from one organisation to another depending on the aims and objectives, the size of the establishment, the time and money invested, the level of BIM expertise, and the resources available. Due to the amount of relevant information to be included in model from the design stage therefore the design team carries extra responsibilities, liabilities, and work.

The first step for a building owner to achieving a BIM compliant asset management system is to develop an asset classification system which in the case study of this research, there is already an existing asset classification system. For existing buildings or asset with no formal structure for asset information this step has to be taken first in collaboration with the BIM implementation team.

After a physical asset is finished, BIM provides a library of precise information about the built asset and its components that can be utilised for facility management. During the maintenance phase, the FM has quick and simple access to crucial information. Additionally, the FM can update this information over time, which can lead to better asset management (D. Elliman & T. Pridmore, 1999).

Three key enablers have proved crucial for the deployment of BIM. The first is the emergence of improved IT infrastructure and the ability of computers to create and show 3D models with underpinning massive datasets. The interoperable formats developed by BuildingSMART, is the second enabler. Thirdly, BIM is receiving more support and relevance on a global scale (Robbert Anton Kivits & Craig Furneaux, 2013).

One of the steps of BIM implementation is connecting the 3D model of the produced asset to a database that can store all the data regarding the asset. With this new functionality, designers, engineers, builders, and facility managers may now work together more extensively throughout the whole life cycle of physical assets. Another feature of BIM is that information that is created only once can be reused numerous times, leading to fewer errors, higher consistency, clarity, and correctness as well as obvious authorship responsibilities. The steps to BIM compliance are discussed in this chapter as it is a multi-faceted process that will involve both technological and cultural changes

5.1. Software Integration

The asset management software tested out in this project is IBM Maximo. This is because of its wide use in the asset management industry and implementation for the case study (Sonae MC). The 3D model was modelled using Revit 2022. The model was further checked as illustrated in Figure 22 using the model checking tool available in Revit interoperability toolkit

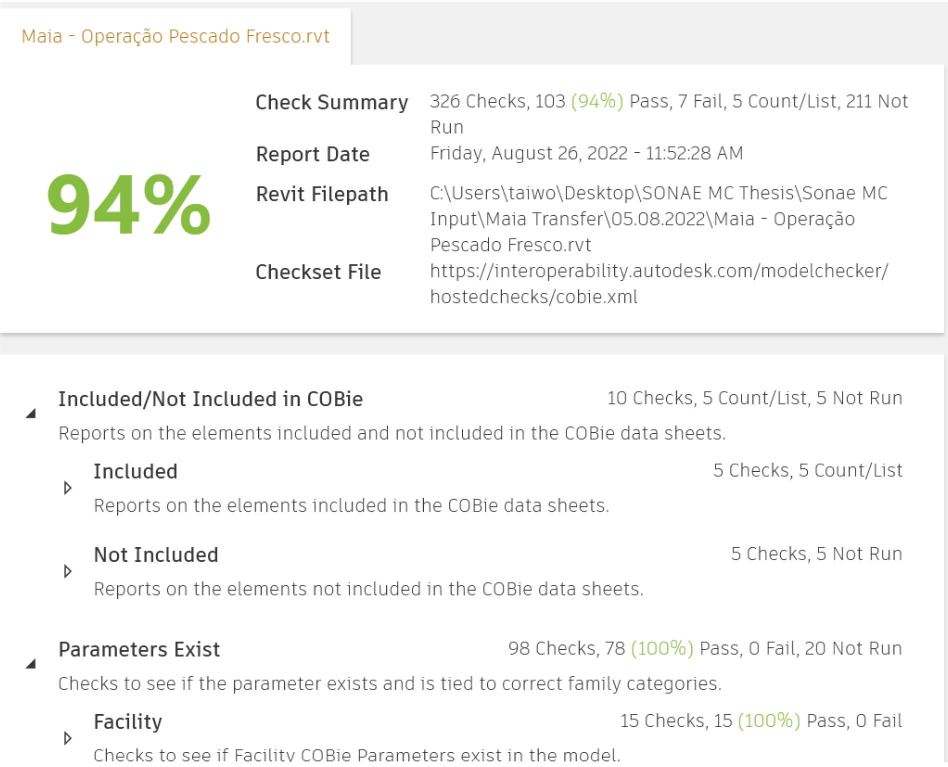

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Figure 23 - Model checking with Revit interoperability toolkit

It is recommended to model for the specific BIM use but the modelling requirement vary for different stages in construction. Currently, most of the knowledge needed for facility maintenance is related to mechanical equipment components. According to anecdotal data, mechanical system failures are the top reason for service, repair, and maintenance requests. The richness of information required for the design of mechanical components is represented in the BIM model(Talebi, 2014b).

5.1.1. Case Study Asset Management Software: IBM Maximo

IBM Maximo is one of the most used CMMS (Computerized Maintenance Management System) It is supplied with Maximo Enterprise Adapter, which handles all import and export processes (Nisbet, 2008).

The Maximo extensions for BIM is offered as trial software. Trial software is not supported by the IBM Maximo support program; however, support is available directly from the IBM Maximo development team(IBM Tivoli, 2011). Maximo Extensions for Building Information Models (BIM) provides support for integrating BIM data into, Maximo and for 3D display of BIM data in context with Maximo applications and processes.

5.1.2. Data Mapping: COBie and EAM Software (IBM Maximo)

The model information in COBie format can be uploaded into Maximo locations, assets, systems, persons, company, Job Plan, Preventive maintenance, and other tables. The import feature supports COBie information update.

Locations and assets in Maximo require a unique identifier like a GUID (Global Unique Identifier) or proprietary software element ID in the case of Revit (Revit element ID). These IDs are used in the interface for identifying assets and locations and internally for creating the linkage between them. In conventional usage, Maximo has been populated 'by hand' and these identifiers have been hand-crafted to satisfy this dual use.

One important decision the BIM implementation personnel has to perform is to select the appropriate element ID and to use it throughout the COBie exportation and importation process. Figure 23 shows the external identifier in COBie and the import settings in IBM Maximo there is an option to convert IFC ID to GUID or to convert the Revit unique ID to export GUID. It is nevertheless recommended to use the GUID provided by IFC where data reuse is necessary. Other identities, such as the shorter local unique identifier offered by proprietary software, may be used if the data transfer is a one-time transfer(Nisbet, 2008).

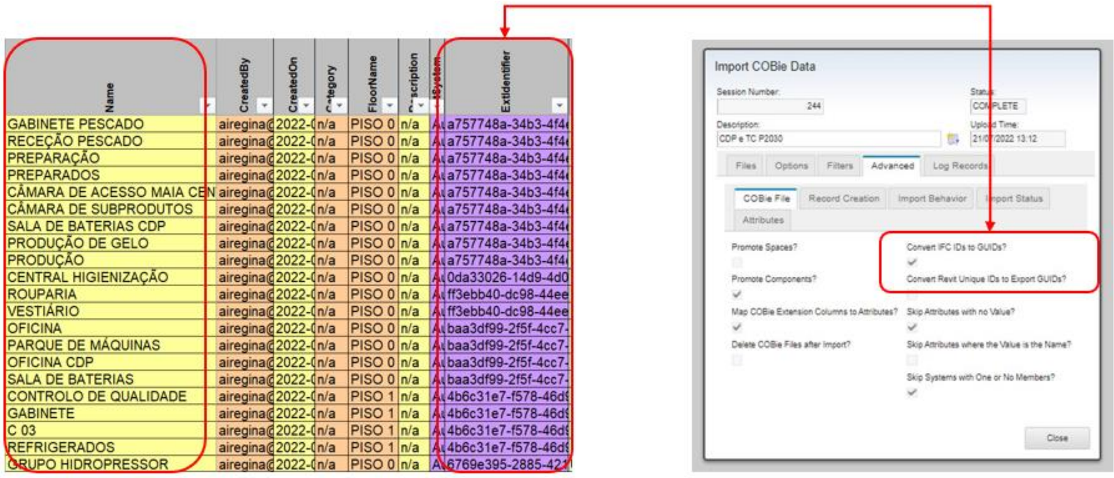


Figure 24 - COBie external identifier used to map parameters to Maximo

5.1.3. Object Mappings- COBie Worksheets

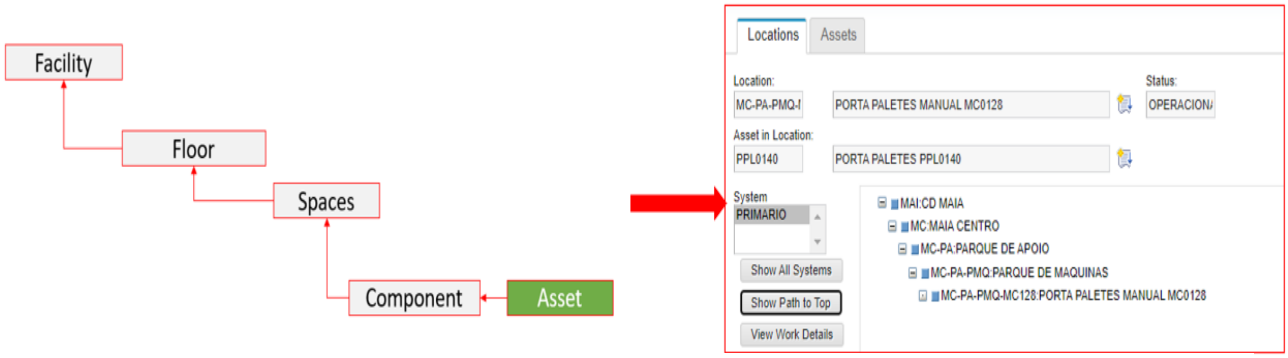
Maximo in-built file reader reads the information from COBie from individual worksheets and converts them to specific Maximo table as shown in Table 6. This Maximo tables are storage buckets for specific information types with the database. Although, extra Maximo tables can be created this requires personnel with high-level skills and knowledge of the Maximo database structure. It is therefore recommended to map objects to their appropriate Maximo table or create multiple tables to perfectly match COBie structure if the expertise id available.

Table 6 - Maximo - COBie worksheet translations

COBie Worksheets	Maximo Translation/Tables
Contact	Company information
Facility	Location hierarchy (1)
Floor	Location hierarchy (2)
Space	Location hierarchy (2)
Zone	System (It was assumed to be read as another layer in the location hierarchy)
Component	Individual Asset
System	System
Attribute	Asset attribute

Recently, manipulating COBie information has become more user-friendly and assessable with the proprietary software environment. For software such as Revit the Interoperability toolkit plug-in makes it easy to map object properties to specific values or property name. Some information is not relevant to the operation and maintenance teams and some examples are static architectural elements like walls, columns and beams this information can be filtered out of the COBie export.

The asset location hierarchy is an important identifier to the asset management team, this identifier is unique for all assets. The location hierarchy provides information about specific asset location, type and in some cases asset use. For COBie imported asset data there are identified differences in their location hierarchy as shown in Figure 24 COBie has a limited number of location hierarchy layers which are (Facility, floor, space and component). This restriction was a limitation for the case-study, the name and description must be chosen to match the asset management teams requirements an example of case study location hierarchy is illustrated in Figure 25. This is one of the reasons of creating the exchange information requirement and bringing in the asset management team in the early stages of a project.



COBie Location hierarchy in Maximo

Figure 25 - Location hierarchy translation in IBM Maximo

Building components are categorised and clustered using an asset hierarchy to reflect related properties or spatial references (Uzarski & Burley, 1997). Although the IFC schema offers a logical hierarchy of building components by the definitions of multiple domains(Motamedi et al., 2014) this is quite different from the structure used in the asset management industry. Naghshbandi (2016) described the effort has been made to bridge the gap between these two industries.

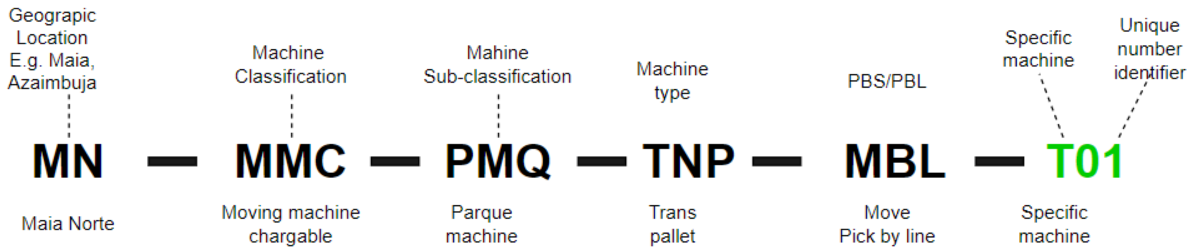


Figure 26 - Sample Asset location hierarchy

5.1.4. Naming Conventions and Construction classification

To guarantee that users would accept and apply the schema, there must be an industry-wide standard for metadata classification. especially when the schema might not be the same as what individual company uses. The Omniclass and Uniclass classification system are examples of multi-table classification systems aligned to ISO 12006-2.

Although classification methods are required, it is unclear at what stage of development these schemes must be for them to be useful in connecting document information to construction models. It is suggested that the classification system be determined in the early stages of a project and used throughout the buildings lifecycle. Links between taxonomy data enable the automatic cross-classification of building data across distinct outline views.

5.2. COBie Format BS 1192-4:2014

COBIE aims to enhance the way information is gathered during design and construction and then made available for use in operations and maintenance stage. After the project is finished, COBIE eliminates the need to produce and deliver boxes full of paper construction records to asset management team (William East, 2007).

In COBIE worksheets, all reference data types are local references. The external reference fields offered on worksheets can be used by users of COBIE data to transfer external references to data inside of COBIE. It's probable that various writers will want to make use of various internal systems. In all circumstances, the user establishing the COBIE record may supply the referenced system name and the id from the reference system.

There are two stages to the COBie validation procedure. The independence of Maximo COBie file or files are first checked for integrity. The model is checked against Maximo in the second stage for problems including missing measurement units, missing classifications, and various field length restrictions.

Asset records that were first established through an import can be intelligently updated by further imports of COBie data. First-time update might link COBie records to already-existing Maximo data that is not COBie related. As shown in Figure 26 the import setting can be manipulated as much as possible to give a semblance to the existing non-COBie information in the Maximo database.

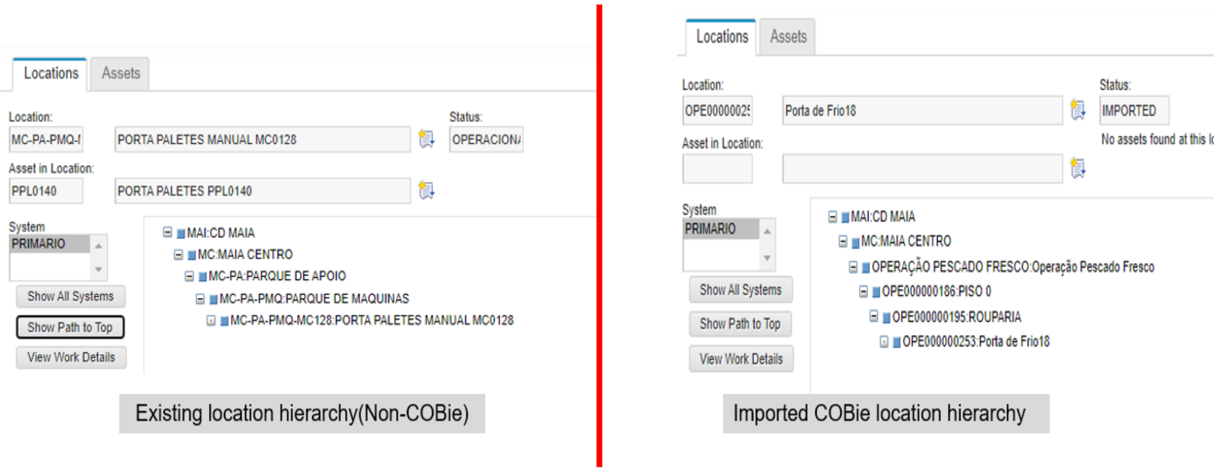


Figure 27 - Comparison between COBie imported location hierarchy and existing asset in Maximo

5.3. Re-engineered Asset management process with BIM and ISO19650 Implementation

The information captured in data-enriched BIM Model is gold mine for the asset management team and when correctly integrated as is the case in this project it further improves the overall asset management process. The implementation of ISO 19650 principles implies that information need for operations and maintenance is clearly defined for all parties involved. Which was done by defining the level of information need and ISO 19650 information requirement documents (OIR, AIR and EIR) as described in the project methodology.

Current information management status in the case study (Sonae MC) as shown in Figure 27 involves updating asset information manually in the CMMS (IBM Maximo) or updating an asset information spreadsheet and then uploading into Maximo using an xml query system loading the asset information into Maximo.

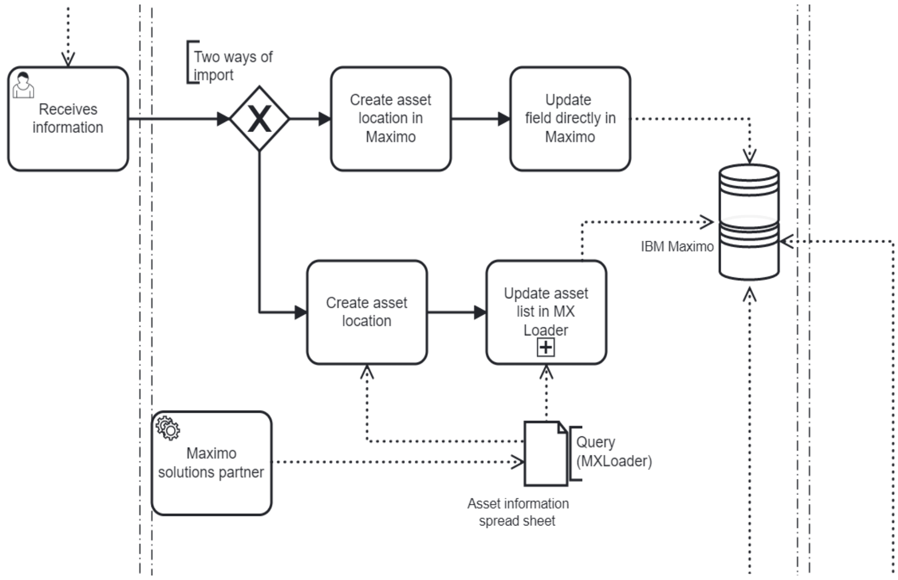


Figure 28 - AS- IS Asset information transfer

The re-engineered asset management system illustrated in Figure 28 shows a different and more efficient information transfer system when compared to Figure 27. The new information transfer process just requires update of geometric information (BIM model) and non-geometric in for COBie. As described in section 5.1.3 COBie information and be updated multiple times within Maximo without duplicating information because every element has a unique identifier which is stored in the Maximo database.

