BIM-FM applied to the UMinho's Canteen of Azurém:
Asset Information Requirements and proof of viability

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STATEMENT OF INTEGRITY

I hereby declare having 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 along the process leading to its elaboration.

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

RESUMO

A adoção do BIM durante a fase de FM (BIM-FM) pode ajudar a alcançar uma comunicação e um fluxo de informação eficazes, visto que a disciplina requer uma vasta gama de dados, que o BIM tem a capacidade de armazenar e transferir. Para que o BIM-FM seja implementado de forma eficiente, o modelo deve conter informações relevantes para as operações a acontecer durante a fase de FM. Atualmente, a falta de requisitos de informação orientados para o uso implica na construção de modelos não úteis para o FM, o que traz a necessidade de desenvolver e aprimorar procedimentos que auxiliem na identificação de requisitos de informação para o gerenciamento de instalações baseado em BIM.

Esta dissertação apresenta o desenvolvimento de Requisitos de Informação de Ativos (AIR) para auxiliar na construção de um modelo BIM para a fase operacional de um edifício. Durante a construção deste trabalho, as normas de gerenciamento de informação mais recentes (ISO 19650 e EN 17412-1) são consultadas para auxiliar no desenvolvimento do AIR proposto. Os procedimentos englobam uma metodologia orientada para o propósito e a aplicação do *'Level of Information Need'* como métrica para a definição dos requisitos. O esquema IFC é consultado desde as primeiras etapas para atender à necessidade de interoperabilidade do modelo, bem como manuais de modelagem são consultados para a coleta de regras gerais de modelação.

Para demonstrar a aplicação desses requisitos, um modelo de um estudo de caso é desenvolvido. A dissertação descreve os principais desafios do processo relacionados à definição dos requisitos e também à sua aplicação. As tomadas de decisões para superar esses desafios são discutidas, com análise minusciosa do problema e discussão de decisões e implicações. Análises de FM são simuladas em uma plataforma de inteligência empresarial usando como fonte de informações primária o arquivo IFC exportado do modelo. Os resultados finais do trabalho demonstram que as normalizações e manuais são eficientes, dado que o modelo BIM criado a partir dos requisitos é comprovadamente capaz de entregar eficientemente as informações necessárias e permitir simular análises de FM.

PALAVRAS CHAVE

Gerenciamento de Instalações (FM), Interoperabilidade, Modelagem da Informação da Construção (BIM), Requisitos de Informação de Ativos (AIR)

ABSTRACT

The adoption of BIM during the FM phase (BIM-FM) can help achieve effective communication and information flow since the FM discipline requires a vast range of data, which BIM has the capability of storing and transferring. For BIM-FM to be implemented efficiently, the model must contain relevant information for the FM operations to occur. Currently, the lack of purpose-driven information requirements implies the construction of models not useful for the FM phase, bringing the need to develop and enhance procedures that assist the identification of operational information requirements for BIM-based processes.

This dissertation presents the development of Asset Information Requirements (AIR) to inform the construction of a BIM model for the operational phase of a building. During the construction of this work, the most recent Information Management guidelines from ISO 19650 series and EN 17412-1 are accessed to assist the development of the proposed AIR. The procedures encompass a purpose-driven methodology and the application of the Level of Information Need as the metric for the requirements definition. The IFC schema is consulted from the first steps of establishing those requirements to address the interoperability necessity of the model. For complementing the requirements, modelling manuals are also consulted for the collection of general modelling guidelines.

To demonstrate the application of those requirements in the modelling stage, a case study model is developed. The dissertation describes the main challenges of the process related to the definition of the requirements and also of their application. The decision-making process to overcome those challenges is discussed, thoroughly analysing the problem and discussing decisions and their implications. FM analyses are simulated in a business intelligence platform using the IFC exported file of the model as its primary information source. The final results of the work demonstrate that the instructions from the standardization and manuals are efficient since the BIM model created from the requirements is proven to deliver the required information efficiently and to allow FM simulations.

KEYWORDS

Asset Information Requirements (AIR), Building Information Modelling (BIM), Facility Management (FM), Interoperability

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List of Abbreviations

AECO: Architecture, Engineering, Construction and Operation

AI: Artificial Intelligence

AIM: Asset Information Model

AIR: Asset Information Requirements

API: Application Programming Interface

BIM: Building Information Modelling

BI: Business Intelligence

BOS: BIM Object Standard

CAFM: Computer Aided Facility Management

COBIM: Common National Requirements for Building Information Modelling

CMMS: Computerized Maintenance Management System

EIR: Exchange Information Requirements

FM: Facility Management

ICT: Information and Communication Technology

IT: Information Technology

IFC: Industry Foundation Classes

IFMA: International Facility Management Association

MEP: Mechanical, Electrical and Plumbing

MVD: Model View Definitions

NBS: National Building Specification

OBOS: Open BIM Object Standard

OIR: Organizational Information Requirements

PIM: Project Information Model

PIR: Project Information Requirements

SASUM: Serviços de Acção Social of University of Minho

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1 INTRODUCTION

1.1 Scope and motivation

The interdisciplinary practice associated with managing buildings and facilities is known as Facility Management (FM). According to the International Facility Management Association (IFMA) [1], FM services are responsible for the efficiency of the built environment as they encompass the facility's functionality, comfort, and safety. The practice is essential since the operational phase is the most extensive one on a facility life cycle, contributing to over half of its total costs [2].

The strategic objectives of Facility Management comprise diverse domains of administration, requiring effectiveness of communication and information flow as one of the essential conditions for achieving them. Therefore, digital technology's high capability of data processing turns it into a source of numerous solutions that facilitate the collection, processing, and compression of information about buildings [3].

The use of Computer Aided Facility Management (CAFM) software began around 1990 [4], when actors involved in the FM sector have started to use it to support the operation and maintenance activities of building assets [5]. Recently, the Information and Communication Technology (ICT) for the FM industry has undergone significant changes and has been showing a growing interest in Building Information Modelling (BIM) due to many benefits and resource savings coming from information management, with impacts to all phases of a facility life cycle [6].

A BIM model contains data on the geometric characteristics of all the elements that constitute a building and includes their properties and attributes, whether physical, financial or related to their construction and management [6]. The adoption of BIM is spread in the design and construction phases resulting in models being created from the first steps of a building life cycle, usually containing the information necessary for those preliminary phases but not necessarily encompassing the operational need [5]. After the models' handover to the operator or owner of a facility, those actors claim to have a large amount of data and, at the same time, a lack of useful information [7].

Another scenario is the development of models for existing facilities to the ongoing operational phase. For this circumstance, a model containing inefficient information is also a reality because of the inability of the owners and managers to define the precise information required for the model [8]. In both cases, the critical challenge faced by those attempting to implement BIM for FM can be summarized as determining the requirements for the models to support the uses intended efficiently.

The lack of efficient information requirements is a significant problem since information requirements are a crucial part of the information management process, defining the input to its procedures, analyses and operations [9]. Therefore, there is a current need to develop and enhance methods that assist the identification of operational information requirements for BIM-based processes.

The ISO 19650 series [9]–[11] and the EN 17412-1 [12] are the most recent normalization on the subject, guiding the actors of a project on the procedures and definitions that support the information management processes for BIM adoption during the life cycle of facilities. The standards include steps, concepts, and a suggested framework to guide the definition of the content, form, and extent of information requirements.

In this context, the project Cognitive Computerized Maintenance Management System (Cognitive CMMS) emerges. The project is a partnership between the company Valuekeep, the Computer Graphics Centre of UMinho (Centro de Computação Gráfica), the Social Action Services of UMinho (Serviços de Acção Social - SASUM) and other entities. The corporation is a software developer that already provides CAFM software but intends to include BIM capability in its system. The consortium (Cognitive CMMS) proposes developing a platform equipped with tools for detecting and predicting failures or anomalies in assets, including analysing the surrounding environment to optimise resources and maintenance operations in a predictive maintenance context and contribute to the efficient energy consumption of buildings.

Within the consortium, the role of the University of Minho is linked with the BIM and sensing aspects of the project. The present dissertation fits in the stages of developing the information requirements based on the current standardization guidelines for one of the project's case studies and constructing a model following those requirements. Since the project is in its early stages, the model created will not be tested in the Valuekeep platform proposed by the consortium. However, the procedures upstream of the model appliance described in this dissertation are still relevant to the consortium context.

1.2 Objectives and methodology

The general objective of this dissertation is to combine the specifications from the most recent information management guidelines applied to the strategic development of operational information requirements to inform the construction of a BIM model considered to be effective in the function of primary information provider for the management phase of a building.

The specific objectives that will assist in achieving the aim of the dissertation are:

- Developing the requirements and modelling rules to construct a model for the operational phase of a building from its operator perspective;
- Apply the requirements developed by constructing the BIM model of the case study;
- Simulate FM analyses and use the model exported file as the source of information.

The information management applicable standards (ISO 19650 series and EN 17412-1) set the primary directions to achieve purpose-driven information requirements. For the application of those requirements, version 2021 of the software Revit from Autodesk is selected to construct the model of the Canteen of Azurém from the UMinho campus, and for its model testing, the business intelligence platform Power BI from Microsoft is the chosen option.

1.3 Layout of the dissertation

Apart from Chapter 1 that shows the introduction of the dissertation, Chapter 2 presents the literature review and state of the art regarding Facility Management and Building Information Modelling. It also presents the current status of the BIM-FM implementation and research on the subject, finalizing with the applicable standards and manuals.

Chapter 3 presents the case study selected, including its contextualization, modes of operation and physical characteristics of the building, with the presentation of its assets. Chapter 3 describes the process for the development of the operator's requirements for the model to encompass the necessities for the FM phase of the building, explaining the steps taken and describing the decision-making process.

Chapter 5 describes the modelling process based on the requirements defined in the previous chapter, including the step-by-step procedure, the challenges faced and the respective decisions that allowed their overcome. A dashboard containing FM analyses with allowance to information interactive visualization was created using the model as its source of information. Chapter 6 presents the main conclusions of the work and suggestions for future studies.

2 FACILITY MANAGEMENT ASSISTED BY BUILDING INFORMATION MODELLING

2.1 Facility Management

According to the European Standard CEN TC 348 cited by [3], the Facility Management area of operation supports and improves the productivity of organizations through the delivery of essential tools and services required for the fulfilment of business objectives. The International Facility Management Association (IFMA) [1] defines FM as a multidisciplinary profession that allows the functionality, comfort, safety and efficiency of the built environment by integrating people, place, process and technology.

According to [13], facilities management has a significant influence on how efficiently companies function in several areas. In financial terms, the management activities represent the second-highest cost for any organization, with few exceptions. In efficiency terms, it influences business assets' life cost and usability since it includes their management, operation, and maintenance. In compliance terms, the health and safety of the building's occupants are guaranteed by facility management operations. Ultimately, in environmental and sustainability terms, facilities management is responsible for the impacts of its operations on the local and overall environment.

Encompassing those several areas, the activities included in the facility management obligations will depend on the size, stature and location of a business. [14] defines the two types of facility management services:

- Soft Services: By the soft facility management, the building environment is transformed into a more pleasant, secure, and efficient place. The services can include landscaping, window cleaning, cleaning, security, waste management, catering, and car parking [14].

- Hard Services: Those are the ones directly related to the fabric of the building, ensuring the health, safety, and welfare of employees. Some examples include lighting, plumbing, heating, air conditioning, building maintenance, and fire safety systems[14].

Among the hard services, building maintenance is an expensive process both from financial and environmental aspects. Maintenance includes the activities undertaken to reach the intended functions and optimal performance of a building, including enhancing the indoor environment quality and improving occupant productivity and satisfaction [15].

Maintenance activities are divided into Preventive and Reactive maintenance. Preventive maintenance includes activities for which there is prior planning, encompassing inspections and assessment of the conservation state of the buildings. It includes subsequent repair work on its various elements, with a record of the activities, which are repeated systematically and periodically. It can be time-based when it follows pre stipulated time intervals, or condition-based when the assessment of the assets will dictate the occurrence of the maintenance activity [15]. On the other hand, reactive maintenance includes the non-planned activities necessary to deal with failures or other problems as soon as they arise. Since it only takes place when a piece of equipment loses its total or partial function, it can possibly lead to downtime having a higher cost than preventive maintenance [15].

Including maintenance, activities happening during the Facility Management phase of a building are responsible for generating information about the building and its assets and can also depend on previous information to happen. Therefore, the efficiency of communication and information flow is one of the essential conditions for achieving the strategic objectives of FM, which implies the need for advanced technological tools that ensure efficient information management and integration of various actions related to FM [3].

Advanced digital technology offers numerous solutions that facilitate the collection, processing and aggregation of information on buildings in use and facilitate the development of cause-effect models, conclusions and forecasts [3]. The application of those technologies has become a facilitator of opportunities in the FM industry, allowing it to gain a competitive advantage, increasing communication and coordination between the various stakeholders, and facilitating access to pertinent information [4].

The Computer Aided Facility Management (CAFM) software has been used since about 1990, supporting operation and maintenance activities of building assets and assisting managers in dealing with the increasing complexity of the management environment [4]. The CAFM system helps managers to find patterns and analyze different aspects regarding the facilities, enabling an efficient decision-making process. In addition, the Computerized Maintenance Management Systems (CMMS) is commonly a part of the CAFM packages. CMMS focuses exclusively on managing maintenance operations related to equipment and facilities, allowing managers and maintenance technicians to obtain a more detailed view of those activities [16].

Aiming to improve the efficiency of the CAFM systems, the FM industry is presenting a growing interest in Building Information Modelling (BIM) due to its expected benefits from retaining and transferring information across the various phases of a facility life cycle [6].

2.2 Building Information Modelling

A Building Information Model (BIM) is a facility digital representation which includes a great and precise amount of information. It typically presents the three-dimensional geometry of the building components and also encompasses non-physical objects, such as spaces and zones, a hierarchical project structure, or schedules. The acronym BIM can be used to refer to the model itself or to the process of creating the model. The virtual process encompasses all aspects, disciplines, and systems of a facility within a single, virtual model, allowing owners, architects, engineers, contractors, subcontractors and suppliers to collaborate more accurately and efficiently than traditional processes [17].

Figure 1 illustrates BIM applications spanning over the entire life cycle of a facility and the possible uses of BIM within each of those phases. As stated by [17], there are several benefits associated with BIM implementation, and they can vary upon the stakeholder and phase being considered.

For the owner, BIM can ensure the project requirements are met from the early design stage, being possible to evaluate the building performance and maintainability, reducing financial risk due to reliable cost estimates and decreasing the number of change orders [17].

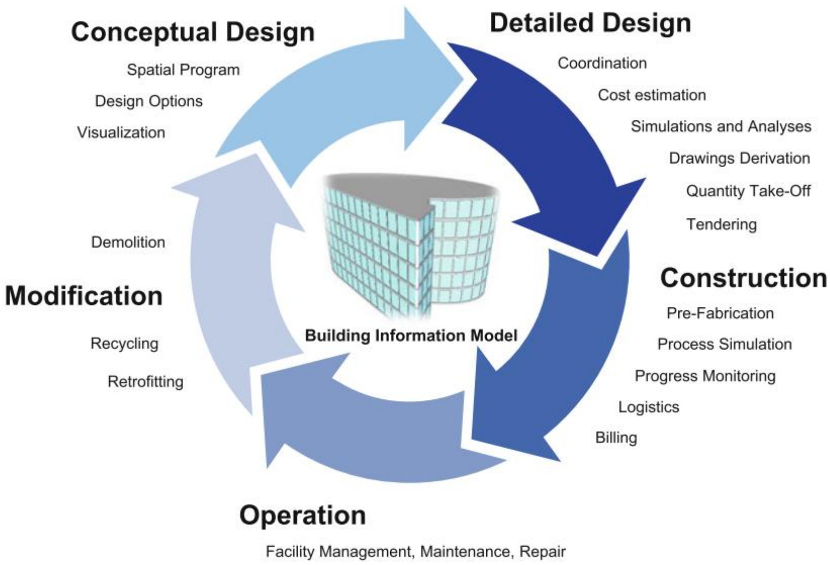


Figure 1: BIM applications during the life cycle of a facility
[5]

In addition, the designers can carefully analyse digital models and visual simulations and receive more valuable input from project owners. It is also possible to anticipate the building environmental performance and act to improve it[17].

From the contractor perspective, BIM can generate a better cost and production estimation and help to discover design errors in the early stage through clash detections. It is also possible to establish previous construction and safety planning with better compression of the cost and schedule [17].

For the operational phase of a facility life cycle, BIM allows essential information to be found in one electronic file. For facility managers, its database provides all information about any asset in the project, decreasing time spent searching for the required information among different sources [17].

The process of application of BIM technology in FM is unique for each organization and "varies depending on the organizational mission and the requirements of the facilities infrastructure supporting it" [18]. Even with the characteristic of the implementation processes being unique and variant, its benefits and challenges are transversely common through different organizations.

2.3 Benefits and challenges of BIM-FM

2.3.1 Main benefits and uses

It is commonly accepted that BIM implementation can have value to facilities management if its adoption is made through strategic planning. The implementation of BIM in the FM phase is still developing, promoting the growth of the number of studies about the subject [19]. In this context, [18] presented with more details the potential of BIM implementation in the FM phase of a facility (BIM-FM) during the Creative Construction Conference in 2016. Among the numerous applications highlighted there are:

- Space management: the facilities operators must understand the operations happening within the building asset. Such knowledge allows adequate space classification, appropriate allocations of space according to its use and enhancement of space standards [20]. According to [18], the application of BIM for this FM service is undeniable relevant since it facilitates space analysis, helps estimating space requirements, as allows spaces visualization and coordination.

- Maintainability studies: the use of the BIM model enables the performance of automated maintainability studies by FM staff. According to [20] cited by [18], maintainability studies are concerned with the following areas: accessibility, sustainability of materials and preventive maintenance.

- Mobile localization of building resources: ordinarily, FM personnel rely on a paper-based facility map for the building resources localization when performing daily procedures. This approach may not be effective enough for ordinary FM operations and even be dangerous for emergency responses. A prompt reaction is crucial for efficient resolution and detection of problems, according to [20] cited by [18]. Therefore, the BIM model and localization technologies integration may optimize productivity, safety, and security by real-time resource location.

- Safety and emergency management: [21] cited by [18] underline that the use of BIM allows critical and sensitive data to be secured and be only accessible by those demanding the information. Having the relevant data in place, organized and accessible, guarantees prompt and adequate reaction in an emergency. Professionals from rescue units could receive the necessary detailed information before its arrival and develop a solution for a response and recovery more effectively [18].

- Renovation and retrofit planning and feasibility: having a BIM model of a facility provides a basis for planning and feasibility studies as the historical database of the existing building is used as a reference for the work planned cost estimation. [22] cited by [18] highlights the possibility of seamless remodelling, refurbishment or demolishing processes as the availability of a BIM model allows the visual information about the designated buildings.

- Energy analysis and control: [23] cited by [18] states the importance of building energy performance for procuring sustained investments. However, there is the current need for a more efficient approach for energy simulation since energy consumptions systems are not fully integrated. [24] cited by [18] presents a BIM-based system that enables complex energy evaluation through integrating energy-related information across the life cycle of the building.

2.3.2 Financial aspects

The operation and maintenance phase of a project can contribute to over half of its total life cycle costs, and still, it is often overlooked by project stakeholders during the design and construction phases [2]. [19] states that much of these costs are due to inefficient business process management, including redundant facility management systems, systems training, rework costs, loss of productivity, among other issues that BIM could address.

2.3.3 Adoption acceptance

The challenge for demonstrating the value of BIM in the operational phase of an organization is faced by facility managers recurrently [25], [26]. [27] proposed implementing a BIM-FM workflow for the Aquatic Centre of the XVIII Pan- American Games in Lima, Peru, and concluded that the lack of proof that it would bring a positive investment return was considered a barrier, causing less investment from the FM team of the project.

Contributing to the restrain of BIM adoption in FM applications, a client's lack of BIM awareness is exacerbated by a deficiency of FM professional BIM skills and understanding. [28] presents that in a survey of BIM professionals completed by the UK National Building Specification (NBS) in 2017, the statement "clients do not understand the benefits of BIM" was agreed by 72% of the surveyed professionals. In addition, the fact "no client demand for BIM" was highlighted as a barrier to BIM adoption by 65% of those. [29] reassures there is a lack of demand by clients for BIM's for FM, added to the general lack of collaboration between project stakeholders for modelling and model utilization [20].