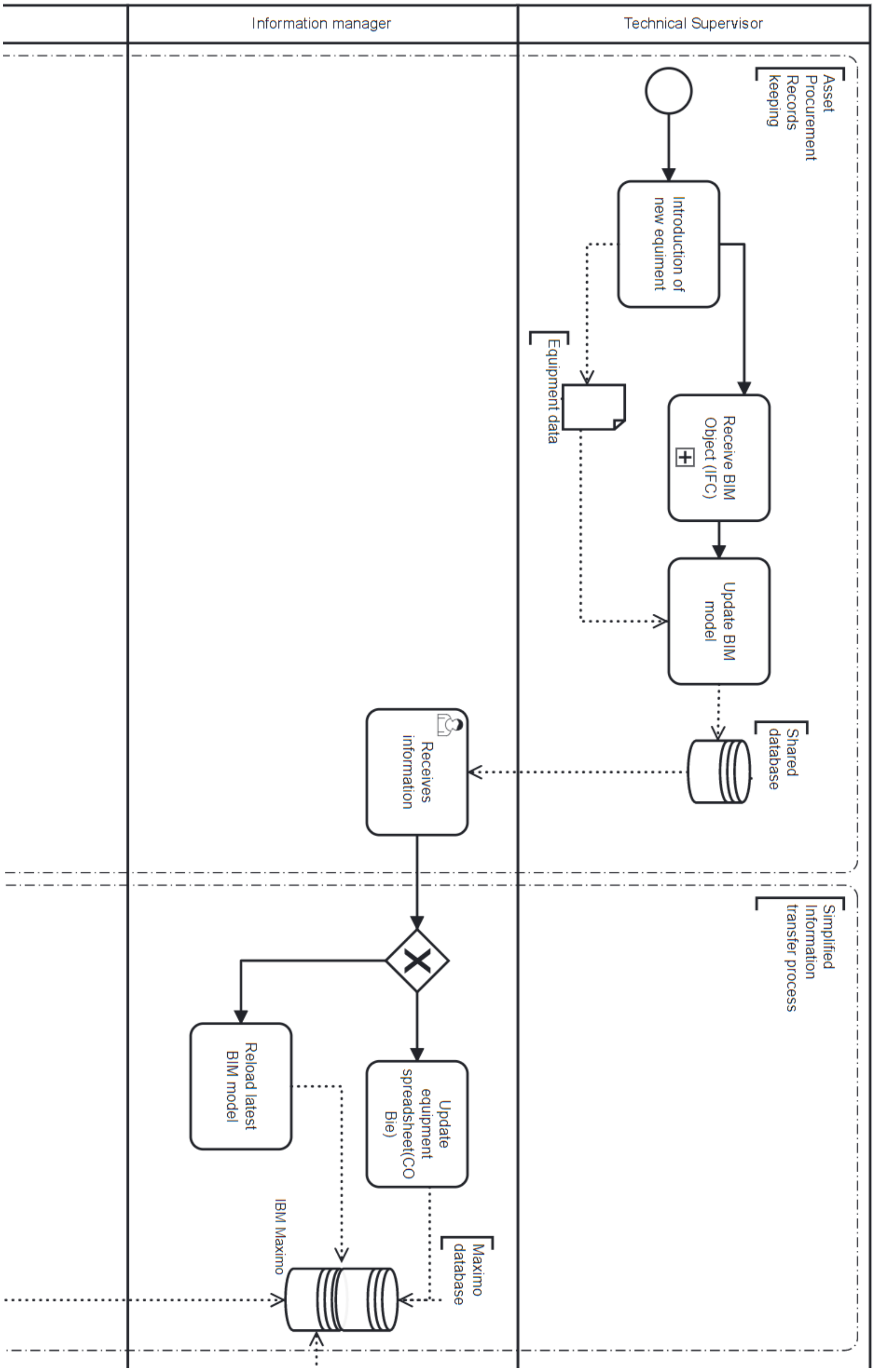


Figure 29 - TO-BE Asset management process (Part 1)

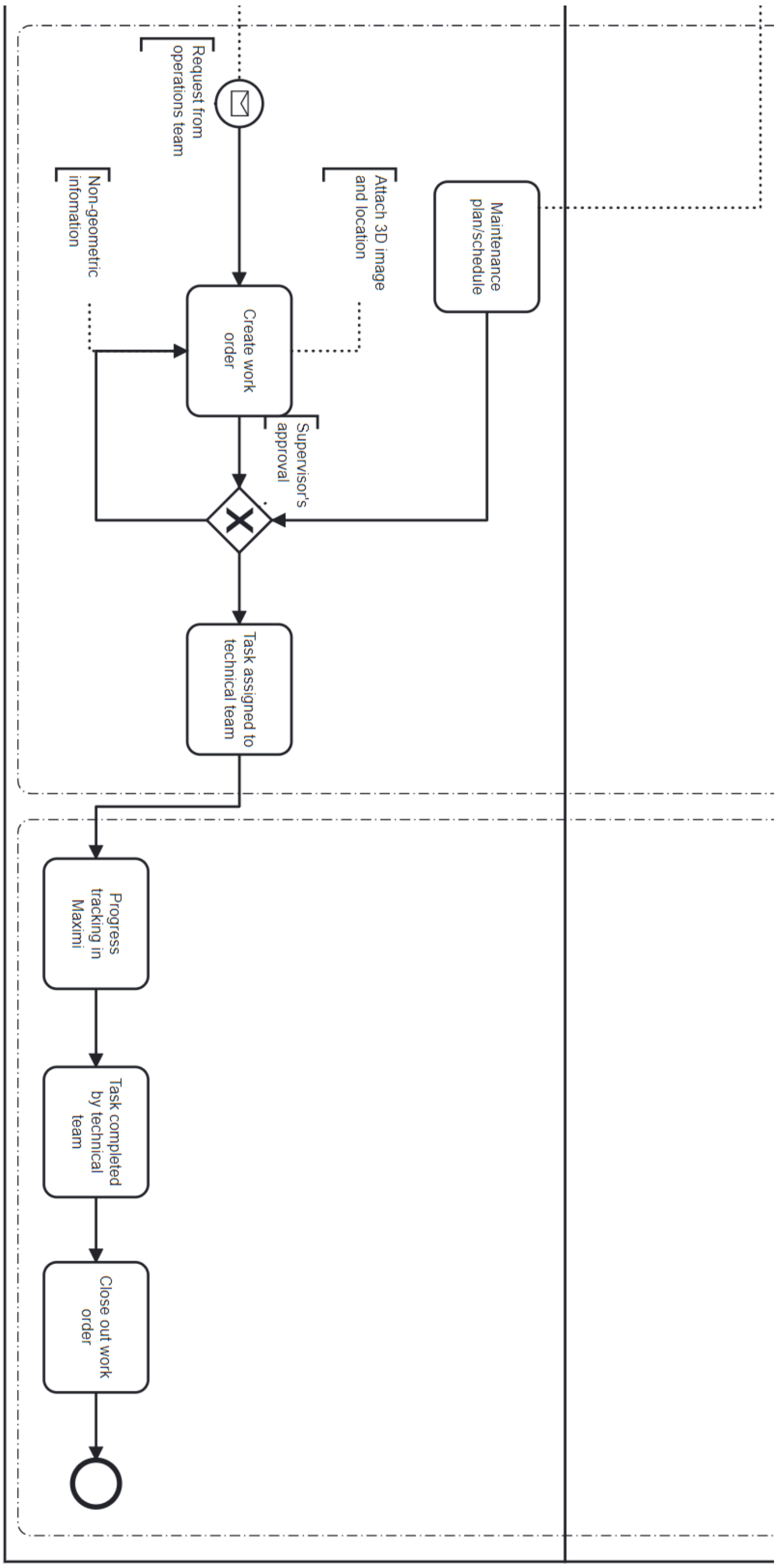


Figure 30: TO-BE Asset management process (Part 2)

5.4. Case study: Sonae MC Asset Management Process

The literature review in section 2.4 has investigated the benefits of BIM in AM for new assets. However, it is of equal importance to investigate how BIM may improve existing structures. The case study Sonae MC was critically studied with the specific case study being a fish processing warehouse. The case study already has a robust asset management system, but it needs to be improved by implementing ISO 19650 information management recommendations. One of the goals of examining the case study is to further understand the steps to full BIM-AM integration for existing building and to understand reasons behind the low adoption rate despite the obvious advantages.

The procedure for implementing BIM will differ from one organisation to another depending on the aims and objectives, the size of the establishment, the time and money invested, the level of BIM expertise, and the resources available.

The improvement in the re-engineered asset management process as shown in Figure 29 & 30 will require some changes. It is recommended that for the TO-BE information management system to be successful that a professional with sufficient knowledge on BIM be a part of the asset management team. The process of asset procurement and record keeping will also require that asset (equipment suppliers), contractors adhere to the information requirements as specified in the EIR.

5.5. Geometric Information Transfer (Autodesk Forge)

One perks that comes with the implementation of ISO19650 framework is having all the advantages that come with visualization in operations and maintenance. For this case study an integration was done with in Maximo and the steps illustrated in Figure 30 were taken to install a BIM viewer in this case Autodesk forge viewer plug. The Forge viewer is a cloud-based viewer. To utilize it in Maximo a subscription from Autodesk is required. The Forge viewer requires a browser that supports WebGL. To install this, assess was needed to work within Maximo database

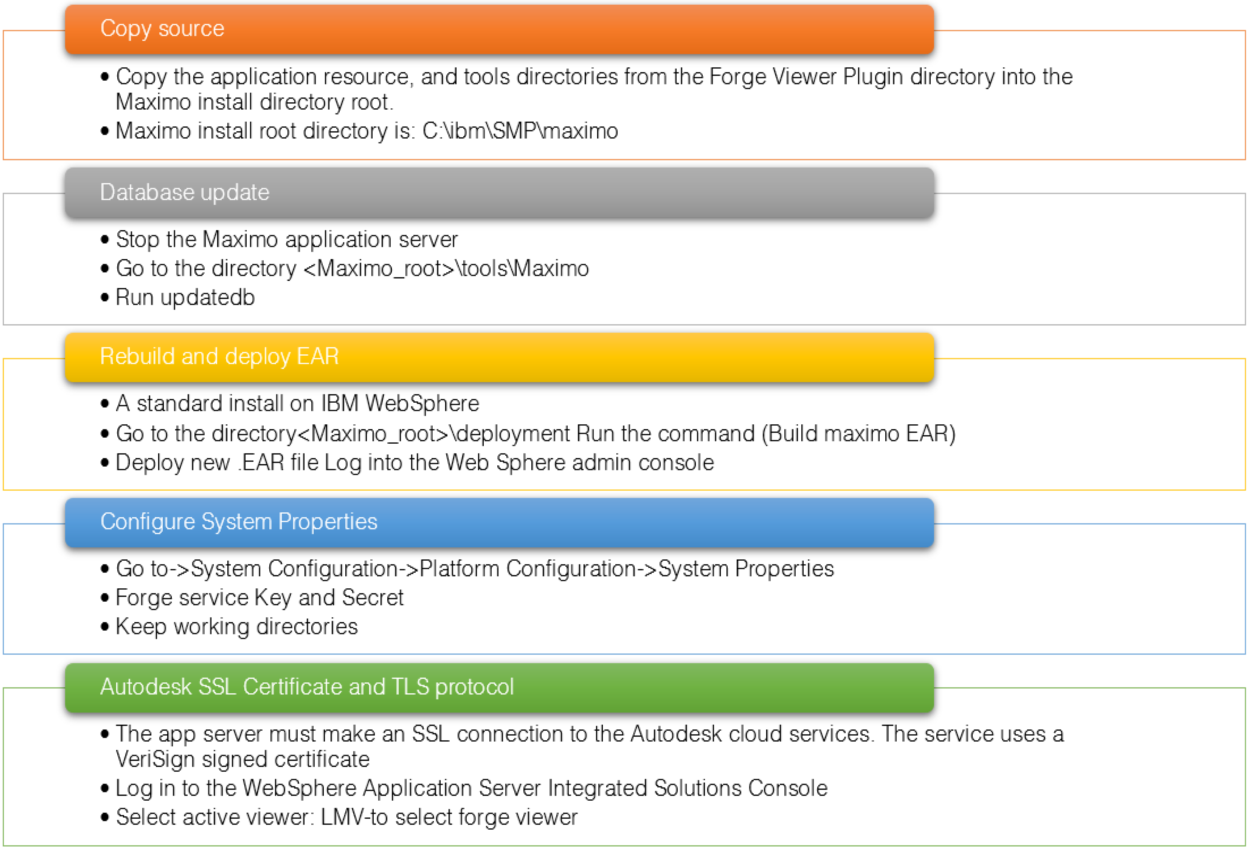


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Figure 31 : Steps to install BIM viewer (Forge) in Maximo

Autodesk Forge can be used with IBM Maximo and other CMMS. It is important to mention that there are, in recent times some CMMS that have in-built BIM viewers; an example is Bexel FM and YouBIM. This software applications are yet to gain wide use in the asset management industry. Traditional asset management software needs to improve their solution by providing software applications that are BIM enabled and accept open formats from the construction industry.

There is need to create a storage bucket to store all the BIM model and CAD drawings. The storage bucket in this case was created using the .NET framework on Visual studio. It can also be created using other platforms. The detailed steps taken to create a storage bucket on Autodesk Forge can be found in Appendix 4.

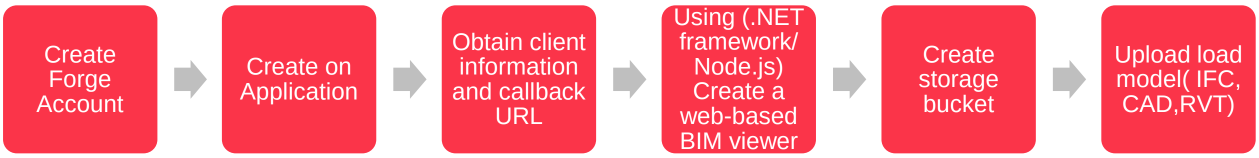

Figure 32: Summary of steps taken to create storage bucket

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6. CONCLUSION

6.1. Conclusions

This study has produced compelling evidence that a BIM integrated asset management system is achievable since it was implemented for a large food distribution company, Sonae MC. Although achievable, it is of importance to note the following conclusions. Due to the isolation between the AEC and the asset management industry which has recently expanded to be called AECO, the asset management team cannot adequately prepare the information requirement and level of information need for BIM models and COBie files, which is a barrier to BIM implementation. The information requirements specified in this study can be used for the operation and maintenance of organisations similar to the case study. The asset management industry is required to have a cultural change and expand their knowledge on building information management in order to harness the data that with from BIM implementation.

One of the conclusions from this research is that more effort must be put into bridging the gap between the AECO industry and the asset management industry in the area of interoperability and naming conventions. The construction industry, through initiatives such as BuildingSMART, has provided interoperable formats relevant to the operation and maintenance stage (IFC and COBie). However, this format is not regularly used by asset management team. Farias et al. (2015) draws our attention to the limitation of the COBie format being in static spreadsheet templates and doubts has been raised about the capability of IFC as a communication protocol in asset management (S. Naghshbandi, 2016). BIM-asset management systems requires bidirectional flow of information using open formats and standardised data mapping.

This research focused on determining the best methods to provide specific data needed by maintenance teams. In addition, it also investigated methods of making data transfers from construction to operations and maintenance. For corrective maintenance, asset managers depend significantly on asset information systems like Computerized Maintenance Management Systems (CMMS). For efficient operation and data transfer during the O&M phase, current asset management information systems lack visualisation and interoperability features. By enhancing interoperability, visualisation, and fragmented data issues, BIM seeks to improve asset management methods. The discussion in the chapter five points out that BIM model kept in open formats like IFC or COBie documentation can be uploaded to a CMMS, in this case IBM Maximo, prior to or during handover, if the asset management team have good knowledge of BIM. The advantage of this integration span from space management, records keeping, fault finding to accurate sustainability analysis planning.

Despite some indicated possible advantages, there are not many concrete evidence and implementation framework approaches, which raises the level of uncertainty. Owners are therefore still faced with the challenge of deciding whether to use BIM based on theoretical benefits. As a result, BIM implementation guidelines that are uniform and flexible such has the research done must be created for organisations of all sizes and industrial sectors. These recommendations must be able to quantify the advantages and take managerial and financial outcome into account.

6.2. Recommendations for Future Developments

One of the limitations of this research is that information transfer was only considered using prevalent data transfer methods such as COBie, IFC and native authoring software formats to determine their compatibility with asset management software (IBM Maximo). Further research should be done to explore other open software solutions such as Information Delivery Manual (IDM), Information Delivery Specification (IDS) and their adaptability to asset management software solutions.

From the conclusions drawn in this dissertation BIM will be always relevant to asset management due to the importance of data in this field. Which brings the question, when do we expect full BIM adoption in the operation and maintenance stage? This dissertation has discussed some of the issues causing low BIM adoption rate in the asset management industry. There is a need to provide evidence of successful BIM implementation in the operation and maintenance stage. This can be tackled by further expanding the research in the BIM-asset management implementation subject area. Frameworks should also define roles, responsibility and contracts.

The dissertation researched into the implementation process and software integration this should be further studied using multiple facilities of various sizes. Construction industry stakeholders have been addressing the structuring of data produced by the AECO industry through formats like IFC and COBie are the primary strategy. Interoperability still remains a grey area in BIM- asset management integration as COBie format with its limitation remains the only open format created solely for information transfer to the operations and maintenance stage. More research on IFC schema usability in asset management similar to the research done by (Shalabi & Turkan, 2017a) should also be expanded.

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LIST OF ACRONYMS AND ABBREVIATIONS

AEC	Architectural, Engineering and Construction
AECO	Architectural, Engineering, Construction and Operations
AIM	Asset Information Model
AIR	Asset Information Requirement
BIM	Building Information Modelling
CAD	Computer Aided Design
CMMS	Computerized Maintenance Management Systems
COBIE	Construction Operations Building Information Exchange
EIR	Exchange Information Requirement
EAM	Enterprise Asset Management
GUID	Global Unique Identifier
ISO	International Organization for Standardization
IFC	Industry Foundation Classes
MEP	Mechanical Electrical and Plumbing
MVD	Model View Definition
NIBS	National Institute of Building Sciences
OIR	Organisational Information Requirement
STEP	Standard for Exchange of Product Data

APPENDICES

APPENDIX 1: LEVEL OF INFORMATION NEED

Architectural and Structural elements

All immovable elements in the architectural and structural model are modelled to have the same geometric information

Architectural and Structural Elements		
Information Delivery Milestone:	Handover of BIM Model	
Purposes/Uses:	Asset Management	
Asset:	Architectural and Structural Elements	Format
Structured Information		
Geometrical Information		
Detail	Wall assembly is represented with overall thickness that accounts for framing and finish specified for the wall system. Wall elements are modelled to specific layouts, locations, heights, and elevation profiles. Penetrations are modelled to nominal dimensions for major wall openings such as windows, doors, and large mechanical elements.	n/a
Dimensionality	3D	
Location	Location defined by space function	
Appearance	Object must have representative colours close to the reality but there is no need for textures.	
Alphanumerical Information		
Identification	Columns	IFC
	Doors	IFC
	Slabs	IFC
	Roofs	IFC
	Stairs	IFC
	Internal walls	IFC
	External walls	IFC
	Insulations	IFC
	Ceilings	IFC
	Windows	IFC

Architectural Equipment

This are all movable elements in the architectural model this group consists mainly of machines and equipment. The geometric level of information of need

Equipment		
Information Delivery Milestone:	Handover	
Purposes/Uses:	Asset management	
Asset:	Equipment/ Machines	Form
Structured Information		
Geometrical Information		
Detail	Modelled as actual size, shape, spacing, and location/connections of equipment, actual size, shape, spacing, and clearances required for all specified anchors, supports, vibration and seismic control that are utilized in the layout of equipment.	n/a
Dimensionality	3D	
Location	Relative Location	
Appearance	For some of the equipment they appear to scale of actual size. Symbolic appearance, with uniform real colour	
Parametric Behaviour		
Asset Information		
Identification	Ice Melter	IFC
	Fish Transport Lines	IFC
	Fish position	IFC
	Ice Production	IFC
	Ice Silo	IFC
	Ice Dispenser	IFC
	Floor Grills	IFC
	Styrofoam Machine	IFC
	Workstations	IFC
	Elevator	IFC
	Pallets	IFC
	Fork-Lifts	IFC
	Truck Doors	IFC

Hydraulic Network

This are all elements in along the pipe network this group consists mainly pipes, pipe fittings and valves. The geometric level of information of need is descried in the table below.

Hydraulic System Network		
Information Delivery/Milestone:	Handover	
Purposes/Uses:	Asset management	
Asset:	Hydraulic Network Elements	Format
Structured Information		
Geometrical Information		
Detail	Modelled as design-specified size, shape, spacing, location, and slope of pipe, valves, fittings, and insulation for risers, mains, and branches. Approximate allowances for spacing and clearances required for all specified hangers, supports, vibration and seismic control that are to be utilized in the layout of all risers, mains, and branches. (LOD 300)	n/a
Dimensionality	3D	
Location	Relative Location	
Appearance	Object must have representative colours close to the reality but there is no need for textures	
Asset Information		
Identification	Cold pipes	IFC
	Hot pipes	IFC
	Check Valves	IFC
	Pipe fittings	IFC
	Isolation valves	IFC
	Pressure gauge	IFC
	Water meter	IFC
	Pressure relief valves	IFC

Hydraulic Equipment

This are all elements in along the pipe network this group consists mainly pipes, pipe fittings and valves. The geometric level of information of need is descried in the table below.

Hydraulic System Equipment		
Information Delivery Milestone:	Handover	
Purposes/Uses:	Asset management	
Asset:	Equipment/ Machines	Format
Structured Information		
Geometrical Information		
Detail	Modelled as design-specified size, shape, spacing, and location of fixtures.. Approximate allowances for spacing and clearances required for all specified supports that are to be utilized in the layout of all fixtures.	n/a
Dimensionality	3D	
Location	Relative Location	
Appearance	The hydraulic equipment is represented as BIM object. Object must have representative colors close to the reality but there is no need for textures.	
Parametric Behaviour		
Asset List		
Identification	Tanks	IFC
	Pumps	IFC
	Water heaters	IFC
	Wash-hand basins	IFC
	Eyewash stands	IFC
	Bibedora/ Water dispensers	IFC
	Manguiera/ Wash hose stand	IFC
	Showers	IFC
	Water closet	IFC
	Soap dispensers	IFC

HVAC System Network

HVAC System Network		
Information Delivery Milestone:	Handover	
Purposes/Uses:	Asset management	
Asset:	HVAC Network Elements	Format
Structured Information		
Geometrical Information		
Geometrical Information	Modelled as design-specified size, shape, spacing, location, and slope of ducts, pipe, valves, fittings, and insulation for risers, mains, and branches. Approximate allowances for spacing and clearances required for all specified hangers, supports, vibration and seismic control that are to be utilized in the layout of all risers, mains, and branches.	n/a
Dimensionality	3D	
Location	Relative Location	
Appearance	Object must have representative colours close to the reality but there is no need for textures	
Asset Information		
Identification	Non-insulated ducts	IFC
	Flexible duct	IFC
	Dampers	IFC
	Condensate pipe	IFC
	Isolation valves	IFC
	Condensate pipe fittings	IFC
	Insulated ducts	IFC
	Duct fittings	IFC

HVAC Equipment Level of Information Need

HVAC Equipment		
Information Delivery Milestone:	Handover	
Purposes/Uses:	Asset management	
Asset:	Equipment/ Machines	Format
Structured Information		
Geometrical Information		
Detail	Modelled as design-specified size, shape, spacing, and location of fixtures. Approximate allowances for spacing and clearances required for all specified supports that are to be utilized in the layout of all fixtures.	n/a
Dimensionality	3D	
Location	Relative Location	
Appearance	The hydraulic equipment is represented as BIM object. Object must have representative colours close to the reality but there is no need for textures.	
Parametric Behaviour		
Alphanumerical Information		
Identification	UTA - Air Handling Unit	IFC
	UTAN - Fresh Air Handing Unit	IFC
	Chillers	IFC
	Splits Units	IFC
	Grills	IFC
	Evaporator	IFC
	Fans	IFC
	Diffusers	IFC
	Extractor fans	IFC
	Fan coil unit	IFC

Fire-fighting Network Level of Information Need

<table>
<tr><th colspan="3">Fire-fighting Network</th></tr>
<tr><td>Information Delivery Milestone:</td><td colspan="2">Handover</td></tr>
<tr><td>Purposes/Uses:</td><td colspan="2">Asset management</td></tr>
<tr><td>Asset:</td><td>Fire Network Elements</td><td>Format</td></tr>
<tr><td colspan="3">Structured Information</td></tr>
<tr><td colspan="3">Geometrical Information</td></tr>
<tr><td>Geometrical Information</td><td>Modelled as design-specified size, shape, spacing, location, and slope of ducts, pipe, valves, fittings, and insulation for risers, mains, and branches. Approximate allowances for spacing and clearances required for all specified hangers, supports, vibration and seismic control that are to be utilized in the layout of all risers, mains, and branches.</td><td rowspan="4">n/a</td></tr>
<tr><td>Dimensionality</td><td>3D</td></tr>
<tr><td>Location</td><td>Relative Location</td></tr>
<tr><td>Appearance</td><td>Object must have representative colour (Red) close to the reality but there is no need for textures</td></tr>
<tr><td colspan="3">Asset Information</td></tr>
<tr><td rowspan="8">Identification</td><td>Iron pipes</td><td>IFC</td></tr>
<tr><td>Pipe fittings</td><td>IFC</td></tr>
<tr><td>Flanges</td><td>IFC</td></tr>
<tr><td>Gate valves</td><td>IFC</td></tr>
<tr><td>Sprinklers</td><td>IFC</td></tr>
<tr><td>Pressure relief valve</td><td>IFC</td></tr>
<tr><td>Pressure gauge</td><td>IFC</td></tr>
<tr><td>Pipe accessories</td><td>IFC</td></tr>
</table>

Fire-fighting Equipment Level of Information Need

Fire-fighting Equipment		
Information/Delivery Milestone:	Handover	
Purposes/Uses:	Asset management	
Asset:	Equipment/ Machines	Format
Structured Information		
Geometrical Information		
Detail	Modelled as design-specified size, shape, spacing, and location of fixtures. Approximate allowances for spacing and clearances required for all specified supports that are to be utilized in the layout of all fixtures.	n/a
Dimensionality	3D	
Location	Relative Location	
Appearance	The Fire-fighting equipment are represented as BIM object. Object must have representative colours close to the reality but there is no need for textures.	
Parametric Behaviour		
Alphanumerical Information		
Identification	Fire pumps	IFC
	Fire hose reel	IFC
	Fire extinguisher	IFC
	Fire hydrants	IFC
	Spools	IFC
	Tanks	IFC
	Water meters	IFC
	Fire assembly	IFC
	Fire blankets	IFC

Refrigerating (COLD) Network Level of Information Need

Refrigerating System Network (COLD)		
Information Delivery Milestone:	Handover	
Purposes/Uses:	Asset management	
Asset:	Cold Network Elements	Format
Structured Information		
Geometrical Information		
Detail	Modelled as design-specified size, shape, spacing, location, and slope of pipe, valves, fittings, and insulation for risers, mains, and branches. Approximate allowances for spacing and clearances required for all specified hangers, supports, vibration and seismic control that are to be utilized in the layout of all risers, mains, and branches.	n/a
Dimensionality	3D	
Location	Relative Location	
Appearance	Object must have representative colours close to the reality but there is no need for textures	
Asset Information		
Identification	Check Valves	IFC
	Pipe fittings	IFC
	Metal pipe	IFC
	Condensate pipe	IFC
	Isolation valves	IFC
	Condensate pipe fittings	IFC
	Duct fittings	IFC
	Insulated ducts	IFC
	Isolation valves	IFC
	Pressure gauge	IFC
	Pressure relief valves	IFC

Refrigerating (COLD) Equipment Level of Information Need

Refrigerating System (COLD)		
Information Delivery Milestone:	Handover	
Purposes/Uses:	Asset management	
Asset:	Equipment/ Machines	Format
Structured Information		
Geometrical Information		
Geometrical Information	Modelled as design-specified size, shape, spacing, and location of equipment; dampers, fittings, insulation for risers, mains, and branches; approximate specified allowances for spacing and clearances approximate allowances for spacing and clearances required for all specified anchors, supports, vibration and seismic control that are utilized in the layout of equipment;	n/a
Dimensionality	3D	
Location	Relative Location	
Appearance	Object must have representative colours close to the reality but there is no need for textures	
Asset Information		
Identification	Compressors	IFC
	Evaporators	IFC
	Ventilators	IFC
	Heat exchangers	IFC
	Motors	IFC
	Temperature sensors	IFC
	Chillers	IFC
	Actuators	IFC
	Gas Tanks	IFC
	Electrical boards	IFC
	Liquid Depositors	IFC

Sanitation Network Level of Information Need

Sanitation Network		
Information/Delivery Milestone:	Handover	
Purposes/Uses:	Asset management	
Asset:	Sanitation Network Elements	Format
Structured Information		
Geometrical Information		
Detail	Modelled as design-specified size, shape, spacing, location, and slope of pipe, valves, fittings, and insulation for risers, mains, and branches. Approximate allowances for spacing and clearances required for all specified hangers, supports, vibration and seismic control that are to be utilized in the layout of all risers, mains, and branches. (LOD 300)	n/a
Dimensionality	3D	
Location	Relative Location	
Appearance	Object must have representative colors close to the reality but there is no need for textures	
Asset Information		
Identification	Drain pipes	IFC
	Vents	IFC
	Pipe fittings	IFC
	Isolation valves	IFC
	Floor drains	IFC
	Gutters	IFC
		IFC

Sanitation Equipment Level of Information Need

Sanitation System Equipment		
Information Delivery Milestone:	Handover	
Purposes/Uses:	Asset management	
Asset:	Equipment/ Machines	Format
Structured Information		
Geometrical Information		
Geometrical Information	Modelled as design-specified size, shape, spacing, location, and slope of ducts, pipe, valves, fittings, and insulation for risers, mains, and branches. Approximate allowances for spacing and clearances required for all specified hangers, supports, vibration and seismic control that are to be utilized in the layout of all risers, mains, and branches.	n/a
Dimensionality	3D	
Location	Relative Location	
Appearance	Object must have representative colours close to the reality but there is no need for textures	
Asset Information		
	Filters	IFC
	Sanitation boxes	IFC
	Oil separators	IFC
	Pumps	IFC
	Hydrocarbon separator	IFC
	Wastewater treatment plant	IFC

Rainwater System Level of Information Need

Rainwater System		
Information/Delivery Milestone:	Handover	
Purposes/Uses:	Asset management	
Asset:	Elements	Format
Structured Information		
Geometrical Information		
Geometrical Information	Modelled as design-specified size, shape, spacing, location, and slope of ducts, pipe, valves, fittings, and insulation for risers, mains, and branches. Approximate allowances for spacing and clearances required for all specified hangers and supports.	n/a
Dimensionality	3D	
Location	Relative Location	
Appearance	Object must have representative colors close to the reality but there is no need for textures	
Asset Information		
Identification	Pipes	IFC
	Pipe accessories	IFC
	Gutters	IFC
	Floor drains	IFC
	Vents	IFC

Electrical System Level of Information Need

Electrical System		
Information Delivery Milestone:	Handover	
Purposes/Uses:	Asset management	
Asset:	Equipment/ Elements	Format
Structured Information		
Geometrical Information		
Geometrical Information	Modelled as design-specified size, shape, spacing, location, and slope of ducts, pipe, valves, fittings, and insulation for risers, mains, and branches. Approximate allowances for spacing and clearances required for all specified hangers, supports, vibration and seismic control that are to be utilized in the layout of all risers, mains, and branches. (LOD 300)	n/a
Dimensionality	3D	
Location	Relative Location	
Appearance	Object must have representative colors close to the reality but there is no need for textures	
Asset Information		
Identification	Electrical cables	IFC
	Conduit	IFC
	Cable trays	IFC
	Lighting fixtures	IFC
	Electrical outlets	IFC
	Electrical Distribution board	IFC
	Transformers	IFC
	Lighting arrestor	IFC
	Micro controllers	IFC

APPENDIX 2: PROPERTY DATA TEMPLATES

Architectural Element Data Template

ARCHITECTURAL ELEMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Name/Description	Properties Identity Data	IBM Maximo Asset. Description	Text	n/a	Free text to describe product
Material		-	Text	n/a	General material assignment
Omniclass Classification		-	Character	n/a	Construction classification system
Finish		-	Text	n/a	If available (outer coat material)
Gross Weight	Dimensional data		Integer	Kg	Suggested weight supplied by manufacturer
Height			Integer	m	Height from FFL (manufacturer supplied)
Area			Integer	m^2	Contact surface area
Volume			Integer	m^3	Volume supplied by manufacturer (space requirement)
Model Reference/Number	Manufacturer's data	IBM Maximo Asset.EQ1	Character	n/a	Manufacturer equipment identity number
Model Label			Character	n/a	If available Manufacturer model class
Manufacturer		IBM Maximo Asset. Vendor	Text	n/a	Manufacturer name
Manufacturer URL			URL	n/a	URL to technical details, e.g., system flow rates, pressure drop curves
Serial Number		IBM Maximo Asset. Serialnum	Integer	n/a	Serial number manufacturer provided (if available)
Service Life Duration	Warranty Data		Integer	Yrs	Expected service life (manufacturer supplied)
Installation Date		IBM Maximo Asset.Install Date	Character	n/a	Date of installation/first use
Mean Time Between failure			Integer	Min	Maximum time before maintenance (manufacturer supplied)
Warranty ID			Character	n/a	Warranty identity number (manufacturer supplied)
Warranty Start Date			Character	n/a	Warranty start date (manufacturer supplied)
Is Extended Warranty			Boolean	n/a	Information on if warranty is extendible Y/N (manufacturer supplied)
Warranty Period			Integer	Yrs	Warranty validity period (manufacturer supplied)
Product data sheet	Product specific data		PDF	n/a	Product data sheet (manufacturer supplied)
Product URL			URL	n/a	Specific product URL (if available)
Production Year		IBM Maximo Asset.EQ3	Integer	n/a	Year of production (IBM Fabrication Year)
Location		IBM Maximo Asset. Location	Character	n/a	Location based on(Client classification)
IBM Maximo Asset.EQ4	IBM Maximo	-	Text	n/a	IBM Maximo Equipment Classification
IBM Maximo Asset.EQ2		-	Character	n/a	IBM Acquisition Year
IBM Maximo Asset. Priority		-	Character	n/a	IBM Maximo priority of the equipment
BIM Maximo Asset. Total Cost		-	Integer	€	IBM Maximo cost total of acquisition

Architectural Equipment Data Template

ARCHITECTURAL EQUIPMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Name/Description	Properties Identity Element	IBM Maximo Asset. Description	Character	n/a	Free text to describe product
Material			Text	n/a	General material assignment
Uniclass2015 Classification			Character	n/a	Construction classification system
Gross Weight	Dimensional data		Integer	Kg	Suggested weight supplied by manufacturer
Height			Integer	m	Height from FFL (manufacturer supplied)
Area			Integer	m^2	Contact surface area
Volume			Integer	m^3	Volume supplied by manufacturer (space requirement)
Asset Type (Fixed/Moveable)	Manufacturer's data		Boolean	Product	Classify equipment mobility
Model Reference/Number		IBM Maximo Asset.EQ1	Character	n/a	Manufacturer equipment identity number
Model Label			Character	n/a	(If available) Manufacturer model class
Manufacturer		IBM Maximo Asset. Vendor	Text	n/a	Manufacturer name
Manufacturer URL			URL	n/a	URL to technical details, e.g. system flow rates, pressure drop curves
Production Year		IBM Maximo Asset.EQ3	Integer	n/a	Year of production
Serial Number		IBM Maximo Asset. Serialnum	Integer	n/a	Serial number manufacturer provided (if available)
Service Life Duration	Warranty Data		Integer	Yrs	Expected service life (manufacturer supplied)
Installation Date		IBM Maximo Asset. Install Date	Character	n/a	Date of installation/use
Mean Time Between Failure			Integer	Min	Maximum time before maintenance (manufacturer supplied)
Warranty ID			Character	n/a	Warranty identity number (manufacturer supplied)
Warranty Start Date			Character	n/a	Warranty starts date (manufacturer supplied)
Warranty End Date			Character	n/a	Warranty end date (manufacturer supplied)
Extended Warranty			Character	n/a	Information on if warranty is extendible Y/N (manufacturer supplied)
Warranty Period			Integer	Yrs	Warranty validity period (manufacturer supplied)
Location	Product Specific data	IBM Maximo Asset. Location	Character	n/a	Location based on(Client classification)
Product data sheet		-	URL	n/a	Hyperlink to product data sheet (manufacturer supplied)
Operation and Maintenance manual		-	URL	n/a	Hyperlink to Manufacturer O&M Data (if applicable)
Product data sheet		-	PDF	n/a	Product data sheet (manufacturer supplied)
Product URL		-	URL	n/a	Specific product URL (if available)
Voltage	Electrical Data	-	Integer	Volts	Electrical voltage information
Supply Phase		-	Integer	Num	Electrical phase(1,3)
Frequency		-	Integer	Herts	Electrical frequency in Hz
Maximum Power Consumption		-	Integer	Watts	Max. power consumption (manufacturer supplied)
Minimum Power Consumption		-	Integer	Watts	Min. power consumption (manufacturer supplied)
Full Load Current		-	Float	Amps	Electrical current requirement
Fuse Rating		-	Integer	Amps	Safety fuse rating

ARCHITECTURAL EQUIPMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Total Primary Energy Consumption Per Unit	Sustainability Data	-	Integer	Joules	Equipment energy consumption
Water Consumption Per Unit		-	Integer	L	Water consumption in liters (if applicable)
Hazardous Waste Per Unit		-	Integer	kg	Weight of hazardous waste if produced
Embodied Carbon		-	Float	kgCO	Equipment embodied carbon footprint
Environmental Product Declaration		-	Text	n/a	Environmental declaration information
Acquisition Cost	Cost Data	IBM Maximo Asset. Total Cost	Integer	€	Equipment cost information
IBM Maximo Asset.EQ4	IBM Maximo Data	-	Text	n/a	IBM Maximo Equipment Classification
IBM Maximo Asset.EQ2		-	Character	n/a	IBM Acquisition Year
IBM Maximo Asset. Priority		-	Character	n/a	IBM Maximo priority of the equipment