Additionally, there are cultural challenges for BIM adoption since the AECO industry is historically hesitant in adopting new technology processes, as highlighted by [20]. The author also considers that unless the professionals can prove the BIM for FM benefits, its adoption in the industry will continue to be insufficient.

2.3.4 Model creation

The BIM model may be created in the beginning of the life cycle of a building, starting at the design phase, going through the construction phase, and being posteriorly delivered for the facility manager or owner for its use during its operation. For that case, the manager receives an as-built model from which relevant data can be extracted. In this case, the determination of data relevant to the operation phase involves the reduction of the data volume to which is necessary, making it more straightforward to manage over the entire lifecycle of the property [5]. Another option from models created before the operational phase of a facility is establishing the information requirements in the early stages of the project. Instead of retrieving the usable information from an overpopulated model, it guarantees the collection and delivery of just the necessary information for the handover moment.

In addition, models for the operational phase of a facility can be produced after the building is constructed. In that case, an initial investment of effort must be made to create the model and select relevant information. The base for the modelling process may come from drawings, on-site surveys or measurement of the spaces and building parts, resulting in an Inventory BIM [30]. The Inventory models usually are utilized as initial data for the design of repair construction projects, or they can also serve as a spatial BIM for facility management software in case of upgrading it to model-based information management.

[31] uses a case study to examine the development of BIM models for existing buildings and presents four critical challenges for developing the Inventory BIM. The first challenge is identifying the critical information required. Secondly, the decision upon the level of effort that should be made to create the model. The third challenge is managing how the information is transferred between the BIM model and FM tools. Finally, defining the procedures to handle the incompleteness of the documentation.

In the case of identifying the critical information, [30] states the necessity for carefully consider the modelling accuracy and the level of details in the BIM to construct, so benefices and costs are well balanced. [30] also suggested that the information can be restricted to the basic data of spaces and objects if the modelling is performed primarily for the needs of facility management software.

2.3.5 Model update

The operational phase of a building is a living process. The events occurring during the phase are responsible for modifying and creating new information about the assets. For the BIM-FM efficient application, it is relevant that the source model is updated once the events happen to keep it being a trustful source of information to support the management process.

An updated BIM guarantees the information required for routine facility management activities and emergency ones are kept as updated as necessary to allow those operations to happen. As for the utilization of this information during those operational activities, [32] proposed an ontology to manage BIM-based FM information by linking the BIM-based building elements to historical work records in an FM system database. Other integration approaches for BIM and FM data have been proposed recently, focusing on the integration of mechanical, electrical and plumbing (MEP) data from as-built BIM models with maintenance data to run routine operation and maintenance tasks and respond to MEP-related emergencies [33]. A similar approach was also used to enable the automatic scheduling of facility maintenance work orders [34].

In addition, [5] states that all changes in a existing facility must be recorded in its digital twin since this constant update makes the model an excellent basis for more significant renovations or modifications required later. For the end of the building life cycle, considering it will be demolished, the digital twin can provide detailed information about the materials used in its construction to planning their recycling or disposal [5].

Even though the model updating is understood to be necessary, a study by [27] that proposed a BIM-FM workflow to a case study, highlights the model updating was a barrier in the process of implementing this workflow since the facility management team had no qualification for using the authoring BIM tool.

2.3.6 Interoperability

Interoperability is the ability of computer systems or software to exchange and make use of information. The lack of interoperability of current systems and fragmentation of existing information is among the several challenges of BIM adaptation for asset management [4]. [35] states that one of the reasons for the lack of interoperability between BIM and FM systems is that the latter are usually already utilized for one or two decades in existing assets. In addition, the susceptibility of the various stakeholders involved in a building life cycle to using diverse software, each of them focused on its function within the design, construction, and operation chain, can cause the lack of interoperability.

With open formats not being efficiently utilized, and data transfers between the model and the operation software not being automated, owners and facility managers have financial expenses for the person-hours spent on the relevant data inserted into FM systems [35]. BIM supports the idea of the use of a building model as the basis for all data exchange operations aiming to avoid the re-entering of data and reducing the risk of errors. The adoption of BIM enables from the digital transference of building data to contractors in the construction phase to the “handover” of building data to the client or operator of the building, among other data exchange scenarios.

To support the transference of building data between software products using BIM and with low data loss, a data exchange format is required. [5] states that such format must present unequivocal descriptions of geometric information and detailed description of semantic information, including the classification of building components within a standard hierarchy of types, describing the relationships between them and their relevant properties.

Industry Foundation Classes (IFC)

In this context, the Industry Foundation Classes (IFC) schema was developed by buildingSMART to address interoperability for all data transfer to occur during a facility life cycle. IFC is registered with ISO 16739:2018, which specifies the EXPRESS and XML data schema definitions.

The open data model describes architectural, building, and construction industry data. According to [36] "the schema specification can describe how a facility or installation is used, how it is constructed, and how it is operated". The IFC encompasses geometrical, syntactical, and semantical requirements and specifications of BIM data exchanges.

The IFC format is constantly updated to meet the user needs, amend gaps, and improve its application range. The schema has undergone several updates (Figure 2) since it was launched in 1997 under the version "IFC 1.0", in which version "IFC4 ADD2 TC1 4.0.2.1" currently applies as the newest regulated one [37].

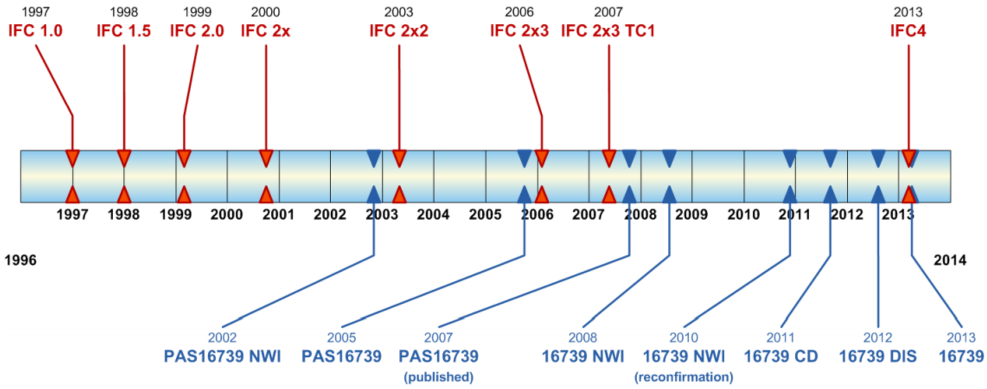


Figure 2: Developed versions of the IFC format
[38]

The schema is extensively employed within the Architecture, Engineering, Construction and Operation (AECO) and civil infrastructure industries. Industry experts and researchers apply and study the schema intending to accomplish desired BIM data exchanges between heterogeneous BIM authoring and application tools [39].

Numerous BIM software applications have implemented data import and export interfaces for this format, and buildingSMART has developed a corresponding certification procedure to ensure the quality, reliability, and standard of data exchange. The certification procedure allows software developers to maintain their quality assurance processes, and buildingSMART provides an online list of certified software [40].

The Model View Definitions (MVD) are the base for the software certification since they define different conformance levels [41]. According to [41], the concept of MVD was created as a selection of entities from the complete IFC schema, so the certified software did not necessarily have to implement its entire scope. Over the years, with the introduction of the term "use-case," the definition of MVD can be the "standardized exchange of data for a specific use-case". There are two current 'official' MVDs in IFC4 (Reference View, and the upcoming Design Transfer View), and five additional ones are being developed [42].

For the scope of this work, any term retrieved from the IFC schema will appear in italic formatting (i.e. *IfcWall*).

2.3.7 Definition of information requirements

There is a lack of a standard process or set of best practices for an FM-enabled BIM creation that is capable of addressing different types of organizations and their information requirements, the owners and managers have no clear direction of what BIM deliverables demand [8]. A poor understanding of information requirements among them in terms of the level of detailing, nature of data, and format required has affected the adoption of BIM in facility management [43].

The issue causes an insufficient use of BIM models by building managers and owners since they either do not contain the information needed [44], or, in many cases, contain unnecessary information. This implies the necessity of identifying the use for the required information during operations and gathering it from the project participants in a useful way [45]. The definition of the right amount and type of information to populate a BIM is essential for the efficient performance of FM functions since having a high volume of unrequired information makes it challenging to manage.

[46] cited by [7], states that the amount of information that lacks purpose becomes unused data, having the high volume of data as a challenge faced by facilities management to reach the full potential of BIM [45] referenced by [7]. In addition, [7] states that owner guides and standards are usually generic but also notices a change in the scenario since BIM adoption encourages owners to provide more precise information regarding required deliverables.

Despite the relevance of the subject, FM needs in relation to information requirements have not been extensively studied [20], [48]. Some studies aim to develop a information requirement document that sets out the information for handover, including standards and procedures as part of the project delivery process [49],[50]. However, these studies present generic documents that do not detail the operational information requirements.

In an effort to identify these requirements, [20] highlighted areas of BIM implementation in asset operations that could create business value for asset owners by defining their business-level data requirements. Similarly, [45] developed an iterative approach to identify information requirements through linkages with business needs. In addition, there have been efforts to develop and test an information requirements template, including a guidance document designed to meet the organisational needs of BIM-based processes [50], [51].

To better understand the process of developing operational information requirements, [45] investigated two large owner organisations. Although it attempts to identify common information requirements, the study does not consider the impact of the asset owners' business sector on these requirements. Therefore, a knowledge gap arises in identifying the critical operational information requirements for FM business processes [52].

2.4 Software and platforms for BIM-FM

The use of technological support to analyses and activities during the FM phase of a facility has already been justified. Among the possibilities of software and platforms to be used to assist facility managers, there are the considered FM systems created to perform the required activities for this discipline. In addition, other platforms capable of data analyses can be considered helpful for the operational processes.

Considering the FM systems [53] , two ways of implementing them in organizations are on-premises or cloud-based. In the first option, the customer keeps the system in a private data centre inside their firewall, while in the second, the system is kept in a data centre provided by the software vendor. The second option is the most common because of its increased security promoted by cloud-based systems and reduced Information Technology (IT) costs. FM software producers have been looking for ways to integrate BIM models with building management applications, generally choosing between the two mentioned options.

The following subsections will present common BIM-FM software, including a general data analyses platform, and highlight their main characteristics and capabilities.

2.4.1 Archibus

Archibus is an integrated management platform that connects bi-directionally with the BIM model and is easily integrated with mobile devices, GIS and ERP systems such as Oracle, SAP and Sage. Applications provided by Archibus include Real Estate Portfolio Management, Capital Project Management, Space Planning and Management, Asset Management, Environmental and Risk Management, Building Operations and Workplace Services. Archibus is available in both a web-based and a Windows-based platform and can also be cloud-based. In total, it contains three platforms that share the same database: Archibus Web Central, Archibus Smart Client, and Mobile Archibus.

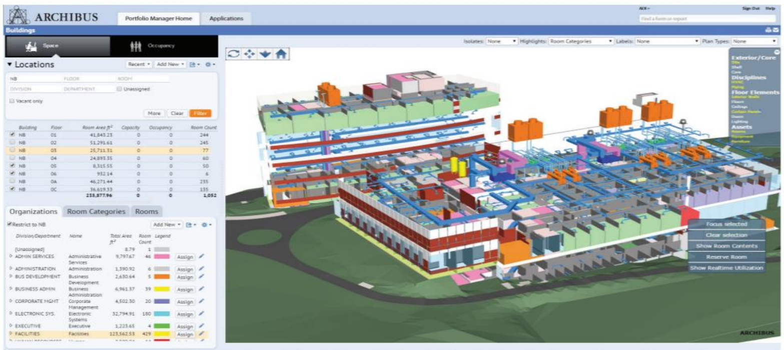


Figure 3: Preview of Archibus web Central 3D browser
[54]

2.4.2 BEXEL Manager

BEXEL Manager supports projects management from the initial phase through all phases of a building's life cycle. The BEXEL Manager FM version allows the manager to carry out tasks related to BIM-FM, containing features such as building management, intelligent document linking, and asset data modelling. In addition, it provides 3D and a cloud-based document management system.

Figure 4 illustrates the operating scheme of BEXEL Manager FM. BEXEL's team of designers and engineers updates the BIM FM model whenever any changes occur in the building. It also creates BIM models for existing buildings, updating any changes previously made to the building. BEXEL also plans maintenance, acting as manager of its clients' buildings or providing support so that the management team can plan maintenance in the best way, using the created BIM FM model.

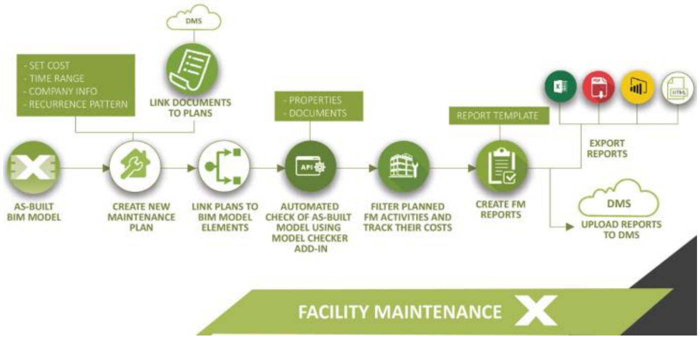


Figure 4: BEXEL Manager FM operating diagram
[55]

The BEXEL file exporter generates files containing the model geometry and associated metadata. The manager can export both native Revit files and all linked files simultaneously. It also supports importing and exporting IFC files. The BEXEL Manager Properties Importer allows the manager to synchronize data between Revit and BEXEL Manager. Properties can be edited or created in BEXEL, and the data can be imported back into Revit, updating or creating their properties if they were initially created in BEXEL Manager.

2.4.3 FM:System

FM:Interact, developed by FM:Systems, is an integrated management platform that provides the functions of space management, sustainability management, change management, maintenance management, strategic planning, real estate management, asset management, and project management. FM:Systems provides a bidirectional connection to AutoCAD and Revit models and drawings. Figure 5 illustrates the integration of the BIM model with FM:Interact.

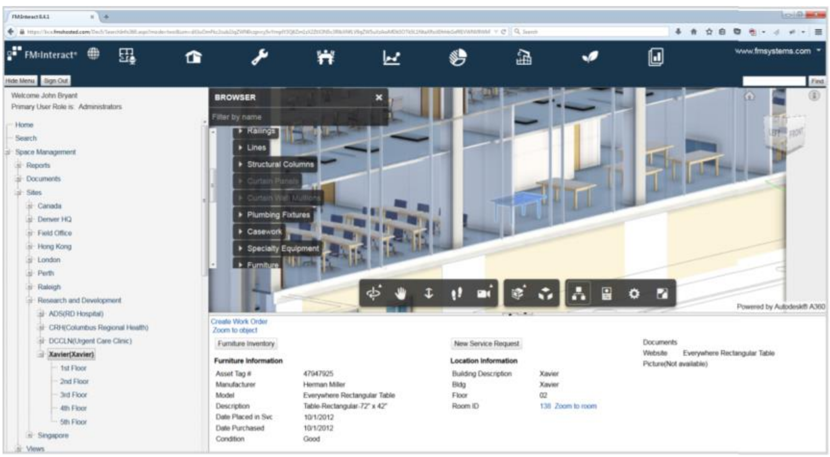


Figure 5: BIM integration in FM:Interact
[56]

The connection between Revit and the cloud-based system allows access to model information and updates via the web on desktop and mobile devices, allowing the sharing of information in the design, construction, and operational phases, reducing the loss of information, and increasing collaboration.

The system can be hosted either in the organization's infrastructure or in the system's hosting environment. FM: Interact also enables integration with database systems previously used in organizations.

2.4.4 YouBIM

YouBIM is cloud-based and is accessible via web browsers and mobile devices. It can be installed on a private cloud or a customer's server. It integrates data from different sources in a 2D or 3D online model, which allows access to operation and performance data, manuals, manufacturer data, warranty, among others.

These data can be imported from databases and can also be manually entered into the YouBIM environment. Maintenance training documents and videos corresponding to assets can also be viewed. These documents can be uploaded to YouBIM, or by integrating YouBIM with other document management systems. Figure 6 shows the visualization of a BIM 3D model in YouBIM.

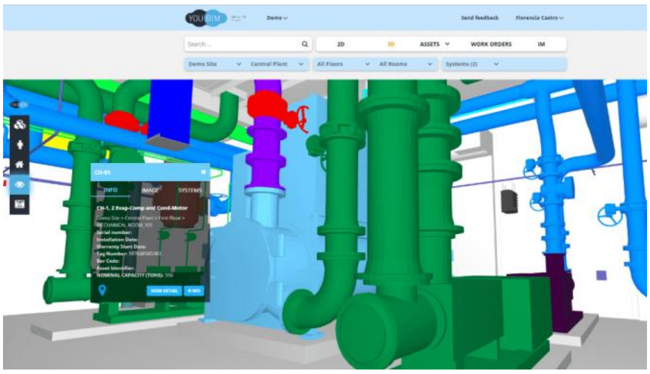


Figure 6: 3D visualization of the BIM model (YouBIM) [53]

In 3D visualization, the manager can hide building components for a better visualization of other elements. The 3D viewer accepts BIM models from different formats and software, including Revit software and formats as IFC, DWG, and NWD. It can also integrate with various building management systems.

There are currently YouBIM plug-ins for Revit and Navisworks, and additional plug-ins are in development for other BIM software. Through plug-ins, models are published in the client's secure cloud, allowing the user to choose only the information necessary for operation.

YouBIM, through the YouBIM WO module, also allows the opening and status updating of work orders and their storage in the history of the corresponding assets.

2.4.5 General purpose data analytics software (Power BI)

FM is a discipline that deals directly and constantly with data analysis. Information from various sources is combined and manipulated to inform FM activities. FM measurements are often based on statistical tools, using histograms and line charts crated using the collected data, and identifying ups and downs. The graphical representations clarify the decision-making process and allow better management presentation [57].

For this context, the Business Intelligence (BI) solutions can work with an integrated set of tools that support data transformation to support decision-making and can be supplied with large amounts of data [58]. Power BI emerges as a business intelligence platform from Microsoft that can encompass FM functions and uses even not being considered as FM software, consisting of three basic elements:

- Power BI Desktop - a Windows desktop application;
- Power BI service - an online SaaS (Software as a Service) service;
- Power BI mobile apps for Windows, iOS, and Android devices.

The platform potential comes from a high customizable interface that allows it to develop a huge range of analyses for any subject. Power BI allows the creation of interactive reports that can be shared with other project stakeholders, having diverse options for visualizing, and configuring data. Figure 7 shows an example of a dashboard created using Power BI with different visuals and analyses.

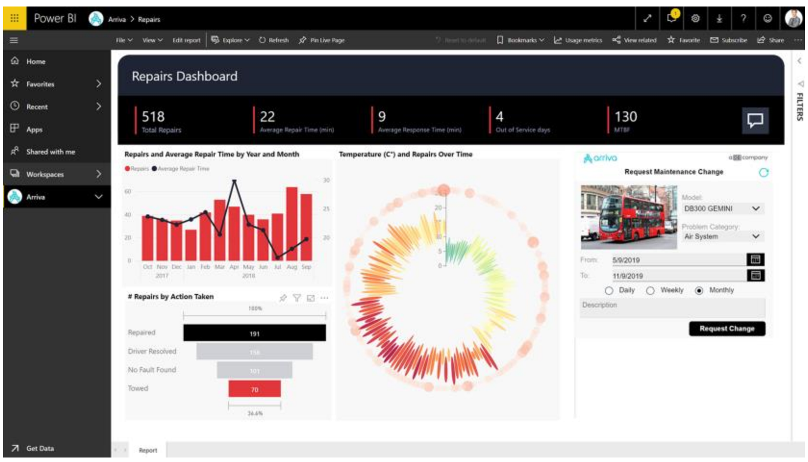


Figure 7: Dashboard example in Power BI Desktop
[59]

Another huge advantage of using Power BI is its capability to use data from diverse sources. The formats of data that can be imported into the platform are the ones from Excel (.xlsx, .xlsm), Power BI Desktop (.pbix), and Comma-Separated Value (.csv). In addition, the platform and its associated plugins can convert data from other sources allowing its utilization in Power BI.