Hydraulic Network Data Template

HYDRAULICS NETWORK DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Name/Description	Properties Identity Element	IBM Maximo Asset. Description	Text	n/a	Free text to describe product
Omniclass Classification			Character	n/a	Construction classification system
Pipe material			Text	n/a	Pipe material
Insulation	Product Specific data	-	Boolean	n/a	If pipe is insulated or non-insulated
Pipe schedule		-	Character	n/a	Pipe classification based on pipe thickness
Location		IBM Maximo asset. Location	Character	n/a	Location based on(Client classification)
Product data sheet		-	URL	n/a	Hyperlink to product data sheet (manufacturer supplied)
Operation and Maintenance manual		-	URL	n/a	Hyperlink to Manufacturer O&M Data (if applicable)
Product data sheet		-	PDF	n/a	Product data sheet (manufacturer supplied)
Product URL		-	URL	n/a	Specific product URL (if available)
Nominal diameter	Dimensional data	-	Float	mm	Nominal diameter as provided in data sheet
External diameter		-	Float	mm	Measurement of external diameter
Internal diameter		-	Float	mm	Measurement of internal diameter
Insulation thickness		-	Float	mm	Measurement of insulation thickness in mm
Length		-	Float	mm	Measurable pipe length
Asset Type (Fixed/Moveable)	Manufacturer's data		Boolean	Product	Classify equipment mobility
Model Reference/Number		IBM Maximo Asset.EQ1	Character	n/a	Manufacturer equipment identity number
Model Label			Character	n/a	(If available) Manufacturer model class
Manufacturer		IBM Maximo Asset. Vendor	Text	n/a	Manufacturer name
Manufacturer URL		-	URL	n/a	URL to technical details, e.g. system flow rates, pressure drop curves
Production Year		IBM Maximo Asset.EQ3	Integer	n/a	Year of production
Serial Number		IBM Maximo Asset. Serialnum	Integer	n/a	Serial number manufacturer provided (if available)
Service Life Duration	Warranty Data		Integer	Yrs	Expected service life (manufacturer supplied)
Installation Date		IBM Maximo Asset. Install Date	Character	n/a	Date of installation/first use
Mean Time Between Failure			Integer	Min	Maximum time before maintenance (manufacturer supplied)
Warranty ID			Character	n/a	Warranty identity number (manufacturer supplied)
Warranty StartDate			Character	n/a	Warranty start date (manufacturer supplied)
Warranty End Date			Character	n/a	Warranty end date (manufacturer supplied)
Extended Warranty			Character	n/a	Information on if warranty is extendible Y/N (manufacturer supplied)
Warranty Period			Integer	Yrs	Warranty validity period (manufacturer supplied)
Embodied Carbon	Environmental Impact Data		Integer	kgCO	Equipment embodied carbon footprint
Environmental Product Declaration			Text	n/a	Environmental declaration information
Acquisition Cost	Cost Data	BIM Maximo Asset. Total Cost	Integer	€	Equipment cost information
IBM Maximo Asset.EQ4	IBM Maximo Data	-	Text	n/a	IBM Maximo Equipment Classification
IBM Maximo Asset.EQ2		-	Character	n/a	IBM Acquisition Year
IBM Maximo Asset. Priority		-	Character	n/a	IBM Maximo priority of the equipment

Hydraulic Equipment Data Template

HYDRAULICS EQUIPMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Name/Description	Properties Identity Element	IBM Maximo Asset. Description	Charac ter	n/a	Free text to describe product
Material			Text	n/a	General material assignment
Omniclass Classification			Charac ter	n/a	Construction classification system
Asset Type (Fixed/Moveable)	Product Specific data		Boolea n	n/a	Classify equipment mobility
PN Rating			Text	n/a	Normal working pressure rating
Colour			Text	n/a	colour of external coating (if applicable)
Installation Date		IBM Maximo Asset. Install Date	Charac ter	n/a	Date of installation/first use
Insulation		-	Boolea n	n/a	If pipe is insulated or non-insulated
Location		IBM Maximo Asset. Location	Charac ter	n/a	Location based on (Client classification)
Product data sheet		-	URL	n/a	Hyperlink to product data sheet (manufacturer supplied)
Asset Type (Fixed/Moveable)	Manufacturer's data		Boolea n	Prod uct	Classify equipment mobility
Model Reference/Number		IBM Maximo Asset.EQ1	Charac ter	n/a	Manufacturer equipment identity number
Model Label			Charac ter	n/a	(If available) Manufacturer model class
Manufacturer		IBM Maximo Asset. Vendor	Text	n/a	Manufacturer name
Manufacturer URL		-	URL	n/a	URL to technical details, e.g. system flow rates, pressure drop curves
Production Year		IBM Maximo Asset.EQ3	Integer	n/a	Year of production
Serial Number		IBM Maximo Asset. Serialnum	Integer	n/a	Serial number manufacturer provided (if available)
Overall Width	Dimensional Data		Integer	mm	Measurement of external width/wideness of equipment
Overall Height			Integer	mm	Measurement of overall height of equipment
Gross Weight			Integer	kg	Equipment weight in kg
Hot Inlet diameter			Integer	mm	Hot water inlet diameter (If applicable)
Cold Inlet diameter			Integer	mm	Cold water inlet diameter
Outlet diameter			Integer	mm	Outlet diameter in mm
Service Life Duration	Warranty Data		Integer	Yrs	Expected service life (manufacturer supplied)
Installation Date		IBM Maximo Asset. Install Date	Charac ter	n/a	Date of installation/first use
Mean Time Between Failure			Integer	Min	Maximum time before maintenance (manufacturer supplied)
Warranty ID			Charac ter	n/a	Warranty identity number (manufacturer supplied)
Warranty Start Date			Charac ter	n/a	Warranty start date (manufacturer supplied)
Warranty End Date			Charac ter	n/a	Warranty end date (manufacturer supplied)
Extended Warranty			Charac ter	n/a	Information on if warranty is extendible Y/N (manufacturer supplied)
Warranty Period			Integer	Yrs	Warranty validity period (manufacturer supplied)
Total Primary Energy Consumption Per Unit	Sustainability Data	-	Integer	Joule s	Equipment energy consumption
Water Consumption Per Unit		-	Integer	L	Water consumption in litres (if applicable)

HYDRAULICS EQUIPMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Hazardous Waste Per Unit		-	Integer	kg	Weight of hazardous waste if produced
Embodied Carbon		-	Float	kgCO	Equipment embodied carbon footprint
Environmental Product Declaration		-	Text	n/a	Environmental declaration information
Acquisition Cost	Cost Data	IBM Maximo Asset. Total Cost	Integer	€	Equipment cost information
Operating Pressure	Performance data		Integer	kPa	Optimum operating temperature as provided by manufacturers
Operating Temperature			Integer	degC	Recommended operating temperature
Maximum Pressure			Integer	kPa	Maximum allowable working pressure
Nominal Capacity			Integer	Litres	water storage capacity in Liters
Effective Capacity			Integer	Litres	optimum working storage capacity
Voltage	Electrical Data	-	Integer	Volts	Electrical voltage information
Supply Phase		-	Integer	Num	Electrical phase(1,3)
Frequency		-	Integer	Herts	Electrical frequecy in Hz
Maximum Power Consumption		-	Integer	Watts	Max. power consumption(manufacturer supplied)
Minimum Power Consumption		-	Integer	Watts	Min. power consumption(manufacturer supplied)
Full Load Current		-	Float	Amps	Electrical current requirement
Fuse Rating		-	Integer	Amps	Safety fuse rating
BMS Links	Control		Boolean	Y/N	Connected to building management system or not?
Temperature sensor			Boolean	Y/N	Is temperature sensor present?
Control valves			Boolean	Y/N	Are pressure control valves present?
IBM Maximo Asset.EQ4	IBM Maximo Data	-	Text	n/a	IBM Maximo Equipment Classification
IBM Maximo Asset.EQ2		-	Character	n/a	IBM Acquisition Year
IBM Maximo Asset. Priority		-	Character	n/a	IBM Maximo priority of the equipment

HVAC Network Data Template

HVAC NETWORK DATA TEMPLATE					
Property Name	**Property set**	**IBM Maximo**	**Data Type**	**Unit**	**Notes**
Name/Description	Properties Identity Element	IBM Maximo Asset. Description	Text	n/a	Free text to describe product
Omni class Classification			Character	n/a	Construction classification system
Duct shape/type			Text	n/a	Duct shape or characteristics (flexible, vaned)
Duct size			Text	n/a	Duct size as given by manufacturer
Duct material			Text	n/a	Duct material
Insulation	Product Specific data	-	Boolean	n/a	If pipe is insulated or non-insulated
Insulation material		-	Text	n/a	Duct insulation material
Location		IBM Maximo asset. Location	Character	n/a	Location based on (Client classification)
Duct capacity			Integer	cm^3/s or ft^3/s	Maximum allowable air flow speed
Temperature range			Integer	^0C	Minimum and maximum duct working temperature
Pressure rating			Integer	kPa	Duct maximum pressure rating in kilopascal
Product data sheet		-	URL	n/a	Hyperlink to product data sheet (manufacturer supplied)
Duct diameter	Dimensional data	-	Float	mm	Nominal diameter as provided in data sheet
Duct width		-	Float	mm	Measurement of rectangular duct width
Duct length		-	Float	mm	Measurement of rectangular duct length
Insulation thickness		-	Float	mm	Measurement of insulation thickness in mm
Length		-	Float	mm	Measurable duct length
Asset Type (Fixed/Moveable)	Manufacturer’s data		Boolean	Product	Classify equipment mobility
Model Reference/Number		IBM Maximo Asset.EQ1	Character	n/a	Manufacturer equipment identity number
Model Label			Character	n/a	(If available) Manufacturer model class
Manufacturer		IBM Maximo Asset. Vendor	Text	n/a	Manufacturer name
Manufacturer URL		-	URL	n/a	URL to technical details, e.g. system flow rates, pressure drop curves
Production Year		IBM Maximo Asset.EQ3	Integer	n/a	Year of production
Serial Number		IBM Maximo Asset. Serialnum	Integer	n/a	Serial number manufacturer provided (if available)
Service Life Duration	Warranty Data		Integer	Yrs	Expected service life (manufacturer supplied)
Installation Date		IBM Maximo Asset. Install Date	Character	n/a	Date of installation/first use
Mean Time Between Failure			Integer	Min	Maximum time before maintenance(manufacturer supplied)
Warranty ID			Character	n/a	Warranty identity number (manufacturer supplied)
Warranty Start Date			Character	n/a	Warranty start date (manufacturer supplied)
Warranty End Date			Character	n/a	Warranty end date (manufacturer supplied)
Extended Warranty			Character	n/a	Information on if warranty is extendible Y/N (manufacturer supplied)
Warranty Period			Integer	Yrs	Warranty validity period

HVAC NETWORK DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
					(manufacturer supplied)
Embodied Carbon	Environmental Impact Data		Integer	kgCO	Equipment embodied carbon footprint
Environmental Product Declaration			Text	n/a	Environmental declaration information
Acquisition Cost	Cost Data	BIM Maximo Asset. Total Cost	Integer	€	Equipment cost information
IBM Maximo Asset.EQ4	IBM Maximo Data	-	Text	n/a	IBM Maximo Equipment Classification
IBM Maximo Asset.EQ2		-	Character	n/a	IBM Acquisition Year
IBM Maximo Asset. Priority		-	Character	n/a	IBM Maximo priority of the equipment

HVAC Equipment Data Template

HVAC EQUIPMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Name/Description	Properties Identity Element	IBM Maximo Asset. Description	Character	n/a	Free text to describe product
Material			Text	n/a	General material assignment
Omniclass Classification			Character	n/a	Construction classification system
Asset Type (Fixed/Moveable)	Product Specific data		Boolean	n/a	Classify equipment mobility
Colour			Text	n/a	Colour of external coating (if applicable)
Installation Date		IBM Maximo Asset. InstallDate	Character	n/a	Date of installation/first use
Insulation		-	Boolean	n/a	If pipe is insulated or non-insulated
Location		IBM Maximo Asset .Location	Character	n/a	Location based on(Client classification)
Product data sheet		-	URL	n/a	Hyperlink to product data sheet (manufacturer supplied)
Asset Type (Fixed/Moveable)	Manufacturer's data		Boolean	Product	Classify equipment mobility
Model Reference/Number		IBM Maximo Asset.EQ1	Character	n/a	Manufacturer equipment identity number
Model Label			Character	n/a	(If available) Manufacturer model class
Manufacturer		IBM Maximo Asset. Vendor	Text	n/a	Manufacturer name
Manufacturer URL		-	URL	n/a	URL to technical details, e.g. system flow rates, pressure drop curves
Production Year		IBM Maximo Asset.EQ3	Integer	n/a	Year of production
Serial Number		IBM Maximo Asset. Serialnum	Integer	n/a	Serial number manufacturer provided (if available)
Overall Width	Dimensional Data		Integer	mm	Measurement of external width/wideness of equipment
Overall Height			Integer	mm	Measurement of overall height of equipment
Gross Weight			Integer	kg	Equipment weight in kg
Inlet diameter			Integer	mm	Cold water inlet diameter
Outlet diameter			Integer	mm	Outlet diameter in mm
Fan diameter			Integer	mm	Fan diameter in mm
Service Life Duration	Warranty Data		Integer	Yrs	Expected service life (manufacturer supplied)
Installation Date		IBM Maximo Asset. InstallDate	Character	n/a	Date of installation/first use
Mean Time Between Failure			Integer	Min	Maximum time before maintenance(manufacturer supplied)
Warranty ID			Character	n/a	Warranty identity number (manufacturer supplied)
Warranty Start Date			Character	n/a	Warranty start date (manufacturer supplied)
Warranty End Date			Character	n/a	Warranty end date (manufacturer supplied)
Extended Warranty			Character	n/a	Information on if warranty is extendible Y/N (manufacturer supplied)
Warranty Period			Integer	Yrs	Warranty validity period (manufacturer supplied)
Total Primary Energy Consumption per unit	Sustainability Data	-	Integer	Joules	Equipment energy consumption

HVAC EQUIPMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Water Consumption Per Unit		-	Integer	L	Water consumption in litres (if applicable)
Hazardous Waste Per Unit		-	Integer	kg	Weight of harzardous waste if produced
Embodied Carbon		-	Float	kgCO	Equipment embodied carbon footprint
Environmental Product Declaration		-	Text	n/a	Environmental declaration information
Acquisition Cost	Cost Data	BIM Maximo Asset.TotalCost	Integer	€	Equipment cost information
Operating Pressure	Performance data		Integer	kPa	Optimum operating temperature as provided by manufacturers
Operating Temperature			Integer	degC	Recommended operating temperature
Maximum Pressure			Integer	kPa	Maximum allowable working pressure
Nominal Capacity			Integer	Litres	water storage capacity in Litres
Electric motor rating			Integer	Kw	Rating of internal electric motor (if applicable)
Effective Capacity			Integer	Litres	optimum working storage capacity
Voltage	Electrical Data	-	Integer	Volts	Electrical voltage information
Supply Phase		-	Integer	Num	Electrical phase(1,3)
Frequency		-	Integer	Herts	Electrical frequency in Hz
Maximum Power Consumption		-	Integer	Watts	Max. power consumption(manufacturer supplied)
Minimum Power Consumption		-	Integer	Watts	Min. power consumption(manufacturer supplied)
Full Load Current		-	Float	Amps	Electrical current requirement
Fuse Rating		-	Integer	Amps	Safety fuse rating
BMS Links	Control		Boolean	Y/N	Connected to building management system or not?
Temperature sensor			Boolean	Y/N	Is temperature sensor present?
Control valves			Boolean	Y/N	Are pressure control valves present?
IBM Maximo Asset.EQ4	IBM Maximo Data	-	Text	n/a	IBM Maximo Equipment Classification
IBM Maximo Asset.EQ2		-	Character	n/a	IBM Acquisition Year
IBM Maximo Asset.Priority		-	Character	n/a	IBM Maximo priority of the equipment

Fire- fighting Network Data Template

FIRE-FIGHTING NETWORK DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Name/Description	Properties Identity Element	IBM Maximo Asset. Description	Text	n/a	Free text to describe product
Omniclass Classification			Character	n/a	Construction classification system
Pipe material			Text	n/a	Pipe material
Insulation	Product Specific data	-	Boolean	n/a	If pipe is insulated or non-insulated
Pipe schedule		-	Character	n/a	Pipe classification based on pipe thickness
Location		IBM Maximo asset. Location	Character	n/a	Location based on(Client classification)
Product data sheet		-	URL	n/a	Hyperlink to product data sheet (manufacturer supplied)
Operation and Maintenance manual		-	URL	n/a	Hyperlink to Manufacturer O&M Data (if applicable)
Product URL		-	URL	n/a	Specific product URL (if available)
Nominal diameter	Dimensional data	-	Float	mm	Nominal diameter as provided in data sheet
External diameter		-	Float	mm	Measurement of external diameter
Internal diameter		-	Float	mm	Measurement of internal diameter
Insulation thickness		-	Float	mm	Measurement of insulation thickness in mm
Length		-	Float	mm	Measurable pipe length
Asset Type (Fixed/Moveable)	Manufacturer's data		Boolean	Product	Classify equipment mobility
Model Reference/Number		IBM Maximo Asset.EQ1	Character	n/a	Manufacturer equipment identity number
Model Label			Character	n/a	(If available) Manufacturer model class
Manufacturer		IBM Maximo Asset. Vendor	Text	n/a	Manufacturer name
Manufacturer URL		-	URL	n/a	URL to technical details, e.g. system flow rates, pressure drop curves
Production Year		IBM Maximo Asset.EQ3	Integer	n/a	Year of production
Serial Number		IBM Maximo Asset.Serialnum	Integer	n/a	Serial number manufacturer provided (if available)
ServiceLifeDuration	Warranty Data		Integer	Yrs	Expected service life (manufacturer supplied)
Installation Date		IBM Maximo Asset. Install Date	Character	n/a	Date of installation/first use
Mean Time Between Failure			Integer	Min	Maximum time before maintenance (manufacturer supplied)
Warranty ID			Character	n/a	Warranty identity number (manufacturer supplied)
Warranty Start Date			Character	n/a	Warranty start date (manufacturer supplied)
Warranty End Date			Character	n/a	Warranty end date (manufacturer supplied)
Extended Warranty			Character	n/a	Information on if warranty is extendible Y/N (manufacturer supplied)
Warranty Period			Integer	Yrs	Warranty validity period (manufacturer supplied)
Embodied Carbon	Environmental Impact Data		Integer	kgCO	Equipment embodied carbon footprint
Environmental Product Declaration			Text	n/a	Environmental declaration information
Acquisition Cost	Cost Data	BIM Maximo Asset. Total Cost	Integer	€	Equipment cost information

Fire- fighting Equipment Data Template

FIRE-FIGHTING EQUIPMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Name/Description	Properties Identity Element	IBM Maximo Asset. Description	Character	n/a	Free text to describe product
Material			Text	n/a	General material assignment
Omniclass Classification			Character	n/a	Construction classification system
Asset Type (Fixed/Moveable)	Product Specific data		Text	n/a	Classify equipment mobility
PN Rating			Text	n/a	Normal working pressure rating
Colour			Text	n/a	Colour of external coating (if applicable)
Installation Date		IBM Maximo Asset. Install Date	Character	n/a	Date of installation/first use
Insulation		-	Boolean	n/a	If pipe is insulated or non-insulated
Location		IBM Maximo asset. Location	Character	n/a	Location based on(Client classification)
NFPA Class			Text	n/a	NFPA fire class the equipment is used for.
Product data sheet		-	URL	n/a	Hyperlink to product data sheet (manufacturer supplied)
Asset Type (Fixed/Moveable)	Manufacturer's data		Boolean	Produ ct	Classify equipment mobility
Model Reference/Number		IBM Maximo Asset.EQ1	Character	n/a	Manufacturer equipment identity number
Model Label			Character	n/a	(If available) Manufacturer model class
Manufacturer		IBM Maximo Asset. Vendor	Text	n/a	Manufacturer name
Manufacturer URL		-	URL	n/a	URL to technical details, e.g., system flow rates, pressure drop curves
Production Year		IBM Maximo Asset.EQ3	Integer	n/a	Year of production
Serial Number		IBM Maximo Asset.Serialnum	Integer	n/a	Serial number manufacturer provided (if available)
Overall Width	Dimensional Data		Integer	mm	Measurement of external width/wideness of equipment
Overall Height			Integer	mm	Measurement of overall height of equipment
Gross Weight			Integer	kg	Equipment weight in kg
Hot Inlet diameter			Integer	mm	Hot water inlet diameter(If applicable)
Cold Inlet diameter			Integer	mm	Cold water inlet diameter
Outlet diameter			Integer	mm	Outlet diameter in mm
ServiceLifeDuration	Warranty Data		Integer	Yrs	Expected service life (manufacturer supplied)
Installation Date		IBM Maximo Asset. Install Date	Character	n/a	Date of installation/first use
Mean Time Between Failure			Integer	Min	Maximum time before maintenance(manufacturer supplied)
Warranty ID			Character	n/a	Warranty idenity number (manufacturer supplied)
Warranty Start Date			Character	n/a	Warranty start date (manufacturer supplied)
Warranty End Date			Character	n/a	Warranty end date (manufacturer supplied)
Extended Warranty			Character	n/a	Information on ifwarranty is extendible Y/N (manufacturer supplied)
Warranty Period			Integer	Yrs	Warranty validity period (manufacturer supplied)
Total Primary Energy Consumption Per Unit	Sustainability Data	-	Integer	Joule s	Equipment energy consumption

FIRE-FIGHTING EQUIPMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Water Consumption per Unit		-	Integer	L	Water consumption in liters (if applicable)
Hazardous Waste per Unit		-	Integer	kg	Weight of hazardous waste if produced
Embodied Carbon		-	Float	kgCO	Equipment embodied carbon footprint
Environmental Product Declaration		-	Text	n/a	Environmental declaration information
Acquisition Cost	Cost Data	BIM Maximo Asset. Total Cost	Integer	€	Equipment cost information
Operating Pressure	Performance data		Integer	kPa	Optimum operating temperature as provided by manufacturers
Operating Temperature			Integer	degC	Recommended operating temperature
Maximum Pressure			Integer	kPa	Maximum allowable working pressure
Nominal Capacity			Integer	Liters	water storage capacity in Liters
Effective Capacity			Integer	Liters	optimum working storage capacity
Voltage	Electrical Data	-	Integer	Volts	Electrical voltage information
Supply Phase		-	Integer	Num	Electrical phase(1,3)
Frequency		-	Integer	Herts	Electrical frequency in Hz
Maximum Power Consumption		-	Integer	Watts	Max. power consumption(manufacturer supplied)
Minimum Power Consumption		-	Integer	Watts	Min. power consumption(manufacturer supplied)
Full Load Current		-	Float	Amps	Electrical current requirement
Fuse Rating		-	Integer	Amps	Safety fuse rating
Temperature sensor			Boolean	Y/N	Is temperature sensor present?
Control valves			Boolean	Y/N	Are pressure control valves present?
IBM Maximo Asset.EQ4	IBM Maximo Data	-	Text	n/a	IBM Maximo Equipment Classification
IBM Maximo Asset.EQ2		-	Character	n/a	IBM Acquisition Year
IBM Maximo Asset. Priority		-	Character	n/a	IBM Maximo priority of the equipment

Cold System Equipment Data Template

COLD SYSTEM EQUIPMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Name/Description	Properties Identity Element	IBM Maximo Asset. Description	Character	n/a	Free text to describe product
Material			Text	n/a	General material assignment
Omniclass Classification			Character	n/a	Construction classification system
Asset Type (Fixed/Moveable)	Product Specific data		Boolean	n/a	Classify equipment mobility
Colour			Text	n/a	Colour of external coating (if applicable)
Installation Date		IBM Maximo Asset.InstallDate	Character	n/a	Date of installation/first use
Insulation		-	Boolean	n/a	If pipe is insulated or non-insulated
Location		IBM Maximo asset. Location	Character	n/a	Location based on(Client classification)
Product data sheet		-	URL	n/a	Hyperlink to product data sheet (manufacturer supplied)
Asset Type (Fixed/Moveable)	Manufacturer's data		Boolean	Product	Classify equipment mobility
Model Reference/Number		IBM Maximo Asset.EQ1	Character	n/a	Manufacturer equipment identity number
Model Label			Character	n/a	(If available) Manufacturer model class
Manufacturer		IBM Maximo Asset. Vendor	Text	n/a	Manufacturer name
Manufacturer URL		-	URL	n/a	URL to technical details, e.g. system flow rates, pressure drop curves
Production Year		IBM Maximo Asset.EQ3	Integer	n/a	Year of production
Serial Number		IBM Maximo Asset.Serialnum	Integer	n/a	Serial number manufacturer provided (if available)
Overall Width	Dimensional Data		Integer	mm	Measurement of external width/wideness of equipment
Overall Height			Integer	mm	Measurement of overall height of equipment
Gross Weight			Integer	kg	Equipment weight in kg
Inlet diameter			Integer	mm	Cold water inlet diameter
Outlet diameter			Integer	mm	Outlet diameter in mm
Fan diameter			Integer	mm	Fan diameter in mm
ServiceLifeDuration	Warranty Data		Integer	Yrs.	Expected service life (manufacturer supplied)
Installation Date		IBM Maximo Asset.InstallDate	Character	n/a	Date of installation/first use
Mean Time Between Failure			Integer	Min	Maximum time before maintenance(manufacturer supplied)
Warranty ID			Character	n/a	Warranty identity number (manufacturer supplied)
Warranty Start Date			Character	n/a	Warranty start date (manufacturer supplied)
Warranty End Date			Character	n/a	Warranty end date (manufacturer supplied)
Extended Warranty			Character	n/a	Information on if warranty is extendible Y/N (manufacturer supplied)
Warranty Period			Integer	Yrs	Warranty validity period (manufacturer supplied)
Total Primary Energy Consumption per Unit	Sustainability Data	-	Integer	Joules	Equipment energy consumption
Water Consumption per Unit		-	Integer	L	Water consumption in liters (if applicable)

COLD SYSTEM EQUIPMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Hazardous Waste per Unit		-	Integer	kg	Weight of hazardous waste if produced
Embodied Carbon		-	Float	kgCO	Equipment embodied carbon footprint
Environmental Product Declaration		-	Text	n/a	Environmental declaration information
Acquisition Cost	Cost Data	BIM Maximo Asset. TotalCost	Integer	€	Equipment cost information
Operating Pressure	Performance data		Integer	kPa	Optimum operating temperature as provided by manufacturers
Operating Temperature			Integer	degC	Recommended operating temperature
Maximum Pressure			Integer	kPa	Maximum allowable working pressure
Nominal Capacity			Integer	Liters	water storage capacity in Liters
Electric motor rating			Integer	Kw	Rating of internal electric motor (if applicable)
Effective Capacity			Integer	Liters	optimum working storage capacity
Voltage	Electrical Data	-	Integer	Volts	Electrical voltage information
Supply Phase		-	Integer	Num	Electrical phase(1,3)
Frequency		-	Integer	Herts	Electrical frequency in Hz
Maximum Power Consumption		-	Integer	Watts	Max. power consumption(manufacturer supplied)
Minimum Power Consumption		-	Integer	Watts	Min. power consumption(manufacturer supplied)
Full Load Current		-	Float	Amps	Electrical current requirement
Fuse Rating		-	Integer	Amps	Safety fuse rating
BMS Links	Control		Boolean	Y/N	Connected to building management system or not?
Temperature sensor			Boolean	Y/N	Is temperature sensor present?
Control valves			Boolean	Y/N	Are pressure control valves present?
IBM Maximo Asset.EQ4	IBM Maximo Data	-	Text	n/a	IBM Maximo Equipment Classification
IBM Maximo Asset.EQ2		-	Character	n/a	IBM Acquisitions Year
IBM Maximo Asset. Priority		-	Character	n/a	IBM Maximo priority of the equipment

Cold System Network Data Template

COLD NETWORK DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Name/Description	Properties Identity Element	IBM Maximo Asset. Description	Text	n/a	Free text to describe product
Omniclass Classification			Character	n/a	Construction classification system
Duct shape/type			Text	n/a	Duct shape or characteristics(flexible, vaned)
Duct size			Text	n/a	Duct size as given by manufacturer
Duct material			Text	n/a	Duct material
Insulation	Product Specific data	-	Boolean	n/a	If pipe is insulated or non-insulated
Insulation material		-	Text	n/a	Duct insulation material
Location		IBM Maximo asset. Location	Character	n/a	Location based on(Client classification)
Duct capacity			Integer	cm³/s or ft³/s	Maximum allowable air flow speed
Temperature range			Integer	°C	Minimum and maximum duct working temperature
Pressure rating			Integer	kPa	Duct maximum pressure rating in kilopascal
Product data sheet		-	URL	n/a	Hyperlink to product data sheet (manufacturer supplied)
Duct diameter	Dimensional data	-	Float	mm	Nominal diameter as provided in data sheet
Duct width		-	Float	mm	Measurement of rectangular duct width
Duct length		-	Float	mm	Measurement of rectangular duct length
Pipe nominal diameter		-	Float	mm	Nominal diameter as provided in data sheet
Insulation thickness		-	Float	mm	Measurement of insulation thickness in mm
Length		-	Float	mm	Measurable duct length
Asset Type (Fixed/Moveable)	Manufacturer's data		Boolean	Product	Classify equipment mobility
Model Reference/Number		IBM Maximo Asset.EQ1	Character	n/a	Manufacturer equipment identity number
Model Label			Character	n/a	(If available) Manufacturer model class
Manufacturer		IBM Maximo Asset. Vendor	Text	n/a	Manufacturer name
Manufacturer URL		-	URL	n/a	URL to technical details, e.g. system flow rates, pressure drop curves
Production Year		IBM Maximo Asset.EQ3	Integer	n/a	Year of production
Serial Number		IBM Maximo Asset.Serialnum	Integer	n/a	Serial number manufacturer provided (if available)
ServiceLifeDuration	Warranty Data		Integer	Yrs	Expected service life (manufacturer supplied)
Installation Date		IBM Maximo Asset.InstallDate	Character	n/a	Date of installation/first use
Mean Time Between Failure			Integer	Min	Maximum time before maintenance(manufacturer supplied)
Warranty ID			Character	n/a	Warranty idenity number (manufacturer supplied)
Warranty Start Date			Character	n/a	Warranty start date (manufacturer supplied)
Warranty End Date			Character	n/a	Warranty end date (manufacturer supplied)
Extended Warranty			Character	n/a	Information on ifwarranty is extendible Y/N (manufacturer supplied)
Warranty Period			Integer	Yrs	Warranty validity period (manufacturer supplied)
Embodied Carbon	Environmental Impact Data		Integer	kgCO	Equipment embodied carbon footprint
Environmental Product Declaration			Text	n/a	Environmental declaration information
Acquisition Cost	Cost Data	BIM Maximo Asset.TotalCost	Integer	€	Equipment cost information

Sanitation Network Data Template

SANITATION NETWORK DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Name/Description	Properties Identity Element	IBM Maximo Asset. Description	Text	n/a	Free text to describe product
Omniclass Classification			Character	n/a	Construction classification system
Pipe material			Text	n/a	Pipe material
Insulation	Product Specific data	-	Boolean	n/a	If pipe is insulated or non-insulated
Pipe schedule		-	Character	n/a	Pipe classification based on pipe thickness
Location		IBM Maximo asset. Location	Character	n/a	Location based on (Client classification)
Product data sheet		-	URL	n/a	Hyperlink to product data sheet (manufacturer supplied)
Operation and Maintenance manual		-	URL	n/a	Hyperlink to Manufacturer O&M Data (if applicable)
Product data sheet		-	PDF	n/a	Product data sheet (manufacturer supplied)
Product URL		-	URL	n/a	Specific product URL (if available)
Nominal diameter	Dimensional data	-	Float	mm	Nominal diameter as provided in data sheet
External diameter		-	Float	mm	Measurement of external diameter
Internal diameter		-	Float	mm	Measurement of internal diameter
Insulation thickness		-	Float	mm	Measurement of insulation thickness in mm
Length		-	Float	mm	Measurable pipe length
Asset Type (Fixed/Moveable)	Manufacturer's data		Boolean	Product	Classify equipment mobility
Model Reference/Number		IBM Maximo Asset.EQ1	Character	n/a	Manufacturer equipment identity number
Model Label			Character	n/a	(If available) Manufacturer model class
Manufacturer		IBM Maximo Asset. Vendor	Text	n/a	Manufacturer name
Manufacturer URL		-	URL	n/a	URL to technical details, e.g. system flow rates, pressure drop curves
Production Year		IBM Maximo Asset.EQ3	Integer	n/a	Year of production
Serial Number		IBM Maximo Asset.Serialnum	Integer	n/a	Serial number manufacturer provided (if available)
Installation Date		IBM Maximo Asset.InstallDate	Character	n/a	Date of installation/first use
Mean Time Between Failure			Integer	Min	Maximum time before maintenance (manufacturer supplied)
Warranty ID			Character	n/a	Warranty identity number (manufacturer supplied)
Warranty Start Date			Character	n/a	Warranty start date (manufacturer supplied)
Warranty End Date			Character	n/a	Warranty end date (manufacturer supplied)
Extended Warranty			Character	n/a	Information on if warranty is extendible Y/N (manufacturer supplied)
warranty Period			Integer	Yrs.	Warranty validity period (manufacturer supplied)
Embodied Carbon	Environmental Impact Data		Integer	kgCO	Equipment embodied carbon footprint
Environmental Product Declaration			Text	n/a	Environmental declaration information
Acquisition Cost	Cost Data	BIM Maximo Asset.TotalCost	Integer	€	Equipment cost information
IBM Maximo Asset.EQ4	IBM Maximo Data	-	Text	n/a	IBM Maximo Equipment Classification
IBM Maximo Asset.EQ2		-	Character	n/a	IBM Acquisition Year
IBM Maximo Asset. Priority		-	Character	n/a	IBM Maximo priority of the equipment

Sanitation Equipment Data Template

SANITATION EQUIPMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Name/Description	Properties Identity Element	IBM Maximo Asset. Description	Charact er	n/a	Free text to describe product
Material			Text	n/a	General material assignment
Omniclass Classification			Charact er	n/a	Construction classification system
Asset Type (Fixed/Moveable)	Product Specific data		Boolea n	n/a	Classify equipment mobility
PN Rating			Text	n/a	Normal working pressure rating
Colour			Text	n/a	colour of external coating (if applicable)
Installation Date		IBM Maximo Asset.InstallDate	Charact er	n/a	Date of installation/first use
Insulation		-	Boolea n	n/a	If pipe is insulated or non-insulated
Location		IBM Maximo asset. Location	Charact er	n/a	Location based on(Client classification)
Product data sheet		-	URL	n/a	Hyperlink to product data sheet (manufacturer supplied)
Asset Type (Fixed/Moveable)	Manufacturer's data		Boolea n	Produ ct	Classify equipment mobility
Model Reference/Number		IBM Maximo Asset.EQ1	Charact er	n/a	Manufacturer equipment identity number
Model Label			Charact er	n/a	(If available) Manufacturer model class
Manufacturer		IBM Maximo Asset. Vendor	Text	n/a	Manufacturer name
Manufacturer URL		-	URL	n/a	URL to technical details, e.g., system flow rates, pressure drop curves
Production Year		IBM Maximo Asset.EQ3	Integer	n/a	Year of production
Serial Number		IBM Maximo Asset.Serialnum	Integer	n/a	Serial number manufacturer provided (if available)
Overall Width	Dimensional Data		Integer	mm	Measurement of external width/wideness of equipment
Overall Height			Integer	mm	Measurement of overall height of equipment
Gross Weight			Integer	kg	Equipment weight in kg
Hot Inlet diameter			Integer	mm	Hot water inlet diameter (If applicable)
Cold Inlet diameter			Integer	mm	Cold water inlet diameter
Outlet diameter			Integer	mm	Outlet diameter in mm
ServiceLifeDuration	Warranty Data		Integer	Yrs	Expected service life (manufacturer supplied)
Installation Date		IBM Maximo Asset.InstallDate	Charact er	n/a	Date of installation/first use
Mean Time Between Failure			Integer	Min	Maximum time before maintenance(manufacturer supplied)
Warranty ID			Charact er	n/a	Warranty identity number (manufacturer supplied)
Warranty Start Date			Charact er	n/a	Warranty start date (manufacturer supplied)
Warranty End Date			Charact er	n/a	Warranty end date (manufacturer supplied)
Extended Warranty			Charact er	n/a	Information on if warranty is extendible Y/N (manufacturer supplied)
warranty Period			Integer	Yrs.	Warranty validity period (manufacturer