IFC is among the formats that can be converted by specialized plugins and imported into Power BI. The platform's capability to import the converted IFC files allows its utilization to assist the information management process for any phase of a building life cycle, including facility management. The advantages are even bigger for the FM phase because of the variability of uses, assets, procedures, and analyses among different facilities

Figure 8 shows examples of visuals inside the Power BI platform converted by the Trace plugin from Pg apps. The plugin can convert an IFC into spreadsheets to be imported to the platform and it includes the capability of visualizing the managed building. In addition, the existing plugins to IFC conversion usually have pre-prepared Power BI templates that can be downloaded to assist the first steps of using Power BI to support FM.

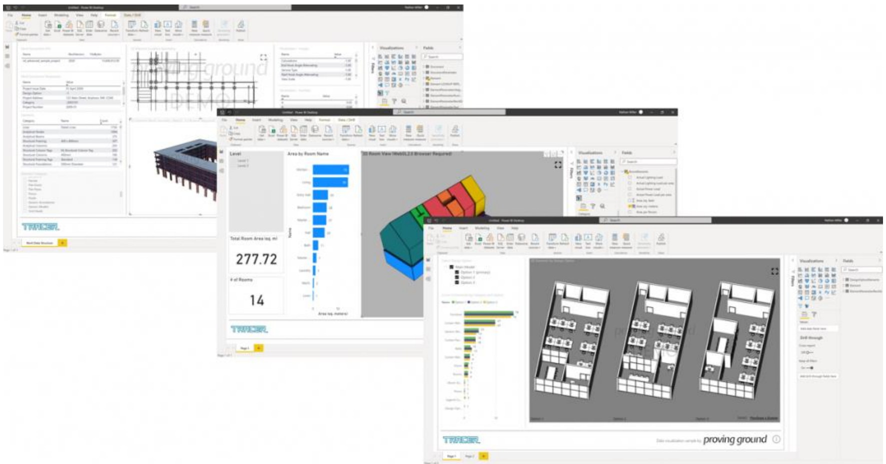


Figure 8: Power BI dashboard using Trace plugin
[60]

Inside the platform, Power Query is a data transformation and data preparation engine. This interface aims to allow the necessary data modifications by interacting with a set of ribbons, menus, buttons, and other interactive components. Inside Power Query Editor, it is possible to connect to a wide range of data sources, including externals ones. The transformation engine carries many pre-built transformation functions that can be used through the Power Query Editor, being as simple as removing a column or rows from the source tables or performing advanced transformation such as merge, append, group by, pivot, and unpivot the cells of the table.

The Editor capacity to work with external sources of information is a relevant tool for the FM discipline since some data usually used for FM activities can come from specific external software. For example, information about Work Orders is usually stored in a separate software and, using the platform, can be integrated and manipulated along with other data about the asset being managed.

2.5 Standardization applied to BIM-based Facility Management

The efficient BIM implementation in the FM phase of a facility can only be made through strategic planning. The process includes considering information management strategies and developing well-defined instructions. Some numerous manuals and guides can be found in the literature to help the complex process of BIM implementation. In addition to those guides, there are also regulated standards on the subject.

The standardizations and guides support selecting information to populate the BIM-FM model, including recommendations regarding the model's requirements for interacting and exchanging information with building management software.

This section presents a summary and highlights the main points from a few guide documents that assist in creating information requirements and also assist the modelling process, emphasising the ones focused on the BIM-FM context.

2.5.1 Information management process based on the ISO 19650 and the EN 17412-1

The ISO 19650 standard is an international standard for managing information over the whole life cycle of a built asset using building information modelling (BIM).

The UK BIM Framework foundation has been developing a Guidance based on the indications of the ISO 19650 series, created to support implementing the normalization in the United Kingdom. The guidance presents a total of eleven parts, being two of them still to be confirmed. For the context of this study, three parts are considered the most relevant.

The first part of the guidance from UK BIM Framework (Guidance Part 1 - “Concepts”) [10] is in its second edition, it is composed of 44 pages with seven chapters, and it was launched in July of 2019. It presents the main definitions for the concepts presented in the ISO 19650 series. Part 3 of the Guidance (“Operational phase of the asset life-cycle”) [11] is in its second edition, and it was launched in February of 2021. It presents ten chapters in 61 pages and is created based on the ISO 19650-3 “Operational phase of the assets". It provides guidance on the roles and responsibilities involved in implementing ISO 19650-3, when it can be applied, and the details of the information management process. The Guidance Part D [9] ("Developing information requirements") has 90 pages subdivided into three chapters and an Annex with examples of information requirements applied to diverse project contexts.

The following subsections will encompass the main concepts and process from the ISO 19650 series retrieved from the Guidance and, at the end of the section, the specifications from the European Standard EN 17412:1 [12] ("Building Information Modelling. Level of Information Need. Concepts and principles") are presented, including their context within the ISO 19650 series.

2.5.1.1 Actors and respective responsibilities

Since implementing a BIM process in a project involves numerous actors, it is necessary to understand who are those actors and which are their activities within the context of the overall project team to ensure collaboration and effective teamwork, the essences of the ISO 19650 series according to [10].

The standard series define three types of actors ("parties") and three types of teams involved on a BIM-based project [10]. Among the actors, there are:

- Appointing Party: the organisation leading the project or asset management, e.g., the client or asset owner;
- Lead Appointed Party: the party coordinating information exchange between task teams or between a delivery team and the appointing party;
- Appointed Party: an actor who generates information about the project, e.g., a contractor, subcontractor, supplier, or consultant.

The teams presented by the standard and their definitions are [10]:

- Project Team: everyone involved in the project;
- Delivery Team: a lead appointed party and their associated task teams, e.g., a contractor and its subcontractors and suppliers;
- Task Team: a person or group of people performing a specific task, e.g., the architecture team or the subcontractor who is constructing the landscaping.

Figure 9 below, derived initially from ISO 19650-3, illustrates the relationship between actors and teams and their position within a project.

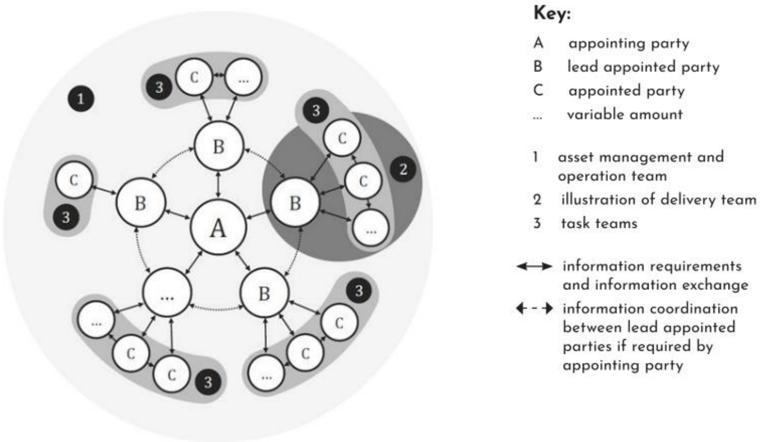


Figure 9: Relationship between parties and teams involved in a project [11]

From the analysis of the image, it is understood that the central party of the project is the Appointing Party (A), to which all the information is aimed. All the participants in the project constitute the Asset Management and Operation Team (1), which is subdivided into Task Teams (3), and those within the teams are the Appointed Parties (C). Each of those teams relates directly with a Lead Appointed Party (B) that could be an individual, part of the corporation teams, which has a direct relationship with the Appointing Party (A), also being responsible for guaranteeing the information exchange. The Lead Appointing Party (B) and the Task Team (3) together create a Delivery Team (2).

To better understand the remaining subsections of this work, it is necessary to emphasize that the term Appointment in the ISO 19650 series is used to describe any agreement between an Appointing Party and an Appointed Party [10] and it implies the occurrence of information exchange [9].

2.5.1.2 Information Requirements

According to [9], the AEC sector tends to be reactive and poor at planning, taking late actions during the asset life cycle. To implement the use of BIM successfully, the mindset needs to be changed and become focused on the information management processes.

As part of the process, there is the definition of information requirements. According to Guidance part 1 [10], "clearly defined, value-driven information requirements prepared at the outset of the project are a key enabler to collaborative and effective information management". Establishing information requirements is decisive since with an ungrounded input in the form of inadequate information requirements, a not valuable output is developed, with insufficient information being created.

The ISO 19650 series assist in understanding what information is required by and from an actor, independently of its position within a project. It also advises on the coordination and sharing of it with other actors or parties [10].

A central statement of the ISO 19650 series is that information must be created for a specific purpose, allowing someone to make use of it. The information requirements need to specify the precise necessary information that enables an action to happen so it can fulfil a purpose successfully. Creating information with its use in mind is the definition of working collaboratively [9].

The standards cover the information requirements from Appointing to Lead Appointed Parties and posteriorly to Appointed Parties. For the Appointed Party, this includes information requirements from both the Appointing Party and Lead Appointed Party. However, information requirements can also exist between task and delivery teams since every party within a project is likely to have information requirements [9].

Focusing on the Appointing Party obligations, the actor requires information both during and at the end of a project with different final objectives [9]. There are four main information requirements documents which are within the Appointing Party responsibility:

- Organizational Information Requirements (OIR)

Those are information requirements at the strategic organizational level. OIR encompasses the high-level information needed about assets throughout their lifecycle. Those requirements are linked to the management of the business by the Appointing Party, allowing an informed and effective process.

- Asset Information Requirements (AIR)

The AIR are high-level information requirements established for the assets and are derived from the purposes of the OIR. The AIR is created when the set of high-level requirements across the organization (OIR) are related to specific assets, and it is directly associated with the operation and maintenance phase.

For an Appointing Party that needs to develop information requirements for multiple assets, it is crucial to create a rationalized hierarchy organization so the AIR can have a consistent structure, being as practicable as possible, possibly related to one or a group of assets.

The set of requirements within the AIR informs the detailing of the information requirements, which are more precisely described in the form of Exchange Information Requirements (ISO 19650-3 clause 5.2.2 according to [9]).

- Project Information Requirements (PIR)

The PIR is partly derived from the OIR, being composed of high-level information requirements for projects. The development of it is linked to the design and construction phases of a project, enabling the understanding of the high-level information the Appointing Party requires during those phases.

- Exchange Information Requirements (EIR)

The EIR are information requirements at the appointment level for assets and projects. Specifically, while the AIR and PIR are developed in relation to specific phases of a facility life cycle, the EIR is part of both cited documents, being linked to a specific appointment to happen during those phases. Indeed, the EIR is the specification for the exact information required. When the moment of creating the EIR, the appointing party already has asset-related purposes defined as part of the AIR and any project-related purposes as part of the PIR.

The Appointing Party develops a set of EIR related to each project, which is then filtered for each appointment. Therefore, there will be multiple EIRs if there are multiple appointments during a project. Even though the EIR is constructed by purpose, the final EIR outputs should be filtered by appointments, and an appointment may contain multiple purposes [9].

From ISO 19650-1, the guidance part 1 [10] states that it is the responsibility of the Appointing Party to understand the required information when concerning their assets or projects, aiming at supporting organisational or project objectives. This actor should clearly express these requirements to other parties through their Exchange Information Requirements (EIR) to specify or inform their work. Figure 10 illustrates the relationship among the cited information requirements previously defined.

Within the requirements documents the required information need to be detailed. According to the ISO 19650 series, four main facets can be used to describe the information detailing [9]:

1. Purpose, as the need that the information will fulfill
2. Content, composed by

a. Content summary, representing the overall content of the information

b. Content breakdown, which brings geometrical and alphanumerical information requirements

3. Form, on how the information must be presented

4. Format, for the information encoding

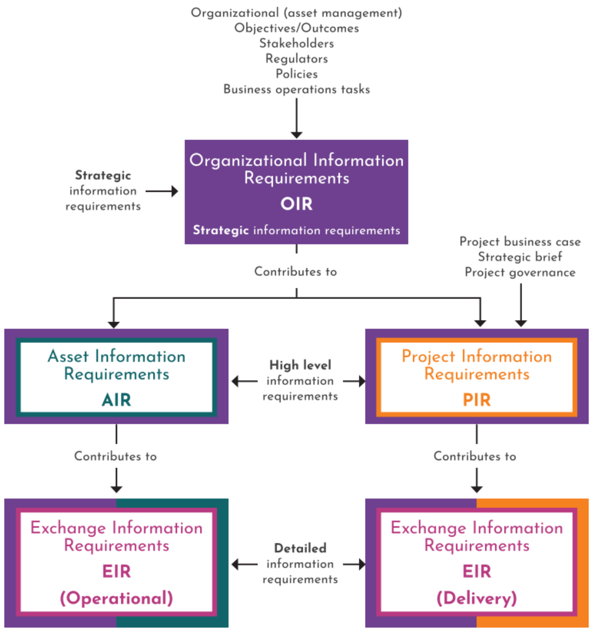


Figure 10: Relationship among the four information requirements [9]

For the definition of those requirements, both structured and unstructured information are considered. [9] states that structured information is machine-readable, while unstructured information is human readable. The idea of information facets was introduced to describe how both types of information could be divided across content, form, and format, and different combinations of these facets contribute to the EIR [9].

As for understanding the application of those information requirements, [10] states that when working on a project level, three separated paths with respective inputs and outputs can be followed when using BIM according to the ISO 19650 series:

1. For project delivery with no asset management considerations: the PIR, EIR and PIM apply

2. For asset management with no project delivery considerations: the OIR, AIR and AIM are used

3. For combined project delivery and asset management: the OIR, AIR, EIR, PIM and AIM are generated; or PIR, EIR, PIM and AIM are established

The termination "R" refers to "requirements" and, for the final result of these requirements, the termination M states for "model", as in PIM (Project Information Model) and AIM (Asset Information Model). [10] highlights that the term 'model' must be understood in the abstract sense since it is not just a single or federated geometrical model but a collection of information containers, however they are created or presented.

2.5.1.3 Trigger Events

The concept of trigger events is presented in Guidance Part 3 [11], and it comes from the ISO 19650-3 as one of the key concepts for managing asset information. Those events occur during the asset's life cycle, creating new information or updating information needed by the appointing party (asset owner/operator).

There are two main types of trigger events. The foreseeable ones, for which it is possible to establish advanced planning, and those that are either unforeseeable or foreseen but for which the time spent in advanced planning is not justified.

Figure 11 from [11] presents examples of possible trigger events that may occur during the operational phase of a facility life cycle. In the illustration, the first grey loop represents the project's delivery phase, as for the moment the operational phase starts. On the other hand, the second grey loop represents a refurbishment of the building, from where new Trigger Events may happen.

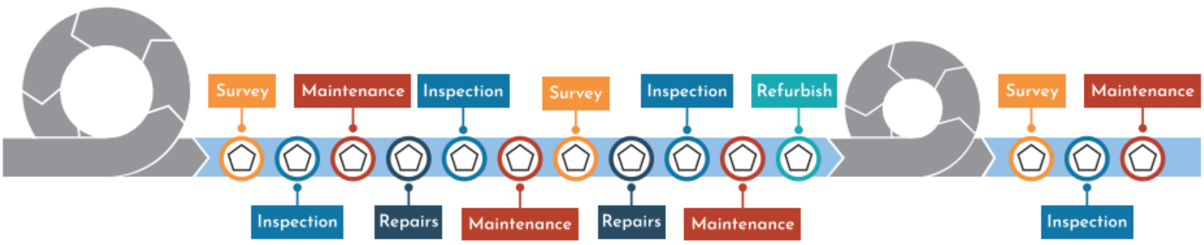


Figure 11: Trigger events during the operational phase of an asset life cycle [11]

According to the ISO 19650-3 [9], information exchange dates and delivery milestones are related to trigger events and respond to them. There might be one information exchange for small trigger responses, such as minor repairs or simple maintenance jobs. More complex triggers, such as larger-scale redecoration or condition survey jobs, might need two or more exchanges.

2.5.1.4 Level of Information Need

The European Standard “Building Information Modelling - Level of Information Need. Part 1: Concepts and Principles” (EN 17412-1 [12]), approved by the European Committee for Standardization (CEN) on 18th of October of 2020, aims to prevent the delivery of unnecessary information for the moment of the exchange processes during a building life cycle. With this intention, the standard presents concepts and principles for defining the Level of Information Need, ensuring the right information for agreed purposes is delivered. It is important to highlights that the “Level of Information Need” term should not be abbreviated [9].

The process for utilising the Level of Information Need framework is regulated by the European Standard and assists in defining the quality, quantity, and granularity of information, helping to specify the minimum information requirements concerning each purpose. Using the Level of Information Need framework permits the information to be consistently structured, enabling possible automated checking [9].

In the context of information management, the Level of Information Need is equivalent to “appointment information requirements” in ISO 19650-1, since it brings the required information for a specific appointment occurrence [9]. The process can happen at different stages throughout the life cycle of an asset .Every time the Appointing Party or Lead Appointed Party establishes an information requirement, the Level of Information Need is defined since it is one of the building blocks of the EIR [9].

EN 17412-1 [12] states the necessity for the unambiguous definition of the Level of Information to avoid different interpretations of the same requirement. Its establishment can relate to an asset or group of assets depending on the breakdown structure established by the Appointing Party. The European standard presents the concepts of Purposes, Information Delivery Milestone, Actors and Objects as the four prerequisites that inform the Level of Information Need specification and how it will be delivered.

The Purpose prerequisite clarifies the need for the information, so the Level of Information Need is used for the motive it has been required. Different objects may have varied information requirements to achieve the same purpose. To specify when the information is needed, it is necessary to specify the Information Delivery Milestone prerequisite, and the definition of the Actors involved determines who is requiring and delivering the information. All the process is only possible if the Objects are considered within a breakdown structure, so it is possible to understand their semantic, functional, or spatial relationships.

For a given Information Delivery Milestone, the aspects of the Level of Information Need should be combined for all assets to ensure all purposes are met. In other words, for a specific delivery milestone, the requirements for a given object can be higher than what is strictly required for one particular purpose since it may be required by another purpose at the same Information Delivery Milestone.

The Level of Information Need describes human and machine-interpretable information requirements subdivided into geometrical information, alphanumeric information, and documentation. The main principle is that different purposes have their own needs of those three types of information. Since there is the possibility of them overlapping or even being contradictory, the European Standard [12] suggests establishing a hierarchy between the information containers.

Geometrical Information

Within the Geometrical Information, there are five independent aspects that must be identified:

- Detail: it is a continuum range varying from simplified to detailed and describing the object geometry complexity. As more refined, more features it presents and closer to the shape of the real world the object will be (Figure 12);

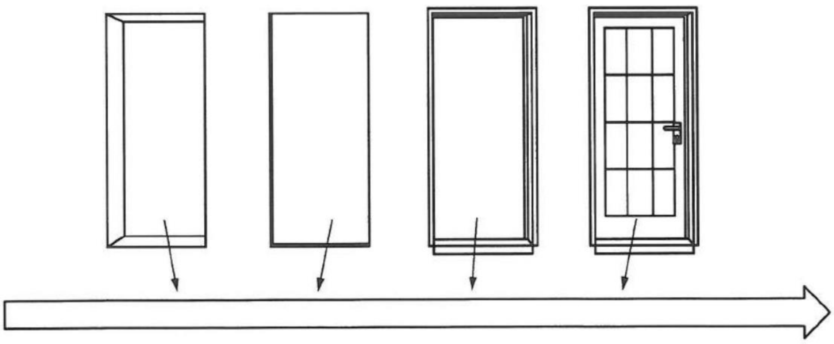


Figure 12: Detail aspect of the Level of Information Need from simplified to detailed [12]

- Dimensionality: describe the number of spatial dimensions required for the object, It can be zero dimensional (0D) for when just a location point is required, one-dimensional (1D) when a path is all the required dimensionality, two-dimensional (2D) for the need of surfaces, and three-dimensional (3D) to require the body and volume of the object.

- Location: can be relative or absolute and describes the position and orientation of an object if it is against an object or a reference point.

- Appearance: it is a continuum range from symbolic to realistic describing the visual representation of the object (Figure 13);

Figure 13: Appearance aspect from symbolic to realistic [12]

- Parametric behaviour: composed of three degrees, describes if the object's shape, orientation, and position allow full or partial reconfiguration. An explicit geometry does not allow for modification of the shape by other parameters, the constructive geometry allows change by shape parameters, and the parametric geometry allows shape modification based on object or context characteristics.

Alphanumeric Information

The alphanumeric information is subdivided into Identification and Information Content. The former aspect allows locating the object within the predefined breakdown structure. The latter is the list of all required properties, which can be grouped if necessary and should be based on a set of objects with similar characteristics.

Documentation

As for the last aspect, Documentation is defined as a set of required documents to be delivered.