SANITATION EQUIPMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
					supplied)
Total Primary Energy Consumption Per Unit	Sustainability Data	-	Integer	Joules	Equipment energy consumption
Water Consumption Per Unit		-	Integer	L	Water consumption in liters (if applicable)
Hazardous Waste Per Unit		-	Integer	kg	Weight of hazardous waste if produced
Embodied Carbon		-	Float	kgCO	Equipment embodied carbon footprint
Environmental Product Declaration		-	Text	n/a	Environmental declaration information
Acquisition Cost	Cost Data	BIM Maximo Asset.TotalCost	Integer	€	Equipment cost information
Operating Pressure	Performance data		Integer	kPa	Optimum operating temperature as provided by manufacturers
Operating Temperature			Integer	degC	Recommended operating temperature
Maximum Pressure			Integer	kPa	Maximum allowable working pressure
Nominal Capacity			Integer	Liters	water storage capacity in Liters
Effective Capacity			Integer	Liters	optimum working storage capacity
Voltage	Electrical Data	-	Integer	Volts	Electrical voltage information
Supply Phase		-	Integer	Num	Electrical phase(1,3)
Frequency		-	Integer	Herts	Electrical frequency in Hz
Maximum Power Consumption		-	Integer	Watts	Max. power consumption(manufacturer supplied)
Minimum Power Consumption		-	Integer	Watts	Min. power consumption(manufacturer supplied)
Full Load Current		-	Float	Amps	Electrical current requirement
Fuse Rating		-	Integer	Amps	Safety fuse rating
BMS Links	Control		Boolean	Y/N	Connected to building management system or not?
Temperature sensor			Boolean	Y/N	Is temperature sensor present?
Control valves			Boolean	Y/N	Are pressure control valves present?
IBM Maximo Asset.EQ4	IBM Maximo Data	-	Text	n/a	IBM Maximo Equipment Classification
IBM Maximo Asset.EQ2		-	Character	n/a	IBM Acquisition Year
IBM Maximo Asset. Priority		-	Character	n/a	IBM Maximo priority of the equipment

Electrical Element Data Template

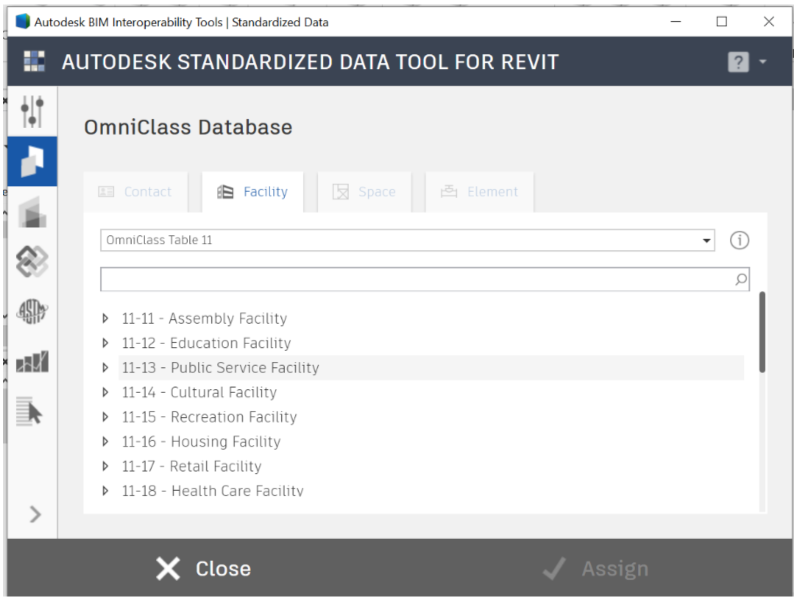
ELECTRICAL ELEMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Name/Description	Properties Identity Element	IBM Maximo Asset. Description	Character	n/a	Free text to describe product
Material			Text	n/a	General material assignment
Omniclass Classification			Character	n/a	Construction classification system
Asset Type (Fixed/Moveable)	Product Specific data		Boolean	n/a	Classify equipment mobility
PN Rating			Text	n/a	Normal working pressure rating
Colour			Text	n/a	colour of external coating (if applicable)
Installation Date		IBM Maximo Asset.InstallDate	Character	n/a	Date of installation/first use
Insulation		-	Boolean	n/a	If pipe is insulated or non-insulated
Location		IBM Maximo asset. Location	Character	n/a	Location based on(Client classification)
Product data sheet		-	URL	n/a	Hyperlink to product data sheet (manufacturer supplied)
Asset Type (Fixed/Moveable)	Manufacturer's data		Boolean	Product	Classify equipment mobility
Model Reference/Number		IBM Maximo Asset.EQ1	Character	n/a	Manufacturer equipment identity number
Model Label			Character	n/a	(If available) Manufacturer model class
Manufacturer		IBM Maximo Asset. Vendor	Text	n/a	Manufacturer name
Manufacturer URL		-	URL	n/a	URL to technical details, e.g. system flow rates, pressure drop curves
Production Year		IBM Maximo Asset.EQ3	Integer	n/a	Year of production
Serial Number		IBM Maximo Asset. Serialnum	Integer	n/a	Serial number manufacturer provided (if available)
Overall Width	Dimensional Data		Integer	mm	Measurement of external width/wideness of equipment
Overall Height			Integer	mm	Measurement of overall height of equipment
Gross Weight			Integer	kg	Equipment weight in kg
Hot Inlet diameter			Integer	mm	Hot water inlet diameter(If applicable)
Cold Inlet diameter			Integer	mm	Cold water inlet diameter
Outlet diameter			Integer	mm	Outlet diameter in mm
Service Life Duration	Warranty Data		Integer	Yrs	Expected service life (manufacturer supplied)
Installation Date		IBM Maximo Asset.InstallDate	Character	n/a	Date of installation/first use
Mean Time Between Failure			Integer	Min	Maximum time before maintenance (manufacturer supplied)
Warrant ID			Character	n/a	Warranty identity number (manufacturer supplied)
Warranty Start Date			Character	n/a	Warranty starts date (manufacturer supplied)
Warranty End Date			Character	n/a	Warranty end date (manufacturer supplied)
Extended Warranty			Character	n/a	Information on if warranty is extendible Y/N (manufacturer supplied)
Warranty Period			Integer	Yrs.	Warranty validity period (manufacturer supplied)
Total Primary Energy	Sustainability Data	-	Integer	Joule	Equipment energy consumption

ELECTRICAL ELEMENT DATA TEMPLATE					
Property Name	Property set	IBM Maximo	Data Type	Unit	Notes
Consumption Per Unit				s	
Water Consumption Per Unit		-	Integer	L	Water consumption in liters (if applicable)
Hazardous Waste Per Unit		-	Integer	kg	Weight of hazardous waste if produced
Embodied Carbon		-	Float	kgCO	Equipment embodied carbon footprint
Environmental Product Declaration		-	Text	n/a	Environmental declaration information
Acquisition Cost	Cost Data	BIM Maximo Asset.TotalCost	Integer	€	Equipment cost information
Operating Pressure	Performance data		Integer	kPa	Optimum operating temperature as provided by manufacturers
Operating Temperature			Integer	degC	Recommended operating temperature
Maximum Pressure			Integer	kPa	Maximum allowable working pressure
Nominal Capacity			Integer	Litres	water storage capacity in Liters
Effective Capacity			Integer	Litres	optimum working storage capacity
Voltage	Electrical Data	-	Integer	Volts	Electrical voltage information
Supply Phase		-	Integer	Num	Electrical phase(1,3)
Frequency		-	Integer	Herts	Electrical frequecy in Hz
Maximum Power Consumption		-	Integer	Watts	Max. power consumption(manufacturer supplied)
Minimum Power Consumption		-	Integer	Watts	Min. power consumption(manufacturer supplied)
Full Load Current		-	Float	Amps	Electrical current requirement
Fuse Rating		-	Integer	Amps	Safety fuse rating
BMS Links	Control		Boolean	Y/N	Connected to building management system or not?
Temperature sensor			Boolean	Y/N	Is temperature sensor present?
Control valves			Boolean	Y/N	Are pressure control valves present?
IBM Maximo Asset.EQ4	IBM Maximo Data	-	Text	n/a	IBM Maximo Equipment Classification
IBM Maximo Asset.EQ2		-	Character	n/a	IBM Acquisition Year
IBM Maximo Asset. Priority		-	Character	n/a	IBM Maximo priority of the equipment

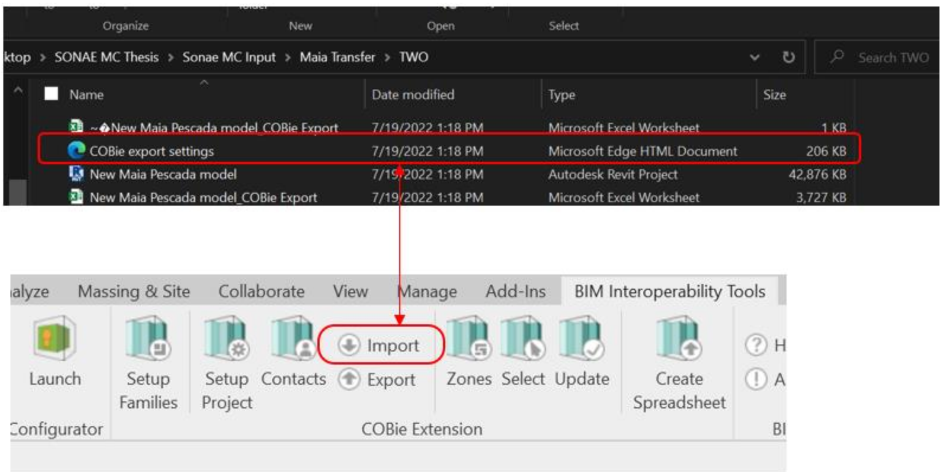
APPENDIX 3: RECOMMENDED STEPS FOR COBIE EXPORT FROM AUTHORING SOFTWARE (REVIT)

The steps below are the recommended procedures for COBie exportation to match SonaeMC information requirement. This should be used in conjunction with shared parameter file and Cobie export settings (.html)

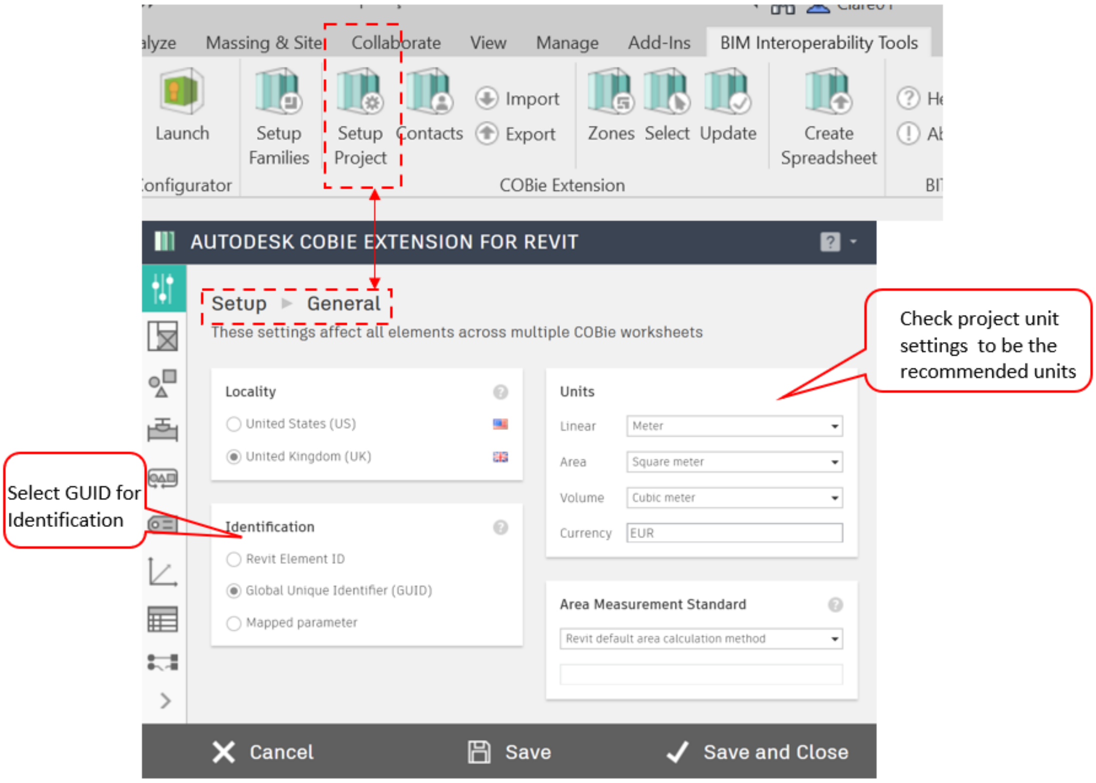
1. Select the recommended classification system which in this case is the (**Omniclass classification**)



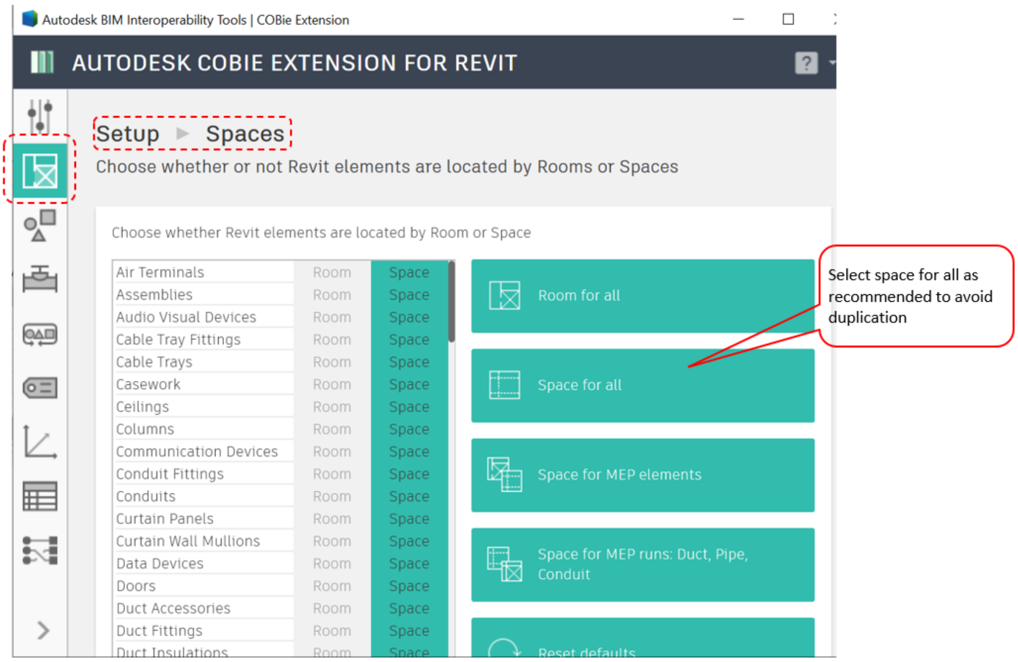
2. Import COBie settings- The COBie settings can be imported into a new project instead of making the changes one at a time.



3. Confirm COBie export settings by checking the **project setup** BIM interoperability toolkit

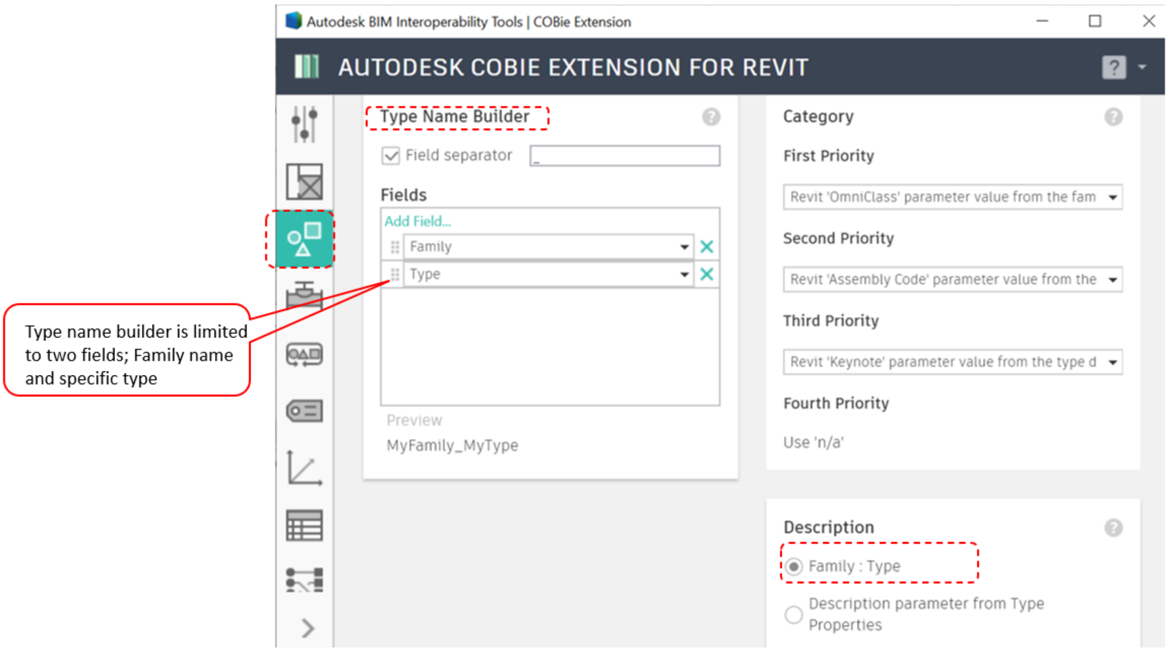


4. Confirm Setup for spaces: The appointing party SonaeMC recommends the use of space

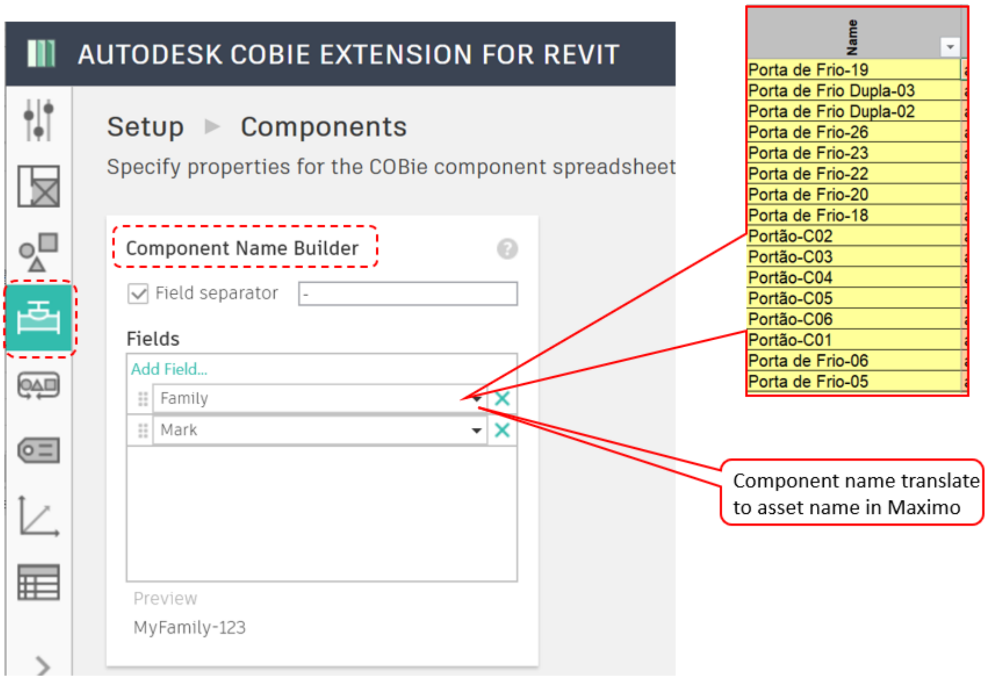


only for all building elements.

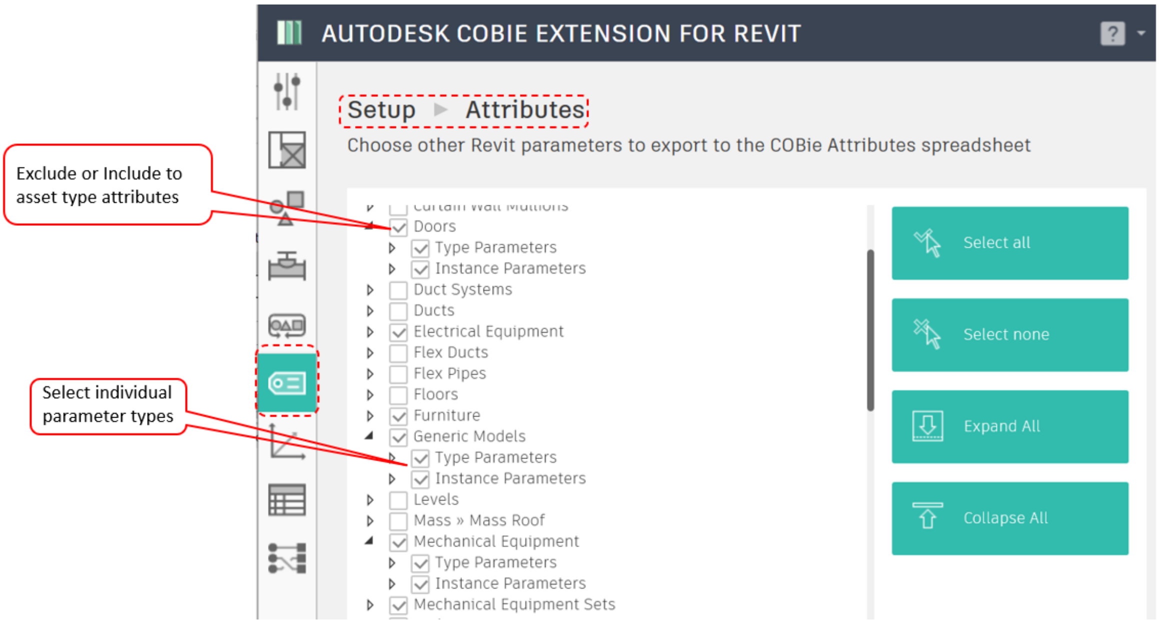
5. Confirm setup for asset Types sheet- Set name builder and category priority as illustrated in the figure bellow.



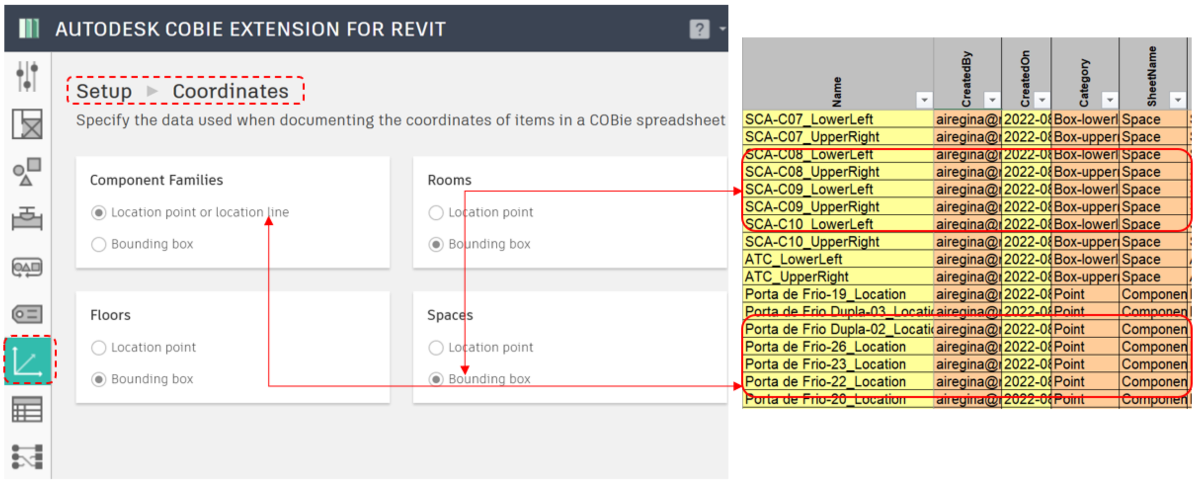
6. Confirm component name setup using family name and a unique mark number for each asset as shown below.



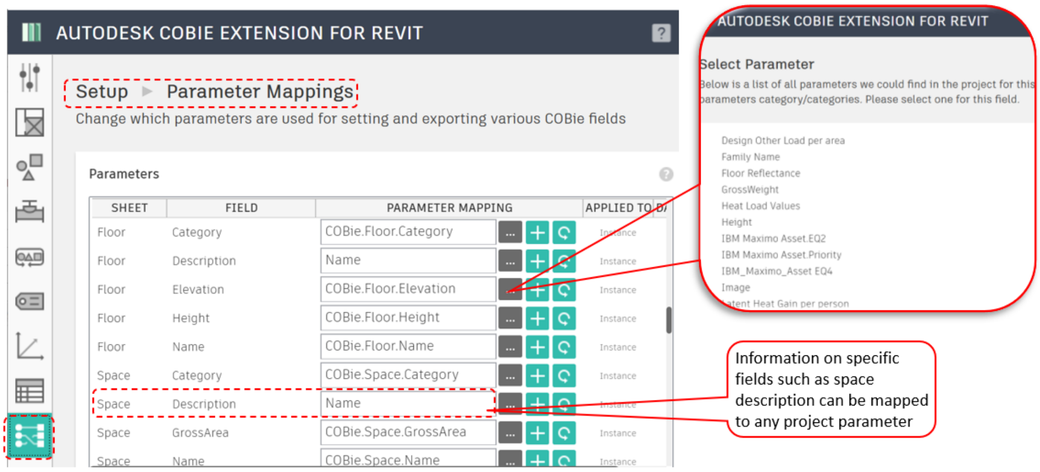
7. Attributes setup- Select relevant asset attributes to be exported to COBie. The goal of Sonae MC is asset management due to this goals, attributes of architectural and structural elements like columns, walls, panels etc. are excluded. The imported COBie setting already selects the relevant attributes but this can be adjusted to meet current information needs.



8. Coordinate sheet setup- It is recommended to use a bounding box when identifying the coordinates of rooms, spaces and floors. Location points should be used for individual component coordinates as shown below.

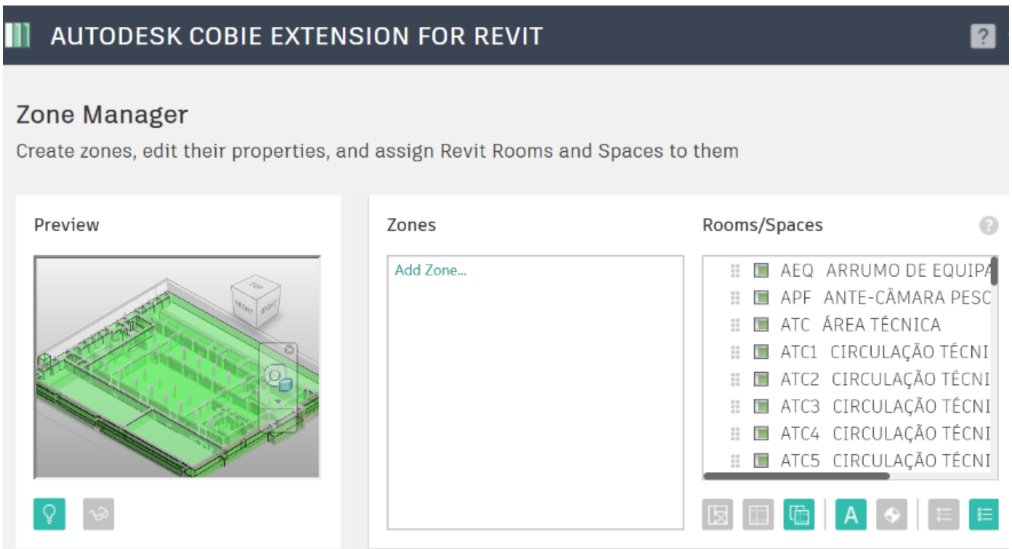


9. Parameter mappings setup- The appropriate Cobie parameter settings will be automatically selected with the COBie settings import. This can be changed by following the steps illustrated bellow. It is recommended to keep the parameter mappings setting as imported because it was selected carefully to match Sonae MC information requirement.

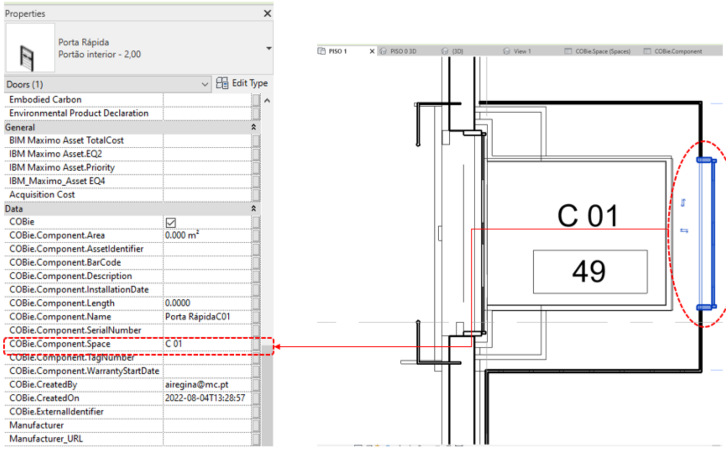


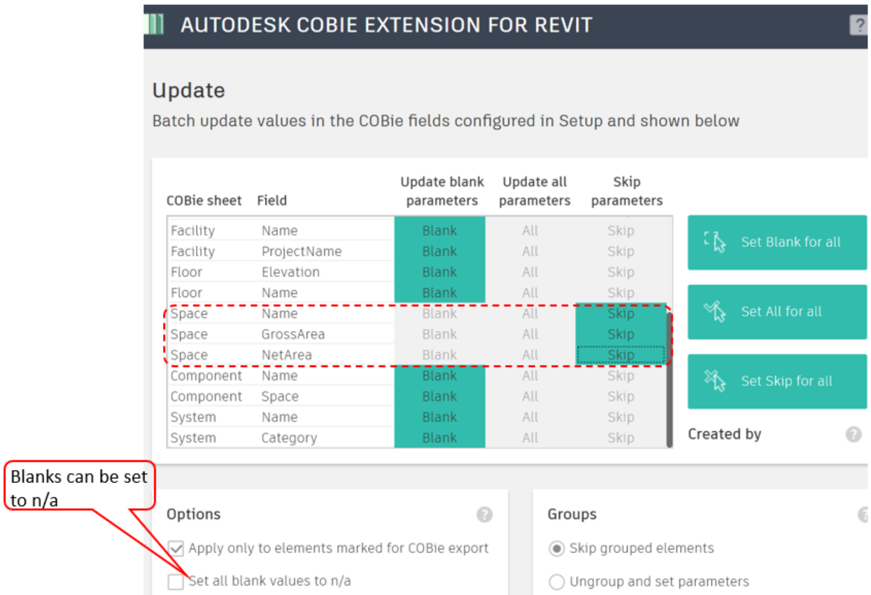
Notes

1. Zones are not created for the COBie export because they are translated as systems in Maximo. We want limit systems to just relevant MEP systems within Maximo.

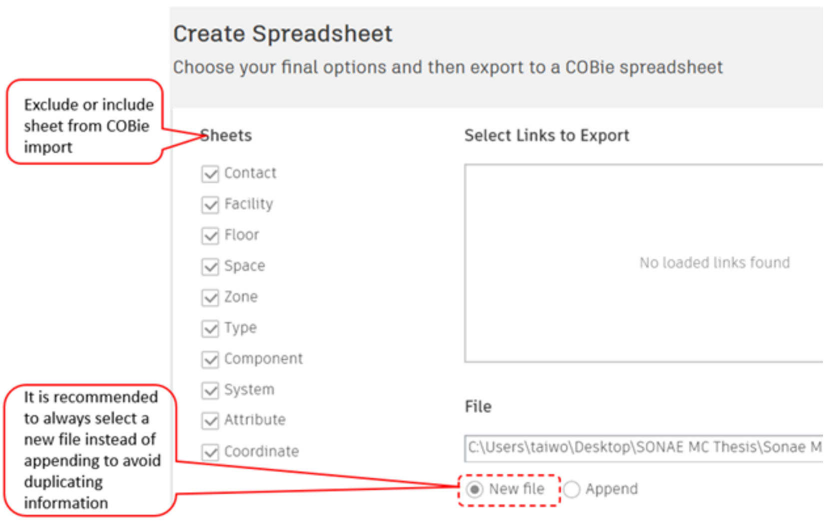


2. For boundary elements such as doors between spaces. The doors are associated with spaces facing the front of the element as shown in the figure below. The spaces association can only be manually adjusted.



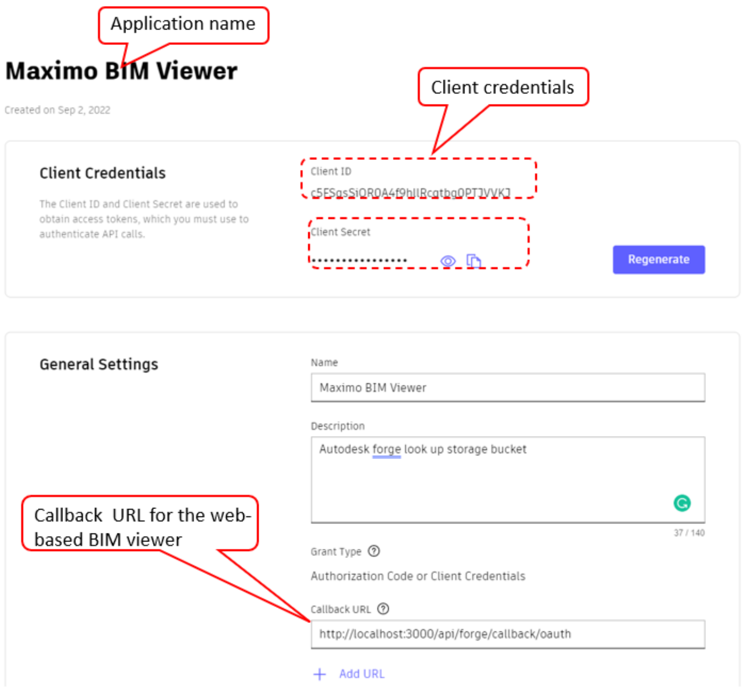


3. It is recommended to un-check the space parameter update when exporting the COBie file after making changes as shown below. The final step for COBie export is create spread sheet.

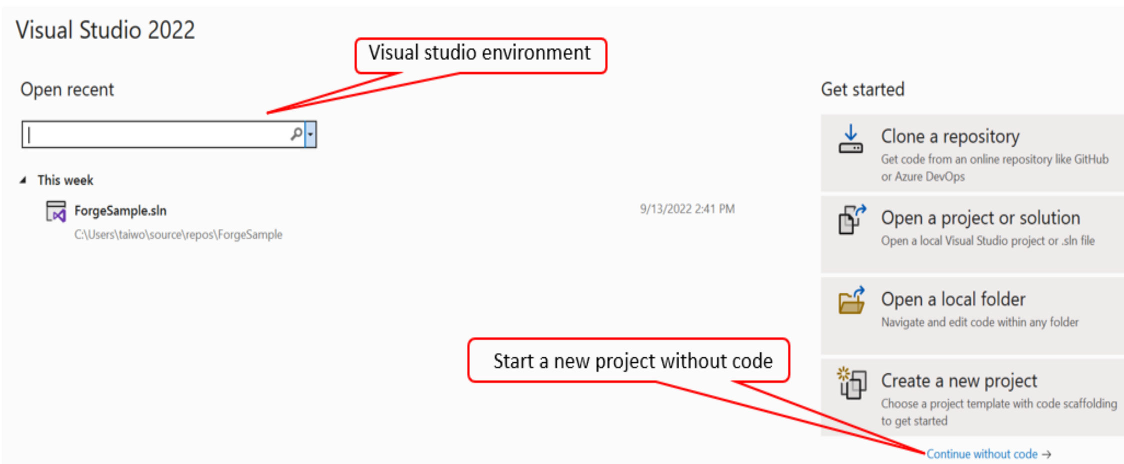


APPENDIX 4: CREATING AUTODESK FORGE STORAGE BUCKET

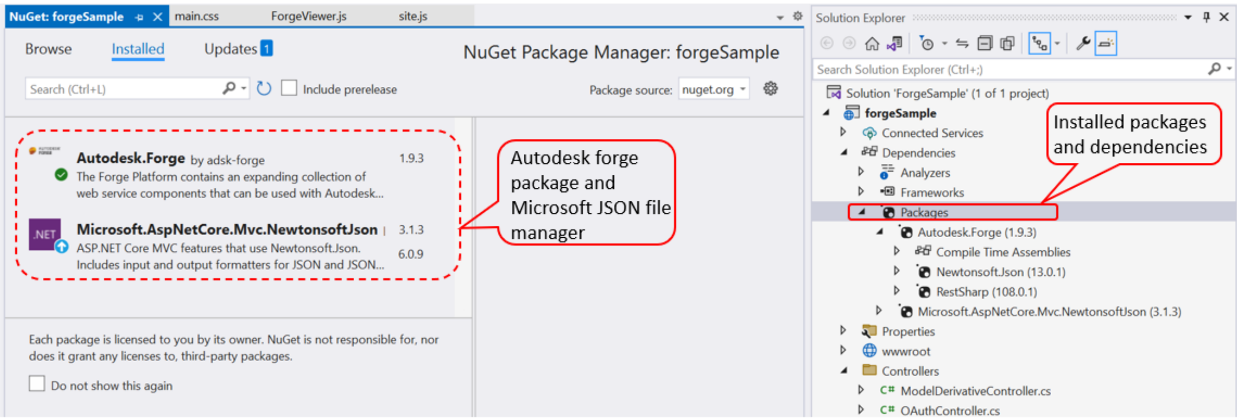
1. Create an application with a Forge account- The app created with forge has a unique client ID and client secret which was used during the forge installation process



2. There are different ways a storage bucket can be created using any of the following programming languages Node.js, .NET Framework, .NET Core, Java, PHP etc. The next step is to create a local sever using any of the programming languages. The .NET core framework was selected in this case because of its simplicity. For a Windows OS environment Visual Studio is required to run .NET Core in a user-friendly environment.



3. The codes used in this process are available on the forge learning platform (https://learnforge.autodesk.io/) After creating a new project the next step is to install the Autodesk Forge NuGet package and (Microsoft.AspNETCore.Mvc.Newtonsoft .Json) to handle JSON data.