The organization of those aspects and the prerequisites to be considered for the establishment of the Level of Information Need are summarized in Figure 14.

[12] states that after the definition of the Level of Information Need and even producing the information deliverable, it should go through manual and machine-interpretable verification and validation processes. According to [12] , the verification process for information deliverables represents checking the presence of objects (i.e. building, window, space), alphanumerical information (i.e. expected life, warranty period), geometrical information (dimensionality, detail, location), and documentation. While validation of

information deliverables ensures that the provided alphanumeric information, geometrical information and documentation are useful for the intended purpose.

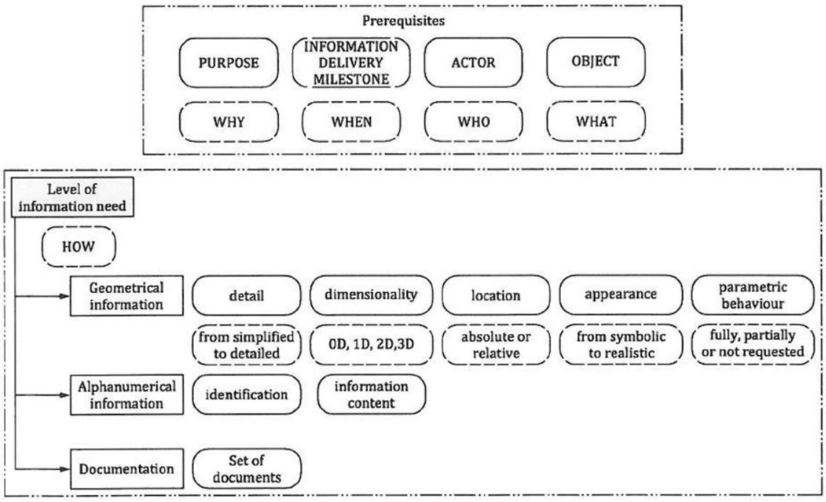


Figure 14: Relationship diagram on the prerequisites and aspects of the Level of Information Need [12]

2.5.2 Other guides and documents

In addition to the European standards already discussed, with the propagation of BIM around the globe, various guides and manuals focused on BIM implementation in the AECO industry have been developed by different countries.

The “Singapore BIM Guide Version 2.0” [61] is a reference for the development of a BIM Execution Plan and outlines the roles and responsibilities of project members, consisting of both BIM Specifications and BIM Modelling and Collaboration Procedures.

In the USA, the General Services Administration (GSA) developed the BIM Guide Series [62] to provide educational and supportive guidance and requirements for project teams, focusing on the corporations working with the GSA.

The College of engineering from the PennState University in Pennsylvania developed the Planning Guides for BIM Implementation [63] presenting four guides. The content of the guides varies. "The Uses of BIM" presents the possible Uses for a model. "Using Models in Construction: A Planning Guide" brings guidance for planning and adopting BIM for the design and construction of a project and different ways it can be used during construction. "BIM Project Execution Planning Guide" defines the parties' responsibilities involved in a BIM project with a structured procedure for creating and implementing a

BIM Project Execution Plan. ''BIM Planning Guide For Facility Owners'' assist in the decisions required to define BIM processes and practices from the organization's owner point of view.

In Brazil, AsBEA developed the Good Practices in BIM Series (Guia AsBEA Boas Práticas em BIM) composed of two fascicles, aiming to support all the parties involved in a BIM project, from design to construction. The first fascicle [64] focused on explaining the main concepts of BIM and assisting design companies in developing BIM projects. From the second fascicle [65], it is possible to understand the main steps for planning and executing projects in BIM.

The Department of Design and Construction of New York City developed the "BIM Guidelines" [66] to assist in the consistent development and use of BIM across multiple building types and for a wide range of municipal agencies, including organizations interested in utilizing BIM for public projects in the city, ensuring uniformity in the use of BIM for all New York City Public Buildings projects.

For the development of this dissertation, three other documents were consulted to assist the definition of general modelling rules. Those three documents are better explained in the following subsection.

2.5.2.1 Common BIM Requirements (COBIM)

Common National Requirements for Building Information Modelling (COBIM) was launched in 2012, being hosted, monitored, and coordinated by BuildingSMART Finland. It consists of 13 documents (series) involving different aspects of a BIM project. The series surge from the need to define more precisely what is modelled and how the modelling is done in the context of BIM implementation in the AECO industry.

For the context of this work, the series about BIM models in building management (Series 12 - Use of models in facility management [30]) is considered relevant. This series discusses the benefits of BIM in building operation management and provides guidance for BIM models to be created and maintained throughout the life cycle of the building. It also comments on FM software usage and the requirements for exchanging information between it and the BIM model. The importance of keeping the BIM model up to date is also emphasized.

For the maintenance phase of construction, Series 12 [30] describes requirements and potential areas of BIM utilization, stating the capability of BIM to support facility management services processes while illustrates examples of its utilization. The document sets minimum requirements for the methods of BIMs quality assessment for the operation phase and how to keep the model updated, including IFC based data transfer.

2.5.2.2 NBS BIM Object Standard (BOS)

This standardization, published by NBS in March of 2019, currently in version 2.1 [67], aims to normalize the information contained in the BIM objects to enable their transference to different stakeholders in various phases of the building design.

Primarily, the document states the necessity of the object to be identified in the authoring software and the importance of their association to the correct their IFC entity types and predefined types. This association is crucial to guarantee the correct mapping of the objects to the IFC schema.

The BOS highlights that IFC properties must be defined for the objects, including the common properties sets that are associated with their specific types within the schema (Pset_xxxxCommon). The document also presents a diverse range of properties options from different sources as suggestions. In the case of properties necessary for the operational phase of the assets, the management-oriented Property Sets from the IFC schema are cited (*Pset_ManufacturerTypeInformation*, *Pset_ManufacturerOccurrence* and *Pset_Warranty*).

In addition, the standard emphasizes the necessity to avoid properties duplications, suggesting that for the moment different properties from multiple sources requires the same information, they should be selected following the hierarchy presented in Figure 15.

Selection Order	Property Set
1	Hard-coded
2	IFC
3	COBie
4	BOS_General
5	<SpecificationSource>_Data
6	USERDEFINED

Figure 15: Hierarchy of properties from different sources [67]

For the fulfilment of those properties, the document states the necessity of establishing standard units for the context of the project and suggests the use of neutral values when the specific property value is not known. The necessity for those neutral values is justified by recommending the not presence of empty properties in an object.

Among the recommendations for the information requirements, the standard establishes nomenclature patterns for the properties (if from an unusual source) and also guide the process of grouping them, as shown in Figure 16.

Property Group	Autodesk® Revit®	IFC, ArchiCAD, Vectorworks & AECOsim
IFC	IFC Parameters	Pset_
COBie	Other	COBie
BOS_General	General	BOS_General
<SpecificationSource>_Data	Data	<SpecificationSource>_Data

Figure 16: Organization of properties in groups
[67]

The document [67] also provides minimum geometry requirements for BIM objects, which involve general aspects such as shape, symbolic data, space data, surface and material data, and connection data. In addition, the standard specifies functional requirements that BIM objects must have, such as behaviour characteristics, connectivity, and object constraints. Concluding the document, the metadata requirements for BIM objects are defined, including naming conventions for files, objects, properties, materials, values, and images.

2.5.2.3 Open BIM Object Standard (OBOS)

Open BIM Object Standard (OBOS) [68] is a standard for creating, maintaining, and using BIM objects throughout their lifecycle. It results from the collaboration between NATSPEC and Masterpec, from Australia and New Zealand, respectively. It is a document with 36 pages launched in 2018.

OBOS defines rules and requirements for naming object files, properties, property sets, materials, views, and material image files. As for the objects, the document requires the designation of IFC4 entity types and predefined types and states the necessity of classifying the object using a classification system applied to the project.

For the definition of properties, the standard also presents the same recommendations of BOS [67] when cites the common property sets for IFC. As for the hierarchy of the property sources, the document reinforces what is established in the BOS [67] but also highlights the possibility of the hard-coded properties existence and emphasizes the necessity of maintaining those properties within the authoring software to not compromise built-in processes.

The standard also presents recommendations for the graphic object modelling, object functionality, importing, exporting, and linking graphical and non-graphical information to objects.

3 Case Study: UMinho's Canteen of Azurém

A sample building was selected as a case study for this dissertation, serving to put into practice the concepts discussed previously. Asset Information Requirements will be developed for the building with the posterior creation of a model following the cited requirements.

The selected building is the Canteen of the University of Minho (UMinho), located on one of the university's three campuses, in Azurém neighbourhood in the city of Guimarães, Portugal. The photos below (Figure 17) show the frontal building facade, composed of a curtain wall through which the exiting of the building occurs and presenting masonry walls in its corners.

Figure 17: Photos of the Canteen building's exterior façades [69]

3.1 Management and operations

The UMinho was founded in 1973, receiving its first students in the 1975/76 academic year. The University is located in the North of Portugal, having campuses in the cities of Braga and Guimarães [70]. Among the Services Units of the University, there is the Social Action Services (SASUM), which is endowed with administrative and financial autonomy. The SASUM's main office is located on the Campus of Gualtar, in Braga, having also offices in Guimarães. Among other services, SASUM works in Accommodation, Scholarships, Medical and Psychological Support, Sporting and Cultural Activities, and Meals. Therefore, the administration and management of the Canteen of Azurém Campus are responsibility of this Service Unit (SASUM). The Canteen began operating in 1996 and it is open from Monday to Friday, having the capacity of serving 1.500 meals per hour, with about 850 seats [69].

The facility management activities of the Canteen building are under SASUM's responsibility, being all directly managed by the main office in Braga. When a maintenance or replacement action needs to be taken in one of the building components, the personnel working in the Canteen is responsible for contacting the SASUM main office. The SASUM can posteriorly contact the maintenance team to take the required actions. If the maintenance happens in a piece of equipment within the building, the maintenance services are realized by a third party that SASUM directly hires.

3.2 Architectural and physical aspects

The canteen is a large building that in its interior follows an earthy colour pattern, as Figure 18 shows. Since the building has the whole frontal facade constructed as a curtain wall and presents some skylights on its roof, it is predominantly lit by natural lighting.

Figure 18: Photos of the Interior of the Canteen
[69]

The Canteen is a multi-story building with five different levels, three main ones (P-1, P0 and P1) and two intermediates (M1 and M2). The building has a total of 3.126,71 m^2 when joining the three main floors and the two intermediate floors areas. A section of the building with the respective architectural finished floor levels can be observed in Figure 19 below.

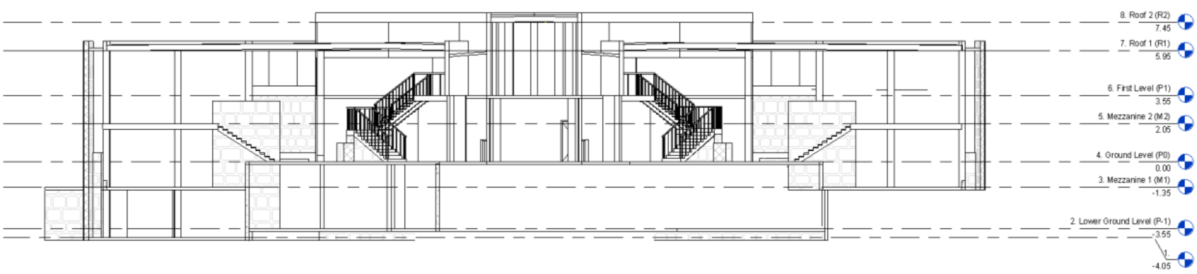


Figure 19: Section of the building showing Canteen's architectural levels

The lowest floor (P-1) has a 907,62 m² total area and can be accessed by stairs or elevator from the P0 of the Canteen or by an exterior door (Figure 20). Out of the five floors cited, P-1 is the only one with restricted access to just the Canteen employees, being most of the floor area dedicated to the storage and preparation of food (pink and dark blue zones in Figure 20, respectively). The light blue zone indicates the rooms dedicated to the employees, encompassing their restrooms, locker rooms, bathroom, and cafeteria.

The arrows in Figure 20 represent the exterior Entrance and Exit location, which is next to the administrative room, and from there, it is possible to access the other zones using the corridors in the green circulation zone. The three technical areas are marked as red and are also close to the Exit zone, from where the only cold storage can be accessed. Since most of the floor is constructed underground, there is no natural ventilation or illumination, both supplied by artificial systems.

Figure 20: P-1 Floor Plan of the Canteen

Considering P0, its total area is 1.200,51m², and its subdivisions can be checked in Figure 21. On this floor, there is a central zone for the Kitchen operation that can be seen in dark (Figure 21), which is not open to public. In addition to the kitchen, the only zones of this floor that the public can not access are highlighted with pink and are the zones for selling the tickets and the interior coffee shop. There are four restrooms marked in light blue (Figure 21), two that can be accessed from the entrance zone (red) and two in the interior, beside the kitchen.

In Figure 21, the arrows are located at the public Entrance and Exit of the building and the direction of the people flow are as indicated by the arrows, with one door for entering and two for exiting. When walking on this floor, the public must follow a unidirectional path presented with indications on the flooring for circulating within the building. The green zones (Figure 21) are the ones dedicated exclusively to the circulation of the public and personnel.

After entering the building, the public can go through one of the two food serving zones (orange) and then access the two intermediate levels (M1 and M2) by going down or up the lateral stairs. The intermediate levels contain the four main dining areas of the building (yellow zones in Figure 21) and, from this floor, the public can also access the P1.

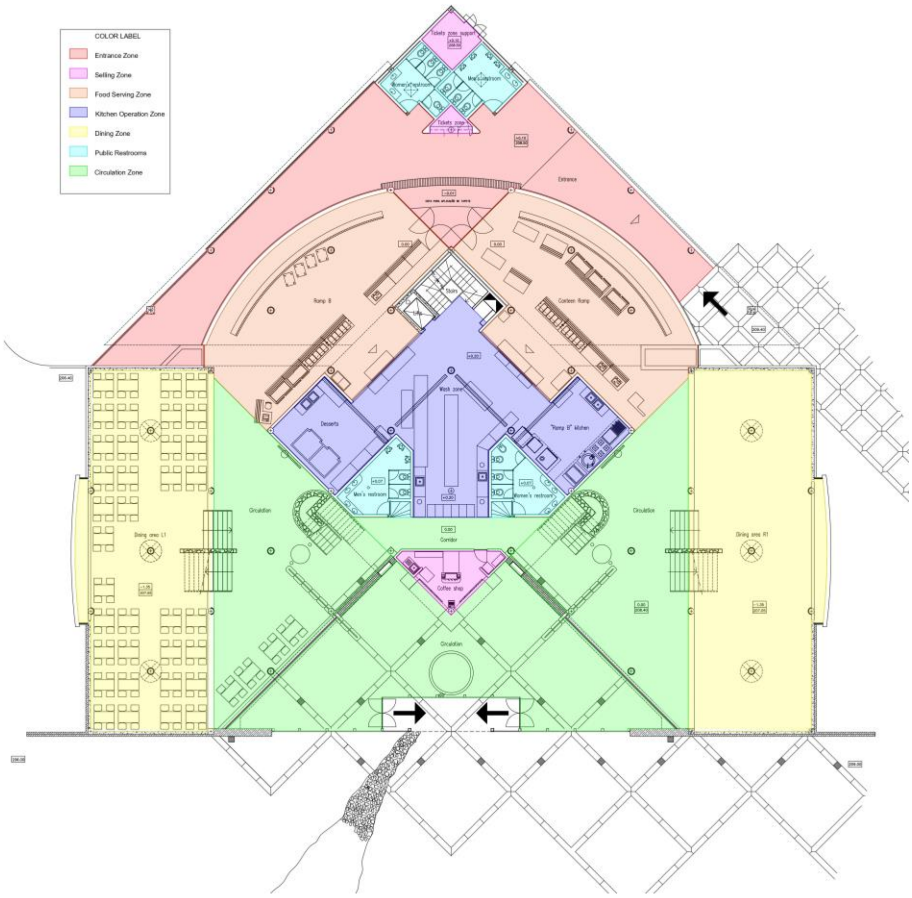


Figure 21: P0 Floor Plan of the Canteen

The last of the three main floors (P1) is built above the central zone of P0, and it has a total area of 274,90m² (Figure 22). It is composed of a central dining zone (yellow) that can be accessed by the public using the external stairs and by the personnel using internal stairs or the lift. The food available on this floor is sold separately from the menu of the Ground Floor, having its own kitchen and food serving area (dark blue in Figure 22). The lateral yellow zones in the figure represent the two dining areas on floor M2.

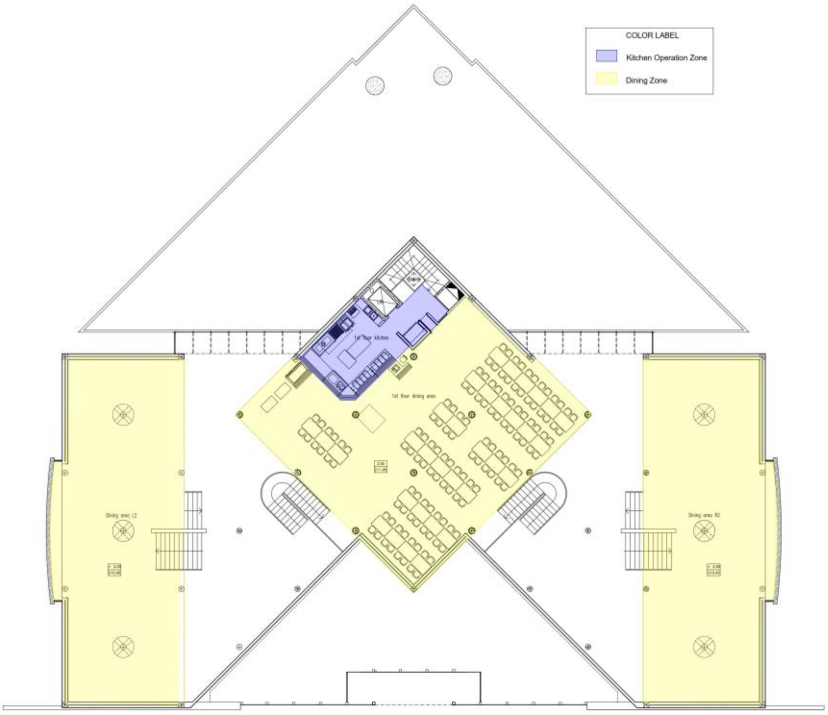


Figure 22: P1 Floor Plan of the Canteen

On the building roof, there are four different areas built on three different levels and its configuration is presented in Figure 23.

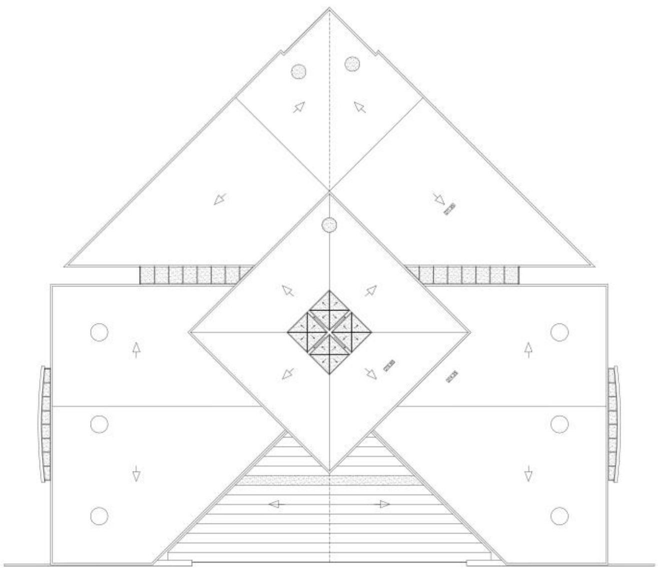


Figure 23: Roof of the Canteen

3.3 Subdivision and assets

The Canteen building is subdivided into smaller components and the elements within it. The hierarchy organization of the assets allows more effective management and assists the understanding of the four main groups of assets that compose the Canteen: Boundary Elements, Moving Components, Building Systems and Spaces (Table 1). The colour pattern of the cited table and the enumeration of the items are used to help identify the elements of the same level within the subdivision, and the following paragraphs explain its organization.

The assets are still more subdivided from the groups presented in Table 1 until the point the individual object types are reached. Within each type of object, in practice, there are the actual individual elements that compose the Canteen, being each of them an item within SASUM's inventory. However, the list of assets presented in Table 1 was unravelled just until the point it was considered adequate to explain the assets organization tree within the SASUM management process.