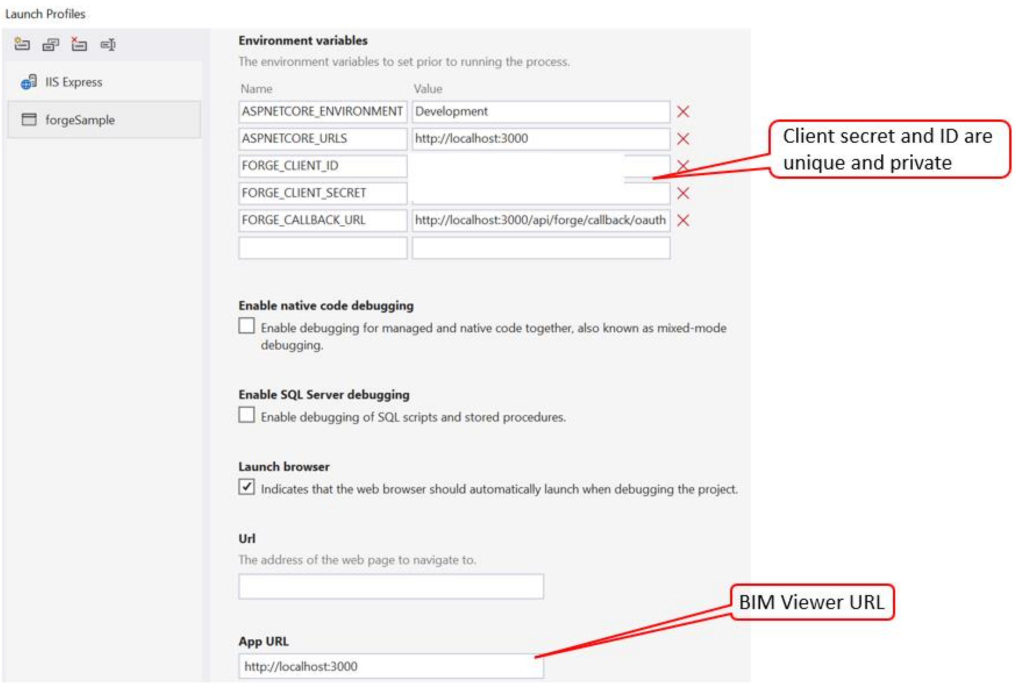
4. The next step is to fill in the Environmental variables under the Debug tab

ASPNETCORE_URLS: use http://localhost:3000 or http://localhost:8080

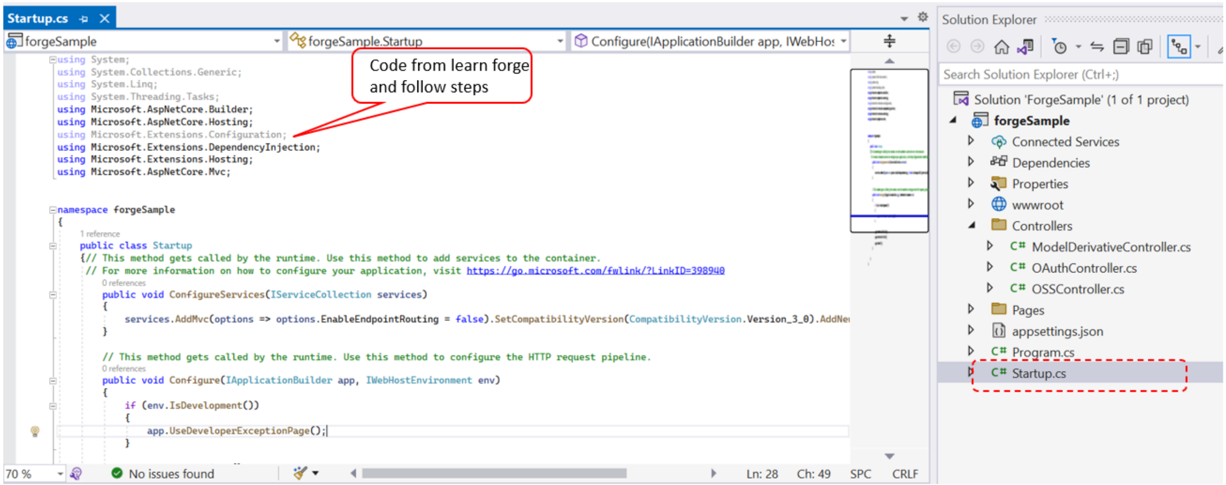
FORGE_CLIENT_ID: use your Client ID here

FORGE_CLIENT_SECRET: use your secret here

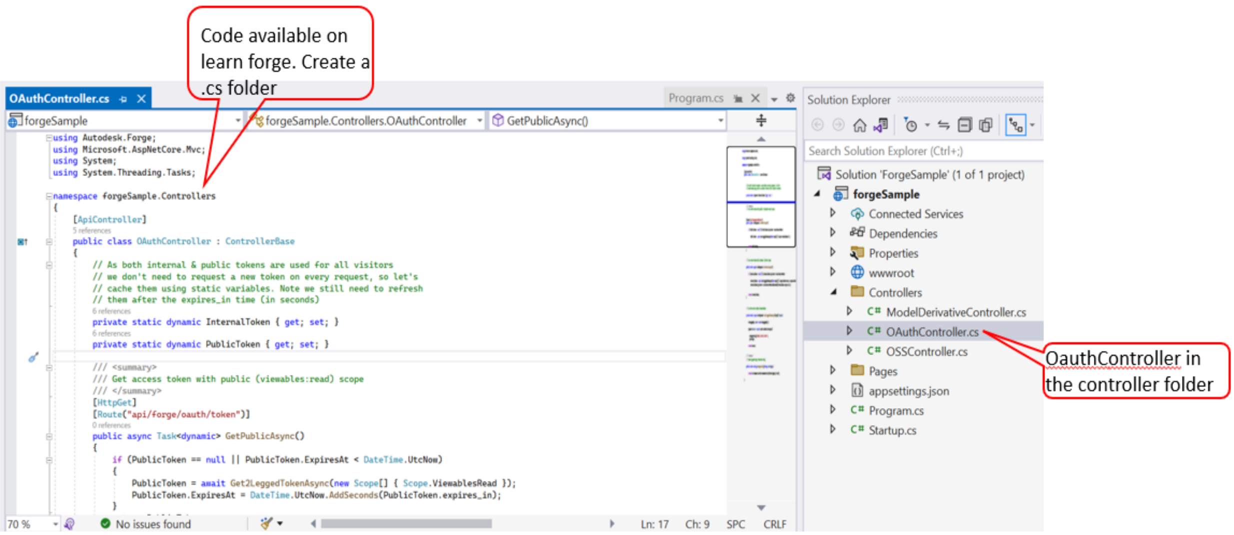
FORGE_CALLBACK_URL: for this sample, use http://localhost:3000/api/forge/callback/oauth



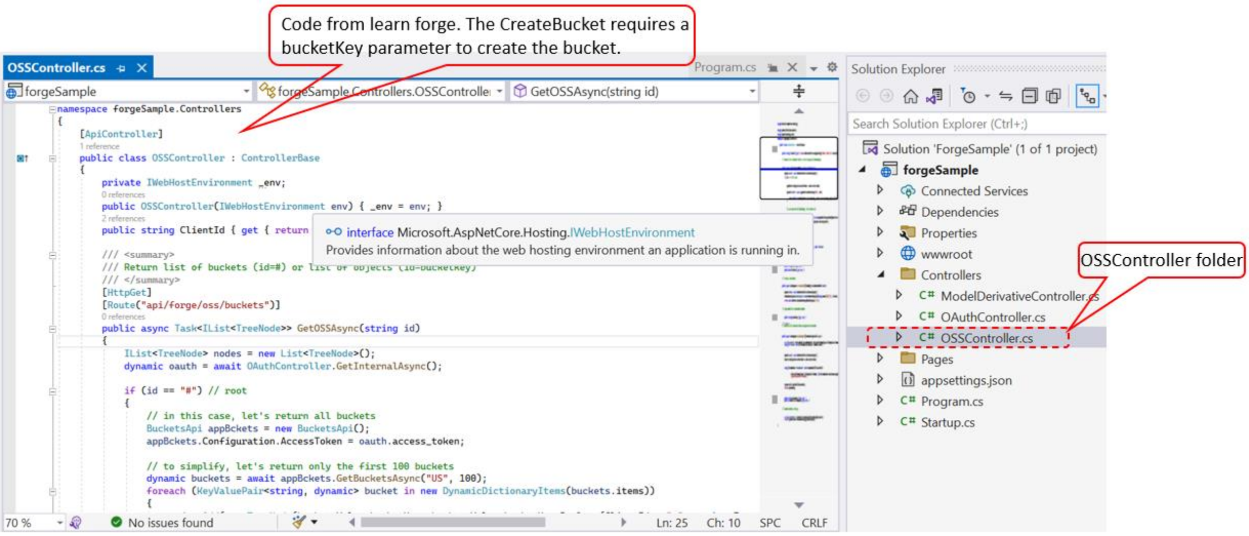
5. Next step open the Startup.cs folder and replace with the code available on the learn forge website (https://learnforge.autodesk.io/#/environment/setup/netcore_2legged) to initialize the static file server.



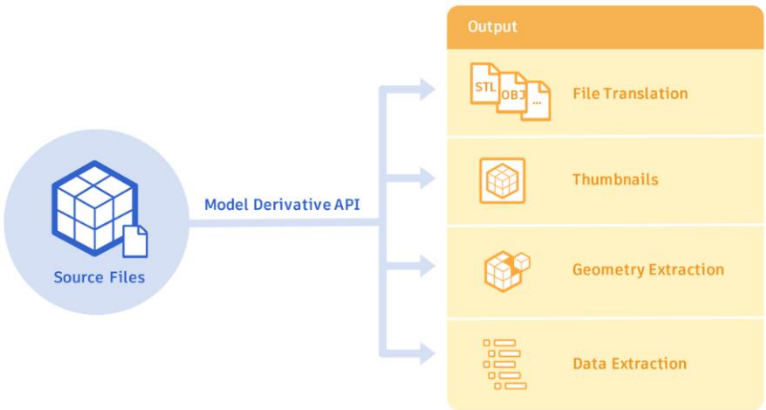
6. Authenticate- OAuth 2-legged- This step is required for accessing any resource on Forge it uses the client credentials to grant access for server-to-server communications. Create folder named Controllers at project root level, then create a class named OAuthController in a class file with the same name (OAuthController.cs) and put in the code available on the learn forge.

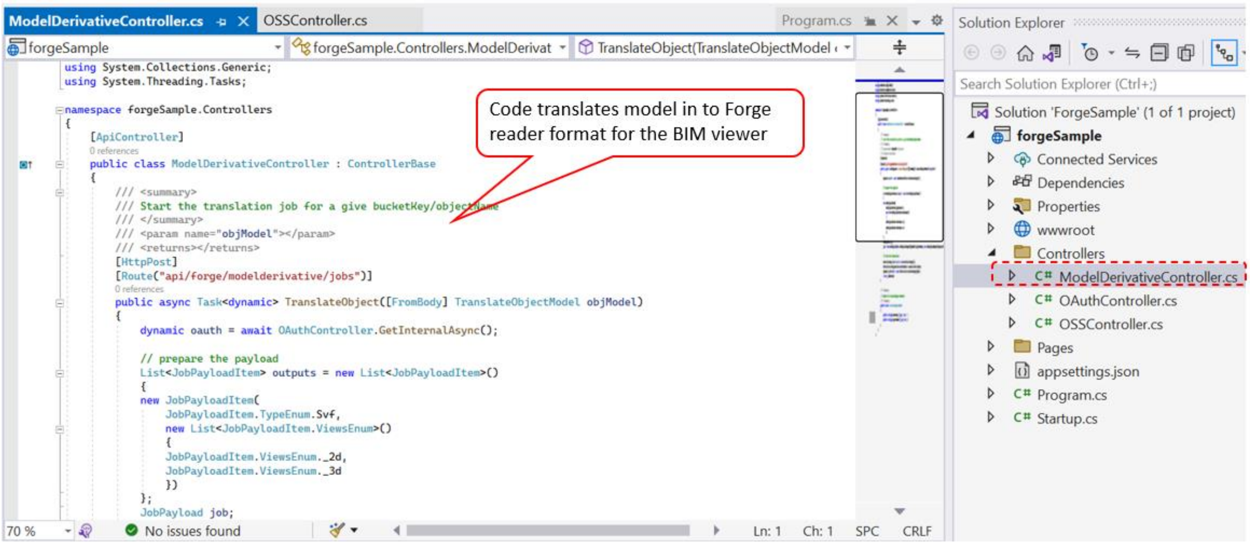


7. OSS Controller- The next will add the create buckets and list bucket feature. Under Controllers folder, create a class named OSSController in a class file with the same name (OSSController.cs) and add the code available on learn forge.



8. Translate file- Under Controllers folder, also create a file named Model Derivative Controller add the code available on forge learn. This code translates the model to SVF format.



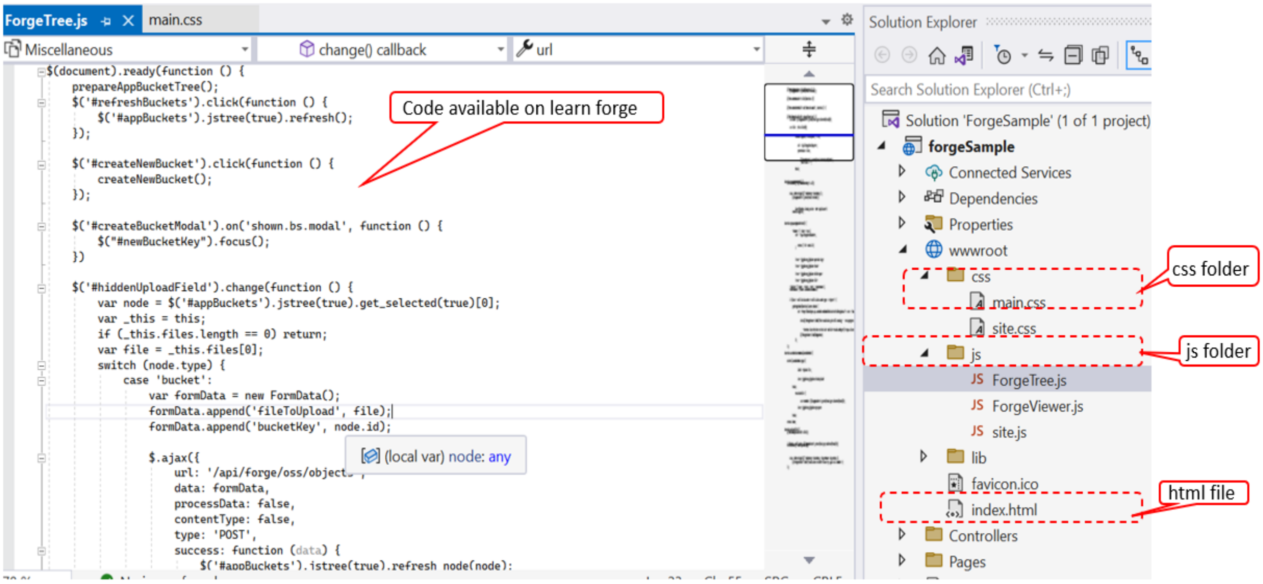


9. Viewer - The Viewer is a client-side library, based on HTML and JavaScript. Under the www.root folder create the following folders and copy the corresponding codes.

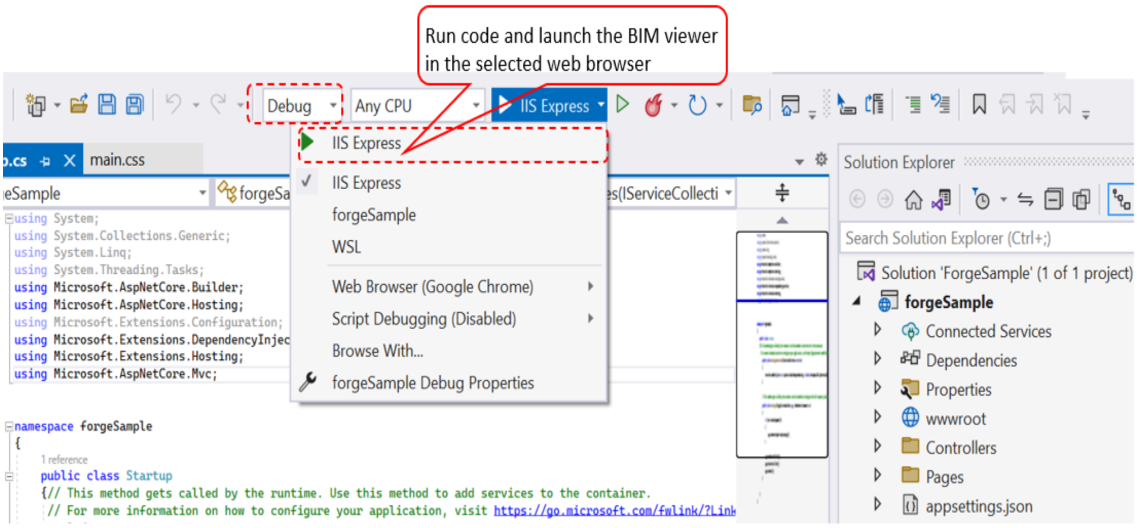
wwwroot/: .html folder

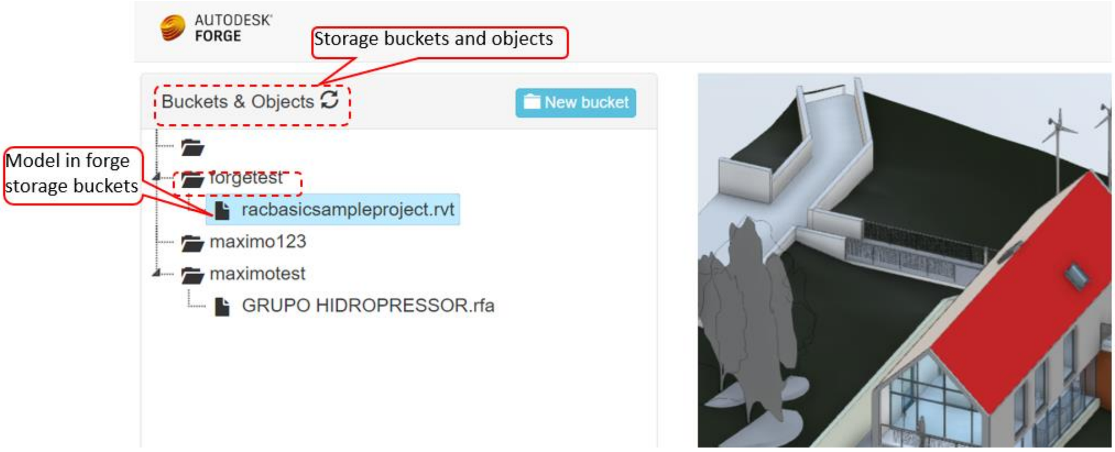
wwwroot/js: .js folder

wwwroot/css: .css folder



10. Run locally and upload file to Bucket- After following the steps listed the next and final step is to run code and debug.




AUTODESK
FORGE
Storage buckets and objects
Buckets & Objects
New bucket
Model in forge storage buckets
forgetest
racbasicsampleproject.rvt
maximo123
maximotest
GRUPO HIDROPRESSOR.rfa