Understanding Table 1 , the architectural elements are the non-structural walls, doors, windows, floors, and any other element located in the building or exterior facades with architectural functions. Among the boundary elements, there are also the structural elements, composed of concrete columns and walls, beams and slabs and also the foundation of the building. The Canteen also presents structural masonry walls that can be noted on the exterior facade of the building and interior ones serving as support for the internal stairs, which gives the public access to the first floor.

For the Moving Components, the ones within the Monitoring Equipment are still to be installed in the Canteen. They are the sensors that will be able to measure the temperature, humidity, and CO2 concentration of the Canteen spaces. In addition, there are beacons that will monitor the equipment positions. These two types of assets were added to the list of assets of the Canteen even though they are currently not part of its composition but since they will, becoming an object of management.

In addition, in Table 1 it is presented the summary of the types of Kitchen Equipment that are found within the Canteen, and in this group, there are the elements that have the function of preparing or storing food. Most of the Kitchen Equipment is located on the P-1 floor since it is where most of the kitchens of the building are located. The Canteen contains 47 pieces of Kitchen Equipment, being 30 of them located on P-1, 12 installed on P0 and the remaining five on P1. From this group, the types of equipment presenting the highest number of units are the freezers with nine units, the refrigerating chambers with seven units, and fryers and ovens with seven units each. The two main industrial dishwashers are located on P0 since the reception of the dishes used by the customers happens on this floor.

For the Kitchen Support Equipment, the elements are those having the function of supporting the process of food preparation and serving. The furniture, on the other hand, helps in the utilization of the Canteen.

Table 1: Canteen's assets

Boundary Elements	
1.1	Architectural Elements
1.1.1	Walls
1.1.2	Windows
1.1.3	Doors
1.1.4	Stairs
1.1.5	Floor
1.1.6	Roof
1.1.7	Ramp
1.2	Structural Elements
1.2.1	Columns
1.2.2	Beams
1.2.3	Walls
1.2.4	Slabs
1.2.5	Foundation
Moving Components	
2.1	Equipment
2.1.1	Monitoring Equipment
2.1.1.1	Sensors
2.1.1.2	Beacons
2.1.2	Kitchen Equipment
2.1.2.1	Refrigerating chamber
2.1.2.2	Freezer chamber
2.1.2.3	Fryer
2.1.2.4	Grill
2.1.2.5	Stove
2.1.2.6	Oven
2.1.2.7	Chiller
2.1.2.8	Dishwasher
2.1.2.9	Cold storage
2.1.2.10	Potato peeler
2.1.2.11	Coffee machine
2.1.3	Kitchen Support Equipment
2.1.3.1	Support table
2.1.3.2	Transport car
2.1.3.3	Defrost car
2.1.3.4	Scale
2.1.3	Kitchen Support Equipment
2.1.3.5	Sink
2.1.3.6	Hotte
2.1.3.7	"Mary's Bath"
2.1.3.8	Greenhouse
2.2	Furniture
2.2.1	Tables
2.2.2	Chairs
2.2.3	Trays
2.2.5	Showcase
2.2.6	Register
Building Systems	
3.2	Water supply system
3.3	Rainwater drainage system
3.4	Sewage drainage system
3.5	HVAC system
3.6	Electrical system
3.7	Fire combat system
Spaces	
4.1	Entrance
4.2	Corridor
4.3	Circulation
4.4	Lift
4.5	Stairs
4.6	Restroom
4.7	Bathroom
4.8	Locker room
4.9	Air handling units
4.10	Administrative Zone
4.11	Tickets zone
4.12	Dinning area
4.13	Kitchen
4.14	Warehouse
4.15	Storage
4.16	Rooms for food preparing
4.17	Ramps for food serving
4.18	Other

The Building Systems are subdivided into seven, with each of them having their component elements in accordance with the design and construction of the building.

The building spaces were grouped according to their types in Table 1, having more the one space for most of the types cited. For example, the table only presents the indication “Restroom”, but the building has a total of six zones of this same type. The P-1 floor is subdivided into 27 spaces, while the P0 and P1 have 17 and 4 spaces, respectively. Even though the ground floor has the highest built area, the P-1 has more subdivisions and more spaces. The spaces are named and delimited following the indications of the architectural floor plans. The delimitations of those spaces are both physical, composed by architectural or structural elements, or theoretical, defined based on a specific portion of the building. For example, in Figure 21 (P0 floor plan), the edge between the orange and green zones has no physical boundaries. Still, those are two zones with totally different usages, food serving and circulating, respectively.

4 SETTING UP PROPOSED BIM-FM REQUIREMENTS FOR THE CANTEEN

During this chapter, a set of proposed BIM-FM requirements for the case study is developed based on the guidelines and concepts derived from the ISO 19650 series [9]–[11] and EN 17412-1[12]. The chapter is developed from the Appointing Party point of view since the author assumes the information management function for this project on behalf of the SASUM. Therefore, the subsections will encompass actions for which the Appointing Party is responsible for taking, and the following paragraphs describe the assumptions made before the start of the process.

Considering the Canteen is a building already in the operational phase of its life cycle, when there will be no design or construction stage, this chapter's main objective is to guide the development of the Asset Information Model (AIM) for the building and, to achieve this goal, a proposed AIR is created, following the definitions of the ISO19650 [10] for this case. Figure 24 summarizes the workflow for the requirements development, illustrates the steps within the following sections and encompass the process within the modelling stage.

The AIM delivery must be associated with a Lead Appointed Party assigned for the role [10], here understood as a company hired by the SASUM to model the assets. Even though the modelling creator is assigned as the Lead Appointed Party, it is not responsible for the actual information generation as the standard series defines. In the context of this study, the Lead Appointed Party is responsible for just creating the Model according to the guidelines from the AIR and populating it with the information provided previously by the Appointing Party, as illustrated in the lowest grey area in Figure 24.

The horizon of application for the AIR can vary according to the assets complexity level, as stated by the ISO19650 [11]. This complexity will depend upon the asset's breakdown structure established by the Appointing Party, and it is its role to determine if the AIR will be created for a unique asset or a group of assets. The Canteen is considered the main asset for this work to which the AIR will be referring.

Furthermore, part of the AIR definitions is the establishment of when the information will be exchanged. It is assumed here that Appointment and Information Delivery Milestone are simultaneous and represent the information exchange date. Since our model will be an Inventory BIM, the AIR refers to just one Information Delivery Milestone here called Handover. The term means the agreed date for the Information Deliverable (AIM) transference from the Lead Appointed Party to the SASUM.

Within an AIR, the required information would appear as Exchange Information Requirements being developed per Lead Appointed Party for the appointments to happen after given Trigger Events. For this work, the concepts of Trigger Events will not be explored, and the AIR will be a collection of requirements for a unique Information Delivery Milestone, the Handover.

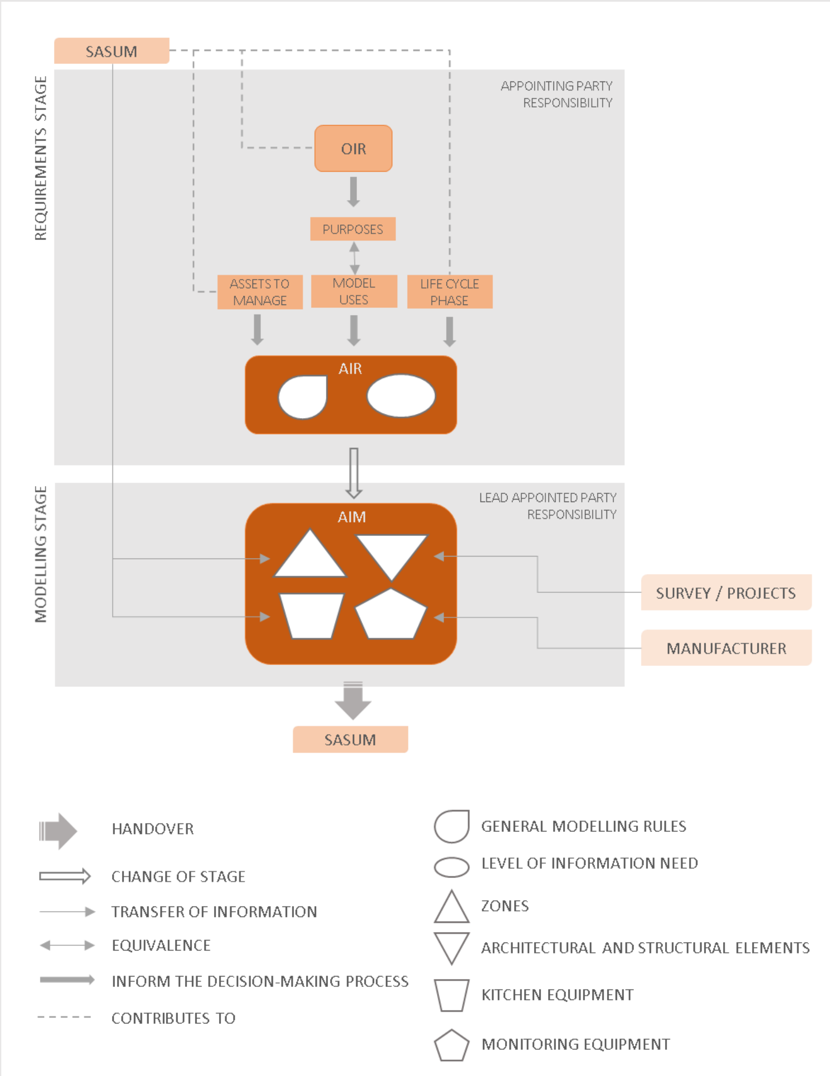


Figure 24: Workflow for the definition of the Information Requirements

The final requirements of the proposed AIR are divided from Appendix I – General Modelling Manual to Appendix IV – Information Content, and the process for its formulation happens as displayed in the highest grey area in Figure 24 as part of the Appointing Party responsibility.

Appendix I – General Modelling Manual is presented as a table and defines general rules for the modelling process, delimitating directives applied to the model as a whole. Standardizing the modelling process is crucial to guarantee an Information Deliverable with just the needed amount of information while ensures it has the required characteristics to allow an efficient exportation using the IFC open format.

Appendix II – OIR, AIR, Purposes and Uses brings the high-level requirements defined for the project and the final Uses to consider for the Canteen model.

To define the extent and granularity of the information required in the model, the Level of Information Need for the assets to manage is presented in Appendix III – Level of Information Need with the Information Content detailed in Appendix IV – Information Content.

As for the Appointing Party role, the ISO 19650 [9] highlights four main facets to go through while defining information requirements. For this work, the next sections of this chapter will present the definition of the:

1. Purposes: the need for the information, developed in section 0 and derived from the Organizational Information Requirements;

2. Content: covered by the definition of the Level of Information Need in section 4.3 that includes geometrical information, alphanumerical information and documentation;

3. Form: how the information will be presented, shown in columns added to the Tables of the Level of Information Need (section 4.3);

4. Format: how the information is encoded, also added to the Tables mentioned before (section 4.3).

4.1 Assets to manage, breakdown structure and classification

The list of the assets of the Canteen building is presented in section 3.3 (Table 1). As part of the Appointing Party responsibility, it is necessary to pick the assets to manage and organize them in a breakdown structure, so their hierarchy is correctly understood, with a posterior classification.

There are three groups of assets to manage that were derived from the list presented in Table 1: Architectural and Structural Elements, Equipment and Spaces. The Equipment group also presents two subgroups: Monitoring Equipment and Kitchen Equipment. Each group or subgroup is composed of items, and items number 1.3 (Slabs) and 1.7 (Walls) are also divided into subitems. Table 2 summarizes the assets selected by the Appointing Party and the correspondence between them, and the codes from the Uniclass 2015 classification system with respective descriptions.

The use of the referred classification system is one of the indications presented in the general rules of the AIR (Appendix I – General Modelling Manual). From the classification system, four out of twelve tables were used to classify the Canteen's assets Ss – Systems, EF - Elements / functions, Pr – Products, and SL – Spaces / Locations.

Table 2: Objects breakdown structure and their classification within the Uniclass 2015 classification system

Breakdown Structure		Classification	
		Uniclass 2015 Code	Description
1	Architectural and Structural Elements		
1.1	Columns	Ss_20_30	Structural columns
1.2	Doors	EF_25_30	Doors and windows
1.3	Slabs		
1.3.1	Slabs	Pr_20_85_14_16	Concrete solid slabs
1.3.2	Ramp	EF_35_20_40	Internal Ramps
1.5	Roofs	EF_30_10	Roofs
1.6	Stairs	EF_35_10_40	Internal stairs
1.7	Walls		
1.7.1	Architectural Walls	EF_25_10	Walls
1.7.2	Structural Walls	Pr_20_93_85_14	Concrete solid wall and composite wall units
1.7.3	Curtain Walls	Ss_25_10_20	Curtain walling systems
1.8	Windows	EF_25_30	Doors and windows
2	Equipment		
2.1	Monitoring Equipment		
2.1.1	Sensor	Pr_75_50_76	Sensors and detectors
2.1.2	Beacon	Pr_75_50_76	Sensors and detectors
2.2	Kitchen Equipment		
2.2.1	Oven	Pr_40_70_35_27	Electric kilns
2.2.2	Fryer	Pr_40_70_17_38	Gas fryers
2.2.3	Refrigerating chamber	Pr_40_70_31	Food refrigerators and freezers
2.2.4	Grill	Pr_25_96_35_96	Water grilles
2.2.5	Dishwasher	Pr_40_70_21_60	Pass-through dishwashers
2.2.6	Blast chiller	Pr_40_70_31_06	Blast chiller cabinets
3	Spaces		
3.1	Entrance	SL_90_10_27	Entrance halls
3.2	Corridor	SL_90_10_15	Corridor
3.3	Circulation	SL_90_10	Circulation spaces
3.4	Lift shaft	SL_90_60_50	Lift shafts
3.5	Stairs	SL_90_10_87	Stairways
3.6	Restroom	SL_35_80_89	Toilets
3.7	Bathroom	SL_35_80_80	Showers
3.8	Locker room	SL_90_20_85	Staff rooms
3.9	Air handling units	Pr_60_65_03	Air handling units
3.10	Administrative Zone	SL_20_15	Administrative spaces
3.11	Tickets zone	SL_90_20_89	Ticket offices
3.12	Dinning area	SL_40_20_22	Dining halls
3.13	Kitchen	SL_35_60_56	Non-domestic kitchens
3.14	Warehouse	SL_30_90_96	Warehouse spaces
3.15	Storage	SL_90_50_29	Food stores
3.16	Rooms for food preparing	SL_25_80_30	Food preparation rooms
3.17	Ramps for food serving	SL_90_20_69	Queuing areas
3.18	Other	SL_90	General spaces

As can be noted in Table 2, among the spaces listed, item 3.9 was classified using the products table (Pr) from Uniclass instead of the table for spaces and locations (SL). This definition was based on the fact that no space classification code and description was found in the SL table that would precisely define the function of the referred zone. Since the room is entirely dedicated to comporting the air handling units of the building, the products' table was used to classify the space by the product it contains.

For the requirements development, even though having different classifications, the subitems are analysed together by their general item. This means that Ramp (1.3.1) and Slabs (1.3.2) will have different classifications but equal requirements and will be referred to as the group Slab (1.3). The same happens for the architectural, structural and curtains walls, referred to within Walls (1.7), but receiving different classifications in the modelling software. Moreover, all different types of spaces in the Spaces group receive the same Level of Information Need but are classified as their usage.

Definition of assets to manage

For the assets' definition, in the Architectural and Structural Elements group, the boundary elements extracted from Table 1 are included. Among those, the architectural elements are understood as relevant for all predicted scenarios within the current building phase as they are the constituents of the physical building boundary and were selected for the requirements development. The Structural Elements from Table 1 were also included since they are boundary elements but additionally because their presence may influence maintenance activities that may take place in the building. The subgroup was limited to the elements from the superstructure to simplify the requirements definition process, even though the foundation is a relevant asset to manage and its good condition is crucial to avoid pathologies in the building elements.

In addition to the mentioned assets, the sensors and beacons planned to be installed in the building were added to the list of assets to manage within the group Equipment, composing the subgroup Monitoring Equipment (Table 2). Since the information derived from those appliances is planned for FM analyses in the building, their presence in the requirements definitions was rated as necessary.

The Kitchen Equipment subgroup encompasses the appliances that allow the Canteen's operation, without which the building may lose its ability to serve the academic community. In the context of FM activities, all the items within the subgroup should have been considered for the requirements development. However, for the development of this dissertation, it was decided to work with a sampling amount of six equipment types (Table 2) out of the total eleven items (Table 1) within this subgroup. The triage criterion was selecting the most relevant types of equipment, avoiding choosing more the one equipment that could present a similar function and, consequently, similar information requirements. Using this determination and considering the correlations between different types of equipment, 35 out of 47 units of Kitchen Equipment will be encompassed by the requirements created. Appendix VI – Location of selected Kitchen Equipment brings the floor plan of levels P-1 and P0 with the position of the selected units of equipment.

Within the Movable Elements groups (Table 1), the subgroups Furniture and Kitchen Support Equipment were discarded from the requirements formulation process due to time limitations in the scope of the present dissertation. However, like any other asset that is part of the University Inventory and is located in the building, they must be considered for future requirements and modelling processes.

The last main group of assets in Table 2 (Spaces) is considered to influence a vast range of activities during the facility management phase since it is directly related to the assets' locations. For the requirements development, it is understood that the subdivision of this group is not relevant, and they receive the same Level of Information Need.

Association with the IFC schema

The Appointing Party intends to use the IFC Property Sets to formulate the required properties for the assets. To assist the process, the assets to manage (Table 2) were previously classified according to the available IFC entity types and predefined types (Table 3), even though the Lead Appointed Party must be responsible for guaranteeing the correct association for the modelling process.

As can be seen, the elements in the Spaces group are joined in one item with the same name as the group. This is justified since, although they received different classification codes (Table 2), they are exported as the same IFC entity (Table 3), despite their usage.

Furthermore, for items 1.3.1 and 1.3.2, even having different IFC entity types, the requirements will be developed based upon the main group *IfcSlab*, and the designation is the same for items 1.7.1, 1.7.2 and 1.7.3, analysed as *IfcWall*.

For the definition of the Level of Information Need and the Information Content inside it, the assets can be referenced by the items' names, groups, or subgroups, according to the organization that is considered most effective for a given stage of the work. From this point, if there is any reference to an item from Table 3, the text formatting will always be the same as written in the cited table.

Table 3: Respective IFC Entity and Predefined Types for each asset

Nº	Object	IFC Entity	IFC Predefined Type
1	Architectural and Structural Elements		
1.1	Columns	IfcColumn	COLUMN
1.2	Doors	IfcDoor	DOOR
1.3	Slabs		
1.3.1	Slabs	IfcSlab	FLOOR
1.3.2	Ramp	IfcRamp	USERDEFINED
1.5	Roofs	IfcRoof	BARREL_ROOF
1.6	Stairs	IfcStair	HALF_WINDING_STAIR
1.7	Walls		
1.7.1	Architectural Walls	IfcWall	STANDARD
1.7.2	Structural Walls	IfcWall	STANDARD
1.7.3	Curtain Walls	IfcCurtainWall	USERDEFINED
1.10	Windows	IfcWindow	WINDOW
2	Equipment		
2.1	Monitoring Equipment		
2.1.1	Sensor	IfcSensor	USERDEFINED
2.1.2	Beacon	IfcSensor	USERDEFINED
2.2	Kitchen Equipment		
2.2.1	Oven	IfcElectricAppliance	ELECTRICCOOKER
2.2.2	Fryer	IfcElectricAppliance	ELECTRICCOOKER
2.2.3	Refrigerating chamber	IfcElectricAppliance	REFRIGERATOR
2.2.4	Grill	IfcElectricAppliance	ELECTRICCOOKER
2.2.5	Dishwasher	IfcElectricAppliance	DISHWASHER
2.2.6	Blast chiller	IfcChiller	USERDEFINED
3	Spaces		
3.1	Spaces	IfcSpace	INTERNAL

4.2 Information Requirements, Purposes and Uses for the model

Information deliverables are produced in response to information requirements which themselves are developed from a clear set of information purposes. In this section, the process begins at the top of the requirements chain by examining the Organizational Information Requirements (OIR) related to the project. After an interview with partners within the SASUM, it is concluded that the unity does not have a formalized OIR document. However, it does have a set of objectives, missions and strategic guidelines that allowed the Appointing Party to establish an OIR considering the SASUM as the organization [69], [71].

Even though the OIR is intended to be related to the organizational level of recommendations and objectives covering all operating scenarios, for this case study, the high-level requirements were determined just for the management of buildings for which the SASUM is responsible. After a careful analysis of the SASUM primary directives, four main Organizational high-level requirements were established by the Appointing Party:

- Keep the university installations and infrastructure efficient and prepared to feed the occupants needs.
- Guarantee the safety, comfort, and health of the buildings' occupants.
- Guarantee the sustainable management of the buildings.
- Improve financial expenses management.

From the OIR, it is possible to derive the purposes for which the information is being required. The purposes, together with the assets defined for a specific phase, will inform the AIR creation. Although the AIR is applicable to any building, from this point, they will be referred to as the requirements for the Canteen. Following the ISO 19650 series [9]–[11] guidelines, the AIR here refers to the set of information requirements related to the whole Canteen, including its Architectural and Structural Elements, Spaces, and Equipment (Table 3).

The AIR includes the purposes, structure, and definition of information. However, at this section, only the Purposes are discussed. For this stage, the AIR is composed of summarised guidelines linked to one of the four main Organization requirements that were created using the purposes established from the OIR (Appendix II – OIR, AIR, Purposes and Uses).

As an example, analysing the Appendix II – OIR, AIR, Purposes and Uses, if we consider the SASUM has a high-level organizational requirement to “keep the university installations and infrastructure efficient and prepared to feed the occupants needs”, the purposes intended to achieve this goal can be, among others, to “maintain up to date facility and equipment data” and also “having a trustful and fast source to access space conditions and requirements”. These two purposes will allow the SASUM, as manager, to allocate the spaces according to the required uses and on keeping an accurate computerized record of the building assets for the Canteen.

Although the ISO 19650 series [9]–[11] and EN 17412-1 [12] only use the term Purposes, the concept of BIM Uses is still spread in current and well-accepted bibliographies about BIM. Accordingly, the terms "Uses" and "Purposes" are used together ("Purposes/Uses") or separately but interchangeably within this work context. It is understood here that, since the purposes are the information use intention, it can also be seen as the use given for the Model.

To the correct association of OIR, AIR, Purposes and Uses, the BIMExcellence Model Uses Table [72] was consulted and filtered to established the Model Uses that could be connected with each of our Purposes. In some cases, the Purposes can be fulfilled by more the one Model Use, and, in other cases, one Model Use is able to fulfil more the one Purpose. The relationship established between the purposes and the uses can also be checked in Appendix II – OIR, AIR, Purposes and Uses). There are also Purposes for which the Uses were considered as "Not Applicable" in the appendix. That is justified since these specific purposes requires more specialized knowledge about the necessary information.

The final ten uses for which the information requirements will be created and their definitions according to BIMExcellence can be checked in Table 4 .

Table 4: Model Uses and its definitions according to BIMExcellence.
Adapted from [72]

CODE	MODEL USE SERIES	MODEL USE	BIM Dictionary
	Capturing and Representing		
2090		Visual Communication	A Model Use where 3D models are generated or enhanced for the purposes of communicating visual, spatial or functional qualities through renderings, fly-throughs, scenography and holography
	Simulating and Quantifying		
4090		Energy Utilisation	A Model Use and a Building Performance metric measuring how and how-much a Facility consumes energy. High-performance buildings typically consume less energy (electricity for lighting, fossil fuels for heating, etc…) than other comparable buildings
4240		Virtual Reality Simulation (VR)	A Model Use where 3D models are part of an Immersive Environment where users experience simulated places, objects and processes. As opposed to Augmented Reality Simulation, VR may require full 'immersion' within multi-projection rooms (CAVE) and/or through stereoscopic goggles and other specialized gear
4250		Life Cycle Assessment (LCA)	Life Cycle Assessment (LCA) is a Model Use representing how multiple methods are applied to BIModels to identify and assess the environmental impacts (e.g. waste) of building products and materials over their whole life
	Operating and Maintaining		
6010		Asset Maintenance	A Model Use where 3D models are used to manage the maintenance of Assets by linking objects to external databases through specialised middleware. Asset Maintenance is a subset of Asset Management
6030		Asset Tracking	A Model Use where 3D models are used to track the location of fixed and movable assets. Asset Tracking is a subset of Asset Management and may include the use of RFIDs and other tracking/tagging technologies
6060		Relocation Management	A Model Use representing how 3D models are used to plan and manage the relocation of movable assets within a Facility
6070		Space Management	A Model Use where 3D models are used to manage the occupancy of rooms and spaces within physical assets. Space Management is a subset of Asset Management
	Monitoring and Controlling		
7040		Real-time Utilization	A Model Use representing how 3D models are used to display information fed in real-time from sensors distributed around a building or site. Information may include current occupancy, temperature, humidity, toxicity and energy consumption… Also refer to Building Management Systems and Internet of Things
	Linking and Extending		
8030		BIM/FM Integration (BIMFMI)	A Model Use representing the integration of BIM technologies and processes with Facility Management deliverables, databases and workflows

For this work, the definition of the Uses does not strictly obey the ones given by [72] in two specific cases: "Energy Utilization" and "BIM/FM Integration (BIM-FMI)". For the first one, even though the source [72] description limits it to energy consumption monitoring, the requirements were decided based upon a larger horizon, including the possibility of improving building performance in terms of energy consumption based on the information provided by the model.

On the other hand, the definition for the second was considered more restricted. Knowing "Facility Management" to be a vast discipline that involves various process and activities, the "BIM/FM Integration (BIM-FMI)" Use was assumed to be the combination of other selected Uses for the development of this dissertation. To be specific, the "BIM/FM Integration (BIM-FMI)" Use requirements will be the compilation of the requirements from: Energy Utilization, Asset Maintenance, Asset Tracking, Relocation Management, Space Management, and Real-time Utilization.

The remaining sections of this chapter will pursue the definition of the information requirements for each of the ten Uses Table 4 , and they will be referred across the numerical label presented in Table 5 when necessary. When referenced by their names, the Model Uses will appear as presented in the table below and between quotation marks (e.g., "Visual Communication").

Table 5: BIM Uses Numerical Label

BIM Uses Label	
1	Visual Communication
2	Energy Utilization
3	Virtual Reality Simulation (VR)
4	Life Cycle Assessment (LCA)
5	Asset Maintenance
6	Asset Tracking
7	Relocation Management
8	Space Management
9	Real-time Utilization
10	BIM/FM Integration (BIM-FMI)

For the majority of the Information Requirements the assets will be associated to each and all of the chosen Purposes/Uses. The exceptions are:

- The Spaces will just be considered as assets for the uses 6 to 10;
- For the "Real Time Utilization" Use the assets from the Kitchen Equipment group will not be considered;
- The subgroup Monitoring Equipment will not have Level of Information Need for the "Energy Utilization" since both genres of assets do not use energy for operating.

4.3 Definition of the Level of Information Need

The Level of Information Need framework presented by the European Standard (EN 17412-1) [12] will guide the information requirements definition for this section. The Level of Information Need for any of the assets within the context of each Use/Purpose will cover the structured and unstructured information required being divided into Geometrical, Alphanumerical and Documental information. As mentioned before, the Form and Format of their content delivery is specified for each type of information.

Since the context of this work is that the assets information will primarily come from the SASUM, be delivered for the Lead Appointed Party to create the model and delivered back to the SASUM in the form of an AIM, if the information from the three different source types of the Level of Information Need (Geometrical, Alphanumerical and Documentation) is found contradictory, the established accuracy hierarchy is equivalent to the following ordination: documentation, alphanumeric information, and geometrical information. This is justified since, in that case, the primary information source is the documentation sent by SASUM.

For the definition of the Level of Information Need and as allowed by the European Standard, the assets and Purposes/Uses are grouped to facilitate the organization of the requirements since, in some cases, they can be the same for more the one asset or use. The tables presenting the Level of Information Need are identified per Purpose/Use, and groups or subgroups of assets (Appendix III – Level of Information Need).

4.3.1 Prerequisites

The first step for the Level of Information Need specification was to consider the prerequisites established by the European Standard (EN 17412-1) [12]. Within the scope of this work, the summarized assumptions made for each of the four prerequisites were:

- Purposes: In the previous section (Table 4) presents the Uses for the information delivery.
- Information Delivery Milestone: for all Purposes/Uses, the only Information Delivery Milestone to be considered within the scope of this work is Handover.
- Actors: The SASUM is defined as the actor requesting the information. On the other hand, the actor responsible for delivering the information is the respective Lead Appointed Party.

- Objects: the assets considered for the requirements determination were the Architectural and Structural Elements of the Canteen, the Monitoring Equipment responsible for real-time measurements and location of assets, six different pieces of Kitchen Equipment distributed in the building, and its Spaces, as established at section 4.1 in Table 3.

These assumptions will inform the decision-making process when specifying the Level of Information Need.

4.3.2 Geometrical Information

The intended goal when establishing information requirements is to gather only the strictly necessary information to fulfil their purposes, being the purpose-driven requirements a rule. In the context of geometrical information, this rule means the ability to do not request more graphical information than necessary since it can impact the model's size.

Heavy files are slower to transfer and can be harder to manipulate and should be avoided when possible. As part of the unstructured information, the geometrical requirements defined here follow the mentioned rule and are requested to be as accurate as necessary for the use under discussion.

From all the Geometrical Information aspects, the Detail is the one presenting the highest variability between the definitions among the Level of Information Need applied to the Canteen. The aspect is set as Not Applicable in three cases. For the Kitchen Equipment associated with "Space Management" and "Asset Tracking" Uses (Appendix III – Level of Information Need), since it is understood that to manage the use of a space or for locating these pieces of equipment within the facility, their details are pointless.

Still considering the Detail aspect, for the Spaces, the geometry complexity is impossible to be applicable, independently of the Purpose/Use (Appendix III – Level of Information Need). As for the rest of the Uses and assets associations, the requirements for the Detail aspect have a large variety. Highlighting that for the visualization driven Purposes ("Virtual Reality Simulation (VR)" and "Visual Communication"), the requirements are the highest, aiming for the assets to present the closest geometric complexity when compared to the real-world objects.

For the Dimensionality, it is required in most of the cases for the assets to be presented three-dimensionally (3D). The only exception is for the Kitchen Equipment when considering exclusively the

"Asset Tracking" Use (Appendix III – Level of Information Need) where just a location point (0D) was requested since it is enough to correctly present the position point of the asset within the Canteen.

The Location aspect of the Geometrical Information is considered the same for all the assets and Purposes/Uses for the whole project. This definition is justified because the necessity of locating the assets will always be as for its positions in relation to another asset, being it an architectural or structural element or, in most cases, a space.

Requirements for the Appearance aspect vary between Not Applicable, Symbolic and Realistic. The realistic requirement was only requested for the "Virtual Reality Simulation (VR)" Use related to all assets (Appendix III – Level of Information Need).The only exception for what was just mentioned is the requirement for this aspect when the asset in question is one of the Spaces, for which the aspect is irrelevant in all Purposes/Uses. A symbolic appearance is requested for the Uses where there is a need for the visualization of the asset with no focus on their close resemblance to reality.

At last, the Parametric Behaviour aspect requires either Explicit Geometry or is considered Not Applicable for all the assets and Purposes/Uses. Among the options presented by the European Standard (EN 17412-1) [12], the Explicit Geometry is the only applicable one since it requires geometry with not allowed shape modification. For an Inventory Model with the assets having predefined dimensions and shapes, there is no necessity for modifying the assets shapes.

On the other hand, there are three cases where the last aspect was considered Not Applicable, being them the same cases as the Detail aspect. The Parametric Behaviour does not apply to Spaces (Appendix III – Level of Information Need). For the Kitchen Equipment, when related to "Space Management" or "Asset Tracking" Uses (Appendix III – Level of Information Need) there, the geometry behaviour of this subclass is irrelevant to be requested.

4.3.3 Alphanumeric Information

Within the Alphanumeric Information, we must specify the Identification and Information Content for the assets. For this section of the Level of Information Need, some assumptions were made:

- The Architectural and Structural Elements function just as a representation of the physical building boundary in all uses except for "Life Cycle Assessment (LCA)". This assumption implies that the only Alphanumeric Information required for these elements in the remaining Model Uses was their Identification, being the list of required properties (Information Content) established as Not Applicable.

- For the "Space Management" Use, the only category of objects presenting the list of required properties (Information Content) was Spaces. For the remaining categories, the only aspect required from the Alphanumeric Information is Identification.

The Identification aspect of all assets will be filled with their respective types, following the breakdown structure presented in Table 3 (e.g., Wall, Sensor, Oven, Space, etc).

4.3.3.1 Properties from the IFC schema

For the Information Content aspect, picking the appropriate properties starts by inspecting the available Property Sets and Quantity Sets from the IFC schema, provided they could be associated with at least one of the proposed Model Uses. From this point, when the term *Property Set* is used, it will be referring to both *Property Sets* or *Quantity Sets*.

As the IFC schema already establishes a list of *Property Sets* related to entity type, these were assessed first. Table 6 shows the names of the *Property Sets* and *Quantity Sets* associated with *IfcWall*, *IfcElectricAppliance* and *IfcSpace*. The coloured Property Sets are the ones selected as potentially applicable ones.

Table 6: IFC Property Sets and Quantity Sets for Object according to their IFC Entity

IfcWall	IfcElectricAppliance	IfcSpace
Pset_WallCommon	Pset_ElectricApplianceTypeCommon	Pset_SpaceCommon
Pset_ConcreteElementGeneral	Qto_ElectricApplianceBaseQuantities	Pset_SpaceCoveringRequirements
Pset_PrecastConcreteElementFabrication		Pset_SpaceFireSafetyRequirements
Pset_PrecastConcreteElementGeneral		Pset_SpaceLightingRequirements
Pset_ReinforcementBarPitchOfWall		Pset_SpaceOccupancyRequirements
Qto_WallBaseQuantities		Pset_SpaceThermalRequirements
		Pset_AirSideSystemInformation
		Pset_SpaceThermalDesign
		Pset_SpaceThermalLoad
		Qto_SpaceBaseQuantities

The process of picking the necessary and valuable properties happens simultaneously with assessing the possible uses for each one of them. Appendix IV – Information Content shows the final data templates created for the case study and the properties and uses associations.

As can be seen in Table 6, for the *IfcWall*, its respective Pset_Common was the only suggested Property Set considered necessary for the Model Use "Life Cycle Assessment (LCA)". Assessing the properties individually, *Reference* and *Status,* were the only ones considered relevant for the Use. The same happens to the other Architectural and Structural Elements (Appendix IV – Information Content p. 108-121).

As for the *IfcElectricAppliance*, both Property Sets suggested were considered relevant. For this specific entity type, all the properties within both sets were selected, totalizing three: *Reference*, *Status* and *GrossWeight*. Therefore, any asset identified as *IfcElectricAppliance* within the IFC schema will have these properties as requirements. Their respective association with the Uses can be checked in (Appendix IV – Information Content p.v128-136).

Therefore, among the assets identified as *IfcElectricAppliance* and for each predefined type, there were also suggested Property Sets. The *Pset_ElectricApplianceTypeElectricCooker* was considered for assets with *ELECTRICOOKER* as *PredefinedType (Oven, Fryer, and Grill)*, and *Pset_ElectricApplianceTypeDishwasher* was considered for the Dishwasher. For the Refrigerating chamber, there were no Property Sets added to the ones already established by its entity type.

In the case of the Spaces group, the assets only have related Information Content for the "Relocation Management", "Space Management", "Real-time Utilization" and "BIM/FM Integration (BIM-FMI)" Uses, since for the rest of the Uses it is understood that the spaces of the building do not require the association of properties. Specifically, for the Uses "Visual Communication", "Energy Utilisation", "Virtual Reality Simulation (VR)" and "Life Cycle Assessment (LCA)", the definition of spaces is considered irrelevant, and for the Uses "Asset Maintenance" and "Asset Tracking", just the positional association between assets and spaces is necessary, dismissing any property. Therefore, all the required properties for this group derive from the five suggested Property Sets highlighted in Table 6.

After filtering the suggested Property Sets, the other available property sets from the IFC schema were inspected to check if they could be considered common to all or a group of assets to manage, provided they could be associated with at least one of the proposed Model Uses.

Since it was already established that for the Architectural and Structural Elements the only use to demand Information Content would be "Life Cycle Assessment (LCA)", all properties from the *Pset_EnvironmentalImpactIndicators* and *Pset_EnvironmentalImpactValues* were added to the data templates list of this group.

For the Equipment group of assets, a total of nine Property Sets were added to the list of required properties. For the "Life Cycle Assessment (LCA)" Use the *Pset_EnvironmentalImpact Indicators* and *Pset_EnvironmentalImpactValues* were considered important. Aiming on tracking the manufacturing and warranty relevant information the *Pset_ManufacturerOccurrence, Pset_ManufacturerTypeInformation,* and *Pset_Warranty* were chosen. The *Pset_Condition, Pset_ServiceLife* and *Pset_Asset* were selected to maintain current asset status information available. Another common Property Set (*Pset_ElectricalDeviceCommon*) was also added to the requirements for all *IfcElectricAppliance.*

4.3.3.2 User defined properties

After the meticulous analysis of the IFC available Property Sets and their inclusion when relevant, in case there was no existing IFC property regarding a piece of the necessary information, custom properties were created and organized in user defined Property Sets.

In our case study, it was unnecessary to create any custom property for the Architectural and Structural Elements or spaces since the ones available in the IFC schema already encompass the required information for the stipulated uses.

In contrast, for the Equipment, two common Property Sets were created (UMinho_TypeInventory and UMinho_Inventory) and applied to all assets of this group, and a third one was necessary in the specific case of the Sensor, the UMinho_SensorHistory. The custom properties created for this case study and their respective definition are presented in Appendix V – User defined properties and their definition.

The Property Sets UMinho_TypeInventory and UMinho_Inventory were created to encompass Type and Instance properties, respectively. The Sensor presented that additional necessity since it can perform three different types of measurement (Temperature, Humidity, and CO2 concentration), and the IFC schema does not have built-in properties to keep the measurements from three different sources at the same time.

The User Defined Property Sets were named according to the nomenclature rules established by BOS [67] and OBOS [68]. Specifically, the name begins with the properties source (UMinho) followed by an underscore and finishing with a content description for the set. For each property within the sets, the source was added at the end of their names, allowing their easy identification as user defined.

4.3.3.3 Tables of information content

In the last step of the Information Content definition, the properties were categorized as Type Properties or Instance properties, and their type of data and units were established when applicable. Appendix IV – Information Content presents the final data templates that complete the Information Content for the Level of Information Need.

Some properties within the table of Information Content will have an asterisk (*) on the end of its name. These properties have an already predefined list defined by the IFC schema with possible values to its fulfilling. Using the number after each asterisk is possible to consult the Table IV.15, which contains these predefined lists for each property, in Appendix IV – Information Content p. 142.

4.3.4 Documents

The Level of Information Need also considers the definition of Unstructured Information in the form of required documents. Hence, the assets and uses were analysed to determine whether the handover of documents was considered necessary. For the majority of the "Purposes/Uses" and assets, the requirement of documents was defined as "Not Applicable" except for the Kitchen Equipment category.

In this case study, the information about the Kitchen Equipment group primarily goes from the SASUM for the Lead Appointed Party and then is inserted in the AIM that is delivered back to the SASUM, as stated previously. The SASUM delivers their available information in the form of one or several documents from where the information is extracted.

On account of this procedure, the request for Documental information is applicable for the Kitchen Equipment for the uses “Asset Maintenance” and “BIM/FM Integration (BIM-FMI)”, where the delivery of the primary documentation sent by the SASUM is requested. By requesting this delivery, the primary documentation is sent back to the Appointing Party for any necessary clarification of which information generated the model of the Kitchen Equipment if the SASUM did not keep a record of it for any reason.

Other documents that were understood as necessary to be accessed were already considered within the Information Content requirements. The Installation Manual or Technical Description, for example, were required as hyperlinks for their web address since it is the most current way of accessing this type of information.

5 PRACTICE APPLICATION: PROOF OF VIABILITY

In this stage, the Canteen Building Model is developed based on the previous established AIR considering the Lead Appointed Party point of view to prove the viability of implementing BIM in the Canteen's FM context. In addition, the IFC file generated from the model is tested in an enterprise business intelligence platform to simulate the model used as the primary information source for facility management analysis.

For the proof of viability, it is established that not all the uses considered in Chapter 4 would be modelled. For this stage, six out of the ten uses are selected (Table 7).

Table 7: Selected Model Uses for the modelling stage

Model BIM Uses Label	
1	Visual Communication
5	Asset Maintenance
6	Asset Tracking
7	Relocation Management
8	Space Management
9	Real-time Utilization

The construction of the AIM follows the general guidelines from the General Modelling Rules (Appendix I – General Modelling Manual) and as stated by the manual, the building file is named as Building_UMinho_CanteenOfAzurem. In addition to the general rules, the modelling process follows the remaining indications of the AIR, including the Level of Information Need defined for the uses. Figure 25 below allows the visualization of 3D views of the final Canteen model in the authoring software.

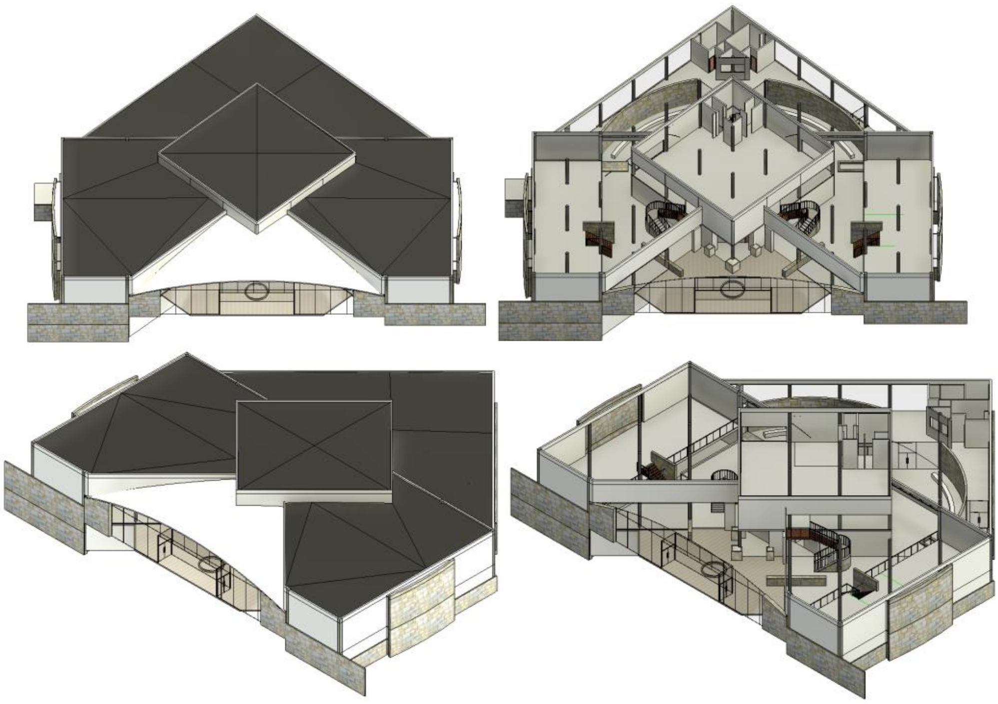


Figure 25: 3D views of the Canteen model in Revit

5.1 Pre-modelling process

This section presents the steps taken by the Lead Appointed Party prior to starting the modelling process.

5.1.1 Software and platform

Following the indications of the modelling manual presented in Appendix I – General Modelling Manual, the selected software for creating the model within this project was Revit version 2021 from Autodesk since it is certified by buildingSMART for the exportation of models in the IFC4 ADD2 TC1 format and version, being it the newest regulated one [37], [40]. In the context of this work, every time a phrase is written using italic formatting and between simple quotation marks (e.g. *'Tool')*, it means it refers to a Revit term.

Moreover, the DYNAMO programming tool that works with Revit is used for the properties insertion when modelling the Equipment group. DYNAMO allows the user to work in the Revit API (Application Programming Interface) by manipulating graphic elements and automating actions.

Power BI is used for applying the model as a primary source of information for Facility Management analyses, encompassing the "Asset Maintenance" Use intended for the model. The final IFC file exported from the authoring software is imported into the platform, where some analyses are simulated, allowing graphics and statistics generation.

Association between Revit and IFC terms

For the correct exportation of the model according to the IFC schema and using Revit as the authoring software, it is necessary to establish the equivalence between some terms from both sources:

- A *Property* in the IFC schema is equivalent to a *'Parameter'* in Revit, and when grouped they form the *Property Sets* and *'Group of parameters'*, respectively.
- The *'Categories'* in Revit are the IFC entity types. When the latter is compared to Revit categories, sometimes they align directly (*'Walls'* to *IfcWall*). However, in some cases, a single category maps to multiple entities, as for the *'Mechanical Equipment'* category that can export to *IfcBoiler*, *IfcCondenser* or *IfcChiller* [73].This reinforces the necessity to ensure the correct mapping between the two sources.

5.1.2 Procedures and analysis

5.1.2.1 Review of information

The Lead Appointed Party received from the SASUM a collection of preliminary information including architectural floor plans, a summary of the Kitchen Equipment information, technical specifications of the Monitoring Equipment, photos, and videos of the building. Posterior to their reception, the accuracy and completeness of the pieces of information were analysed.

The sources of information for modelling the Architectural and Structural Elements group, and posteriorly the Spaces, were the floor plans, photos, and videos. It is essential to highlight that there were no sections of the building among the drawings, and the information source does not guarantee the model represents the as-built form of the building accurately. However, considering the Model Uses established, this circumstance does not compromise the purposes for the Model.

For the Kitchen Equipment and Monitoring Equipment subgroups, the technical specification documents provided the geometrical and alphanumerical information for modelling the assets. However, the sources were considered incomplete since they could not provide the values for most of the Information Content required.

5.1.2.2 Combined Level of Information Need

For each asset, the Level of Information Need varies depending on the Uses and Milestones intended. Thus, the complete set of requirements for the same Milestone (Handover) and same Actor (Lead Appointed Party) is the collection of requirements for the various Model Uses intended for a given asset. Consequently, it is necessary to analyse the Level of Information Need content to establish the final requirement for each aspect inside it to guide the modelling process.

Suppose we analyse the Geometrical Information required for all the Kitchen Equipment: the "Asset Tracking" Use requests the Dimensionality aspect to be 0D, while the other Uses require a 3D representation of the assets. For the model, the final Dimensionality to be applied will then be 3D since it is able to encompass all the different Uses.

Another example is the need for Documentation delivery for the Equipment. Although most of the Uses do not require this type of information, since one of them (Asset Maintenance) does require it, the information must be delivered by the Lead Appointed Party when the specified Delivery Milestone comes.

The same logic applies to the Information Content requirements. Since the list of required properties varies upon the Use, the final set of properties to be inserted in the model is equal to the combination of properties from all the uses. For the Spaces of the building, there is no required property for the Uses "Asset Maintenance" and "Asset Tracking". However, since the model also encompasses "Relocation Management", "Space Management", and "Real-Time Utilization", this group of assets has associated properties.

5.1.2.2.1 Architectural and Structural Elements

When assessing the Level of Information Need for the Architectural and Structural Elements, it is understood that the only type of information needed is Geometrical. Furthermore, for the six Uses, the requirements for the Geometrical Information are the same for most of the aspects, except the Appearance. This aspect is Not Applicable for the "Real-time Utilization" Use, but the colouration of the elements is requested for the remaining ones. Therefore, following the principle to model the asset based on the highest requirement, the elements were modelled with their respective colours.

Considering the other aspects, all the elements must be three-dimensional, having their simplified form and volume, be relativity located to the other elements, and be model with an explicit geometry.

5.1.2.2.2 Spaces

Assessing the Level of Information Need of this group of assets, it is noticed that the only aspects required are their Dimensionality to be 3D and the presence of the required properties from the Information Content.

5.1.2.2.3 Equipment

The Equipment is the assets' group encompassing the highest variability of Level of Information Need among all assets. In the Alphanumeric Information, for the two subgroups (Monitoring Equipment and Kitchen Equipment), the list of properties is the union of all properties required for the five uses, with no duplication. When dealing with Documentation, most of the uses have this aspect set as Not Applicable, but since the "Asset Maintenance" Use requires it, the document is delivered.

Dealing with the Geometrical Information, the assets' requirements are understood better by subgroup. Analysing the subgroup Monitoring Equipment, the assets are modelled in a three-dimensional form and with a relative location since these are the unanimous requirements among all the uses. The subgroup will have explicit geometry for the Parametric Behaviour aspect since this is required by all uses except the Space Management, for which this aspect is considered Not Applicable. The Appearance aspect varies between Not Applicable and Symbolic, the latter being the highest one and, consequently, chosen for the modelling process. Furthermore, for the Detail aspect, the assets of the subgroup are modelled with their simplified form and volume.

As for the subgroup Kitchen Equipment, considering the Geometrical Information, the request for the relative location is an unanimity among the uses. Even though for the "Asset Tracking" Use, the required dimensionality is 0D, the assets will present three-dimensional geometry since this is the requirement for the other four uses. The Appearance and Parametric Behaviour will be symbolic and explicit, respectively, since this is the highest requirement for both aspects, excepting the "Space Management" and "Asset Tracking" Uses for which these aspects are Not Applicable. For the Detail aspect, the assets will have a simplified form and volume, including operation and maintenance spaces around it, as required by the "Asset Management" Use.

5.1.2.3 Properties hierarchy

Inside the Level of Information Need, there is a list of required properties found in the Information Content aspect. When modelling using Revit, the software automatically attributes default sets of built-in properties to their objects within the whole project and for each object, depending on their Revit categories. Therefore, some of these parameters may sometimes encompass a piece of information required in the list of properties defined on the Level of Information Need. When faced with this, it is necessary to analyse the properties from both sources and, using the properties hierarchy suggested by the BOS (Figure 15 in section 2.5.2.2), eliminate from the properties to add the ones considered equivalent to the hard-coded ones.

For the Spaces group, the list of default parameters on Revit can be checked in Figure 26 and the first column of Table 8 shows the association between the Revit's parameters and the required properties that present the same name or the same data. The properties listed in the second column of the table will not be inserted during the modelling process to avoid information duplication.

Analysing the Equipment group, there are two sets of hard-coded parameters automatically associated with them, the one that depends upon their Revit categories and the one that is added to them as soon as they are loaded in the project model. For the first set, the comparison between the default properties and the required ones showed no equivalence between them, and there was no need to eliminate any of the data template's properties. Analysing the the second set, the properties are *'Type Parameters'* (Figure

27) and a total of three hard-coded parameters were found to have the same content as the required ones, and the equivalent ones were eliminated from the DYNAMO code so they would not be added to the model (Table 9).

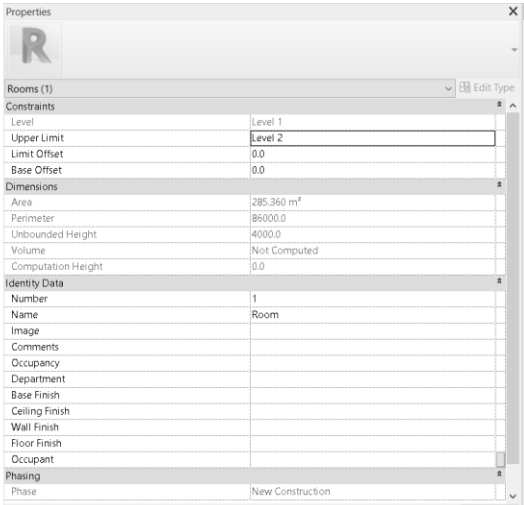


Figure 26: Revit's default Room's properties (Spaces)

Table 8: Revit x IFC properties (Spaces)

Hard-coded parameters	Required properties	Pset
Occupancy	OccupancyType	Pset_SpaceOccupancyRequirements
Occupant	OccupancyNumber	
Height	Unbounded Height	Qto_SpaceBaseQuantities
GrossPerimeter	Perimeter	
NetFloorArea	Area	
GrossVolume	Volume	

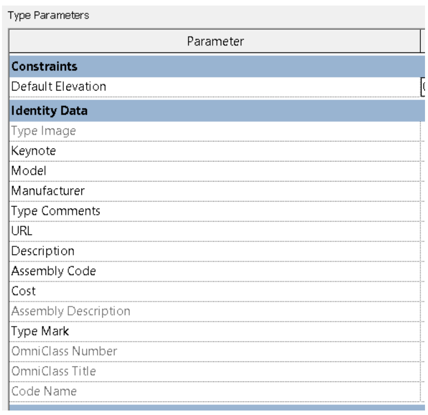


Figure 27: Revit's default Type Parameters (Equipment)

Table 9: Revit x IFC properties (Equipment)

Hard-coded parameters	Required properties	Pset
Manufacturer	Manufacturer	Pset_ManufacturerTypeInformation
URL	ManufacturerURL_Uminho	UMinho_TypeInventory
Cost	AcquisitionCost_Uminho	UMinho_Inventory

For the Architectural and Structural Elements, the comparison from both properties sources is unnecessary since they have no required Information Content.

5.1.2.4 Properties data types and groups

To insert the requested properties in Revit, it is necessary to choose the data types of each parameter carefully since their nomenclature in the IFC schema may be different even when they are referring to the same data type. For example, the data type that only allows True or False values are considered YesNo in Revit but Boolean in the IFC.

Besides the data types, the parameters within Revit are not organized as Property Sets and must be inserted in one of the available groups of parameters. From the requirements for the Information content for the AIM, there are two types of Property Sets, the ones from the IFC schema and the user defined ones. The former will be grouped in Revit as *'IFC Parameters'* and the latter as *'Data'*, following the guidelines from the BOS (Figure 16 in section 2.5.2.2).

5.1.2.5 Properties values

According to the BOS [67] guidelines, no property should be left unset within the model. Therefore, for the properties with lack of information, the Lead Appointed Party follows the recommendation of using the neutral values "n/a", "0", or "1900-12-31T23:59:59" to fulfil the fields requesting alphanumeric, numerical and date values, respectively. However, there is no indication of how to proceed when a Boolean property needs a neutral value. For that case, the decision was to leave the property unfilled in the authoring software.

Even though the decision contradicts the initial indication of the manual [67], if one of the allowed values (True or False) was picked as a neutral value, this could cause misunderstanding since it would imply the property value was known as one of those options. Since the work is being developed in Revit, it is essential to highlight that the software does not export empty parameters to IFC, implying those Boolean parameters will not be exported, and it should be understood as the absence of a value to fulfil them.

Additionally, there is another exception established by the Lead Appointed Party. As explained in subsection 5.1.2.3, Revit has sets of hard-coded properties that will be associated with the objects. Excepting the properties that were assessed as equivalent to the requested ones, the remaining hard-coded parameters have no value to be fulfilled, meaning they would be left empty or would have to be deleted.

BOS [67] and OBOS [68] indicate that no hard-coded property should be deleted from the authoring software since it obeys the premise that these properties may seem necessary for built-in operations. For the Canteen, this is important since not all established Model Uses are considered for the model, implying that the SASUM may request from the same Lead Appoint Party a future model upgrade for which the hard-coded properties can be necessary. However, it is important to highlight the properties would be present only in files of the authoring software and not in the exported IFC file.

In conclusion, for the hard-coded properties that are not equivalent to the requested ones, the properties fields were decided to be left blank instead of deleted. Since the authoring software (Revit) does not export empty properties to IFC, this decision will not compromise the IFC exportation according to the Level of Information Need since it will not include the mentioned properties.

5.2 Modelling process

5.2.1 Architectural and Structural Elements modelling

The Architectural and Structural elements were modelled directly in the project file, using the corresponding modelling tools. First, a *'New Project'* was created using the Metric-Architectural Template, then the architecture finished floor levels and some assistance levels were inserted. Next, the *'Import CAD'* tool was used to import the floor plans so they would be used as the base for modelling this group of assets.

The first elements to be inserted were the structural columns, followed by the structural walls. After that, the architectural walls, first the generic ones followed by the *'Curtain Walls'* were inserted. After finishing the walls, the stairs and ramp were added, with their respective railing. Afterwards, the doors and windows were placed into the walls. The roofs were created using the *'Roof Tool'* to finish the building's physical boundary. However, for the roof above the Canteen exit, it was necessary to create a mass and develop the roof using its form since this area of the roof presents a non-usual geometry.

5.2.2 Spaces modelling

After having the physical boundary of the building modelled, the Spaces were added using the '*Room Tool'* that allows the creation of a volumetric form that receive the association of the *IfcSpace* for the moment of exportation. The spaces' limits could be the physical building boundaries, like walls and slabs, or also abstract limits created using the *'Room Separator Tool'.* The spaces designation and their respective names were extracted from the floor plans provided by the SASUM.

Figure 28 shows the spaces allocation in the authoring software.

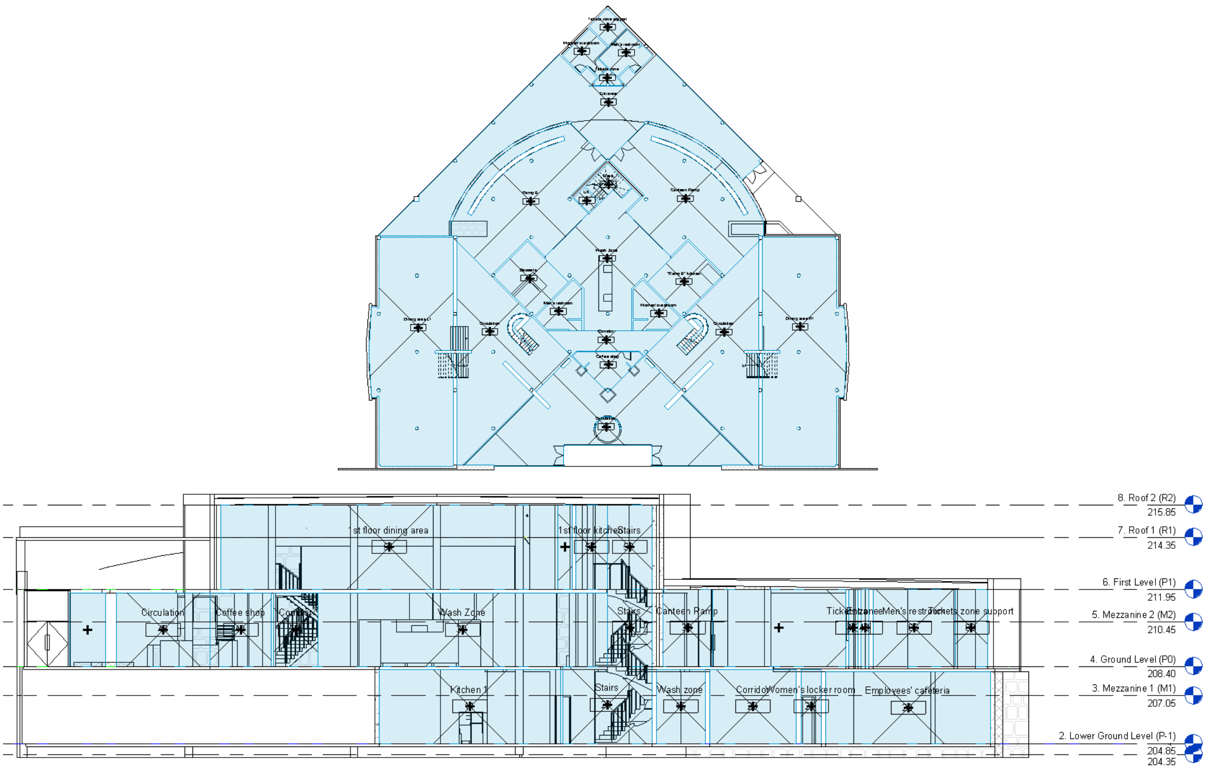


Figure 28: Spaces' allocation in the P0 floor plan and in a section of the building

After the Spaces insertion and nomination, their respective list of requested properties was added as *'Project Parameters'*. As the example shown in Figure 29, the properties were added inside the *'Common Discipline'*, with their respective *'Type of Parameter'* and grouped under the IFC Parameters group, since they are all from the IFC schema.

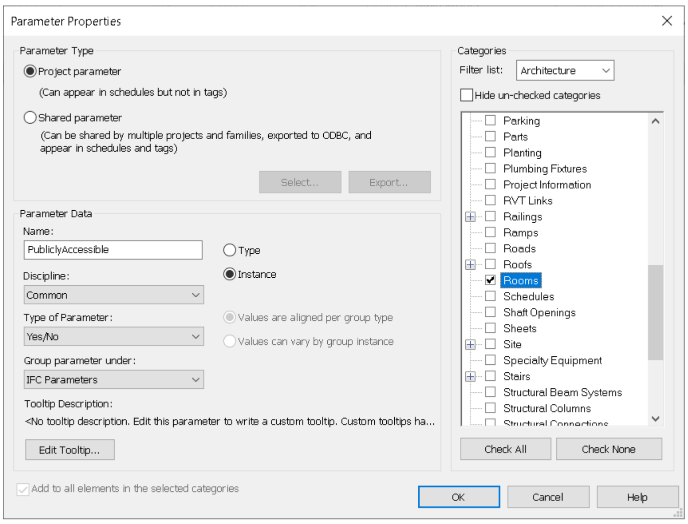


Figure 29: Property insertion example for the Spaces

Posteriorly the properties insertion, their values were added. Some properties are automatically calculated by Revit, such as the 'Area' and the 'Perimeter'. Among the others, since the SASUM did not deliver any other spaces' information besides their nomination, the values were considered neutral or were analysed and filled. For the *PubliclyAccessible* property, it is possible to assess the floor plans to choose the correct value, if each space is accessible for the public or not. On the other hand, for the *OccupancyNumberPeak*, the property must be filled with the neutral value "0".

5.2.3 Equipment modelling

The objects from the Equipment group were modelled using the Revit *'Families Templates'*. Following what is established by the General Rules (Appendix I – General Modelling Manual), the names of the files are:

- Beacon_Accent_iBKS105
- Sensor_GSS_CozIR®-A
- Oven_Fagor_AG102
- Fryer_Fagor_SBG910I
- RefrigeratingChamber_Kide_MGM1128F
- Grill_Horizontal_Gresilva_GHPI2600
- Dishwasher_Elframo
- BlastChiller_Fagor_ATM102

The first step was to model the geometry of the objects, followed by the clearance zones allocation (Figure 30), finalizing with the property's addition inside the *'New Family'* interface using a Dynamo code routine. For the values of the properties, the information comes from the technical specifications of the assets, or they present a neutral value when no fulfilling information is found.

All the assets in the Equipment group were modelled without connectors since the Appointing Party did not require the modelling of the building's systems as stated in the General Modelling Manual (Appendix I – General Modelling Manual). It is essential to highlight that once the Equipment was loaded into the model, the association Spaces x Equipment was automatic. The allocation of the Kitchen Equipment in floors P-1and P0 of the model can be seen in Figure 31

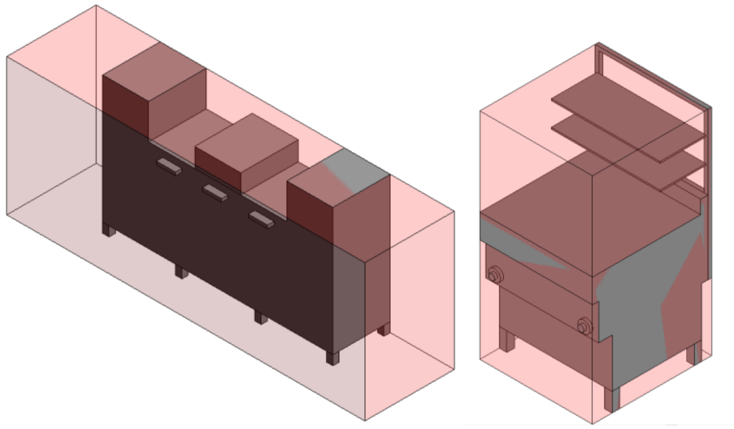


Figure 30: 3D views of the model of the Dishwasher and Grill

Figure 31: Equipment allocation in the building model (Revit)

5.2.4 General modelling

5.2.4.1 Classification system

The IFC schema presents the *IfcClassification* entity to retain the asset classification information. In Revit, the association with this entity is made automatically if the value is filled within the hard-coded parameter *'Assembly Code'*. However, the insertion of this property value can not be done by typing the intended code. Therefore, it was used the *'Additional Settings'* of the software to import a .txt file containing the codes and descriptions of the three tables of the classification system from where the assets codes were extracted.

5.2.4.2 Mapping to IFC entities

For the correct IFC mapping of the assets, it is necessary to associate the Revit categories with their respective IFC entity types and predefined types. The Appointing Party already established this correspondence in section 4.1 (Table 3).

Revit already has an available mapping table for the exportation of the model to IFC that was analysed and proved to have the correct association of the objects for the Architectural and Structural Elements. However,for the Equipment group and Spaces group, the parameters *IfcExportAs* and *IfcExportType* were used to insert their types and predefined types respectively.

5.3 Model exportation

The exportation process will be described following the order of the actions taken according to the software. For the IFC exporter plugin the version 21.2.1.0, from 30/03/2021 was used, and a customized exporter setup was created. Inside the *'Modify setup'* space, two tabs needed to be configured *'General'* and *'Property Sets'* (Figure 32).

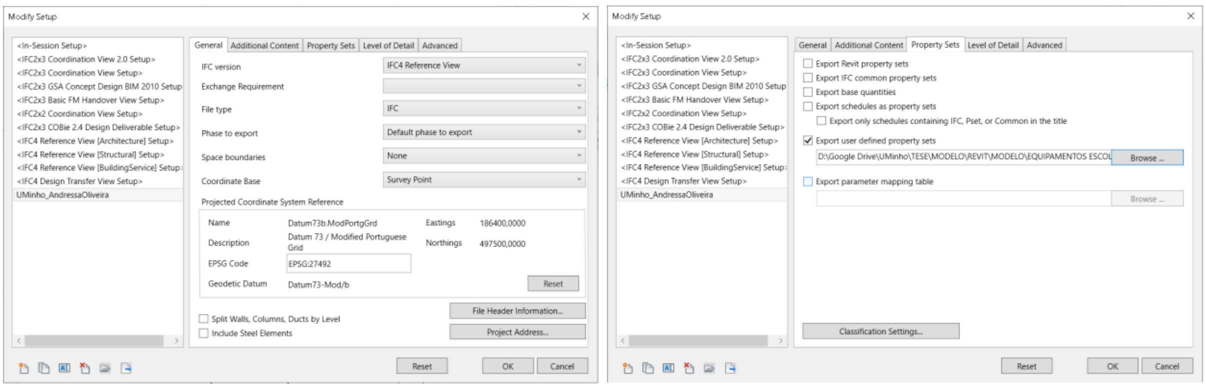


Figure 32: IFC exporter interface and tabs

General Tab

In the *'IFC version'* field there are two options for the selection of the IFC version and respective MVDs for which Revit has been certified to export by buildingSMART [40]. As stated before, the IFC4 ADD2 TC1 is used. For this schema version, Revit exporter presents two options of Model View Definitions: Model Reference View and Design Transfer View [40]. The first one was chosen since it is described as useful for coordination models and since there is no intention of conducting further work on its geometry, the model will then contain the most essential geometric definitions [74]. Therefore, the option *'IFC4 Reference View'* is selected.

Selecting the *'Exchange Requirement'* field enables the print of a title in the File Header [75], which does not apply to the project.

In the *'Phase to export'* case, since all the objects in the building model were constructed considering the same construction phase, the Default phase to export is selected.

For the *'Space Boundaries'*, the chosen option is *'None'* since the information needed from the spaces are already encompassed in the list of required properties [74].

For the *'Coordinate Base',* it is essential to highlight that Revit does not have the coordinate system required by the general modelling rules (EPSG:3763) registered in its database. Also, the location point provided by the building projects for the Canteen is in accordance with another coordination system ESRI:102164 (Lisboa Hayford Gauss IGeoE), also not supported by Revit. Therefore, to guarantee the georeferenced exportation of the model, the coordinates of its location were transformed from the given coordinate system to the deprecated coordinate system for Portugal (EPSG:27492) that Revit supports.

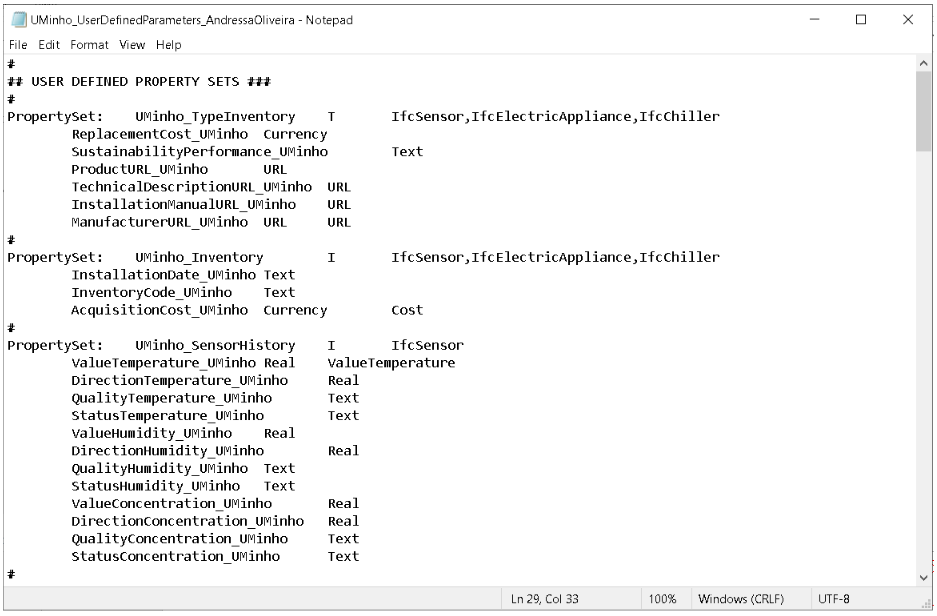
To finish the definitions of this tab, there is no need for checking the *'Split Walls, Columns and Ducts by Level'* box since the Architectural and Structural Elements were already modelled per level as states the general modelling rules guidelines (Appendix I – General Modelling Manual).

The *'Include Steel Elements'* does not apply to the case study exportation.

Property Sets Tab

Revit allows the exportation of the property sets using different options. The *'Export user defined property sets'* is used to export all the properties required from the project, including *Property Sets* from the IFC schema and user defined ones.

For the utilization of this exportation option, a .txt file was created using the guidelines defined by the Revit IFC Manual [74]. Part of the text file structure is as seen in Figure 33, where for each property set it is necessary to define the IFC entity for which these properties will be exported and if the properties within the set will be of Type or Instance. When preparing the file, it is necessary to define the name for the property when exported, the data type for its value and, if different from the first one, the parameter's name within Revit, all separated by an underscore. For the hard-coded properties that contains required information, it is necessary to ensure that they are correctly mapped to the required properties, using the nomenclature established for the project, so that information is not lost during the exportation.


UMinho_UserDefinedParameters_AndressaOliveira - Notepad

File Edit Format View Help

```
#
## USER DEFINED PROPERTY SETS ###
#
PropertySet:    UMinho_TypeInventory    T       IfcSensor,IfcElectricAppliance,IfcChiller
        ReplacementCost_UMinho  Currency
        SustainabilityPerformance_UMinho        Text
        ProductURL_UMinho       URL
        TechnicalDescriptionURL_UMinho  URL
        InstallationManualURL_UMinho    URL
        ManufacturerURL_UMinho  URL     URL
#
PropertySet:    UMinho_Inventory        I       IfcSensor,IfcElectricAppliance,IfcChiller
        InstallationDate_UMinho Text
        InventoryCode_UMinho    Text
        AcquisitionCost_UMinho  Currency        Cost
#
PropertySet:    UMinho_SensorHistory    I       IfcSensor
        ValueTemperature_UMinho Real    ValueTemperature
        DirectionTemperature_UMinho     Real
        QualityTemperature_UMinho       Text
        StatusTemperature_UMinho        Text
        ValueHumidity_UMinho    Real
        DirectionHumidity_UMinho        Real
        QualityHumidity_UMinho  Text
        StatusHumidity_UMinho   Text
        ValueConcentration_UMinho       Real
        DirectionConcentration_UMinho   Real
        QualityConcentration_UMinho     Text
        StatusConcentration_UMinho      Text
#
```

Ln 29, Col 33 | 100% | Windows (CRLF) | UTF-8

Figure 33: File in .txt format to property exportation

5.4 Verification

The generated model must go through a verification process to assure that the Information Container meets the Level of Information Need requirements, according to the designation of the ISO 19650 series [9]–[11]. If it is observed that the model does not contain the required information or was not modelled following the defined modelling rules, the Lead Appointed Party must receive the indication for editing it to meet the requirements.

In the context of this dissertation, the process of verification was not automated, requiring a visual and individual comparison between the properties and their values presented in the authoring software and the ones visible in the model checker from Solibri, using as the list of properties from the Level of Information Need as the basis of comparison. The procedure was conducted individually for each Equipment model and for the final complete one, including the building, the spaces and the cited equipment.

Figure 34 illustrates the building in the Solibri software with the spaces represented as yellow 3D boxes in the platform. When assessing one of the building spaces, it is possible to check the presence of the various required properties sets associated with it and the properties inside each of them (Figure 35).

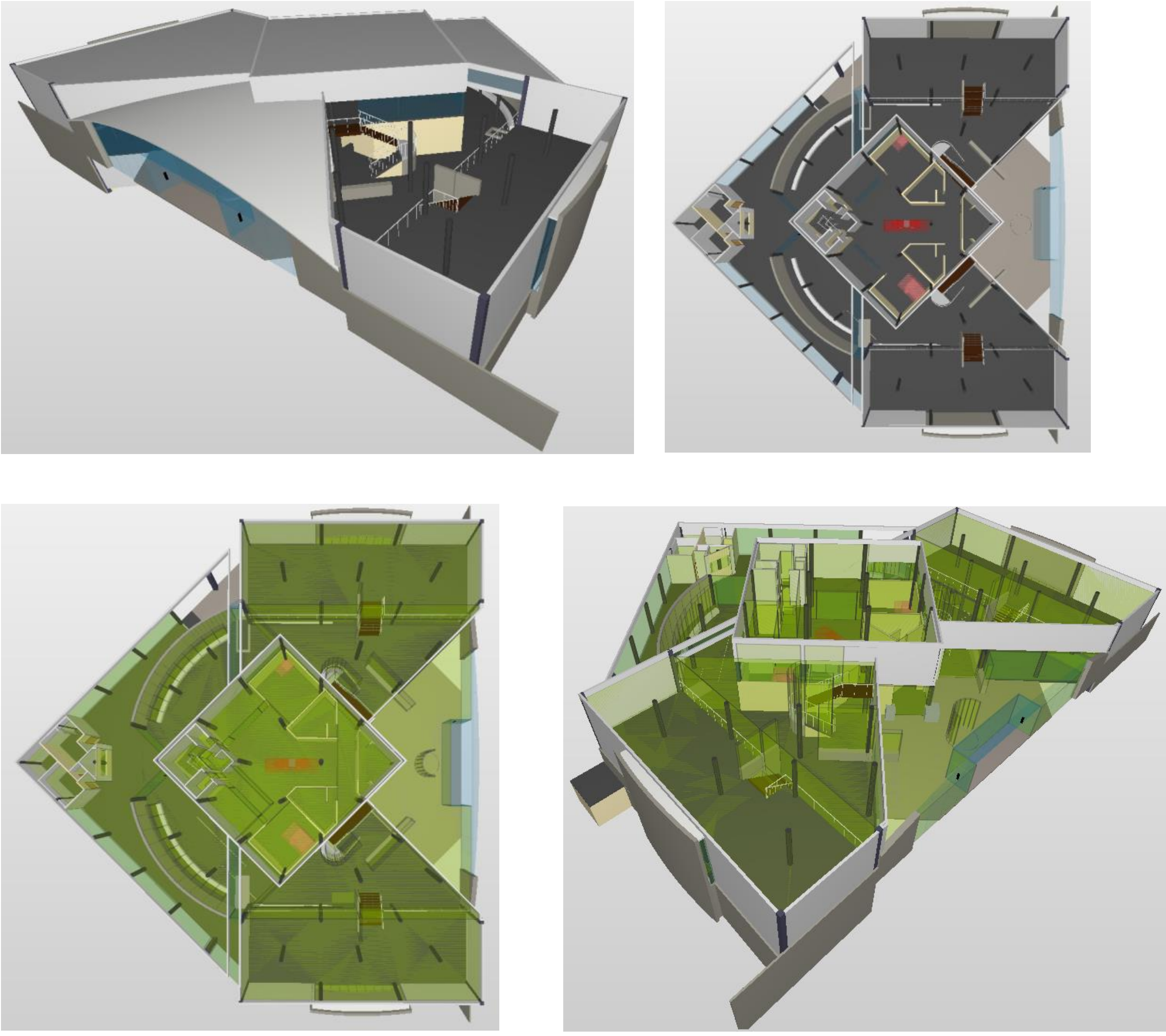


Figure 34: 3D views of the model in the Solibri viewer

INFO

Space.4.1 : Dining area L2[49]

Identification | Location | Quantities | Relations | Space Boundaries | Space Boundary Areas | Classification | Hyperlinks | Pset_SpaceCommon | Pset_SpaceFireSafetyRequirements | Pset_SpaceOccupancyRequirements | Pset_SpaceThermalRequirements | Qto_SpaceBaseQuantities

Property	Value
AirConditioning	True
AirConditioningCentral	True
DiscontinuedHeating	True
MechanicalVentilationRate	0
NaturalVentilation	False
NaturalVentilationRate	0
SpaceHumidity	0
SpaceHumidityMax	0
SpaceHumidityMin	0
SpaceHumiditySummer	0
SpaceHumidityWinter	0
SpaceTemperature	0
SpaceTemperatureMax	0
SpaceTemperatureMin	0
SpaceTemperatureSummerMax	0
SpaceTemperatureSummerMin	0
SpaceTemperatureWinterMax	0
SpaceTemperatureWinterMin	0

Figure 35: List of properties associated with a space in the Solibri viewer

When selecting any equipment in the model, the verification attested to the presence of all required property sets from the Information Content within Level of Information Need, showing the respective properties and the values associated with each one of them (Figure 36). The model verification process assisted in ensuring that the final IFC file generated from it is in accordance with the determinations from the AIR.

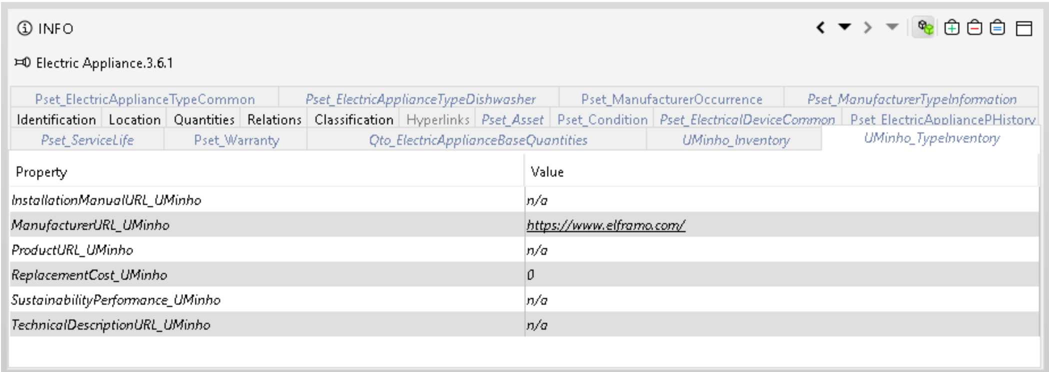


Figure 36: List of properties associated with a piece of Kitchen Equipment in the Solibri viewer

5.5 Application

The exported IFC file was used to simulate the “Asset Maintenance” Use for the model using a business intelligence platform (Power BI). A sample Asset Maintenance interactive report (dashboard) was created allowing the visualization of the Equipment data, presenting their total number, localization, the properties associated with each of them, and a warranty deadline analysis. The complete report can be seen in Figure 37.

On the upper left corner of the report, it is possible to observe the number of spaces, assets, and asset types in the model. Next to them, the model is presented three-dimensionally, allowing interactions by the user, such as elements hiding, localization of assets and building sectioning. In addition, on the right upper corner, the operator has the possibility of consulting properties values depending on the selected equipment, using their names or inventory numbers.

Right below the building 3D visualization, the report also presents a donut chart and a pie chart that allows the perception of the proportion of assets per group (Monitoring Equipment or Kitchen Equipment) and their percentage by type. Additionally, on the right bottom of the report, the quantity of equipment of each type per floor is presented as a table.

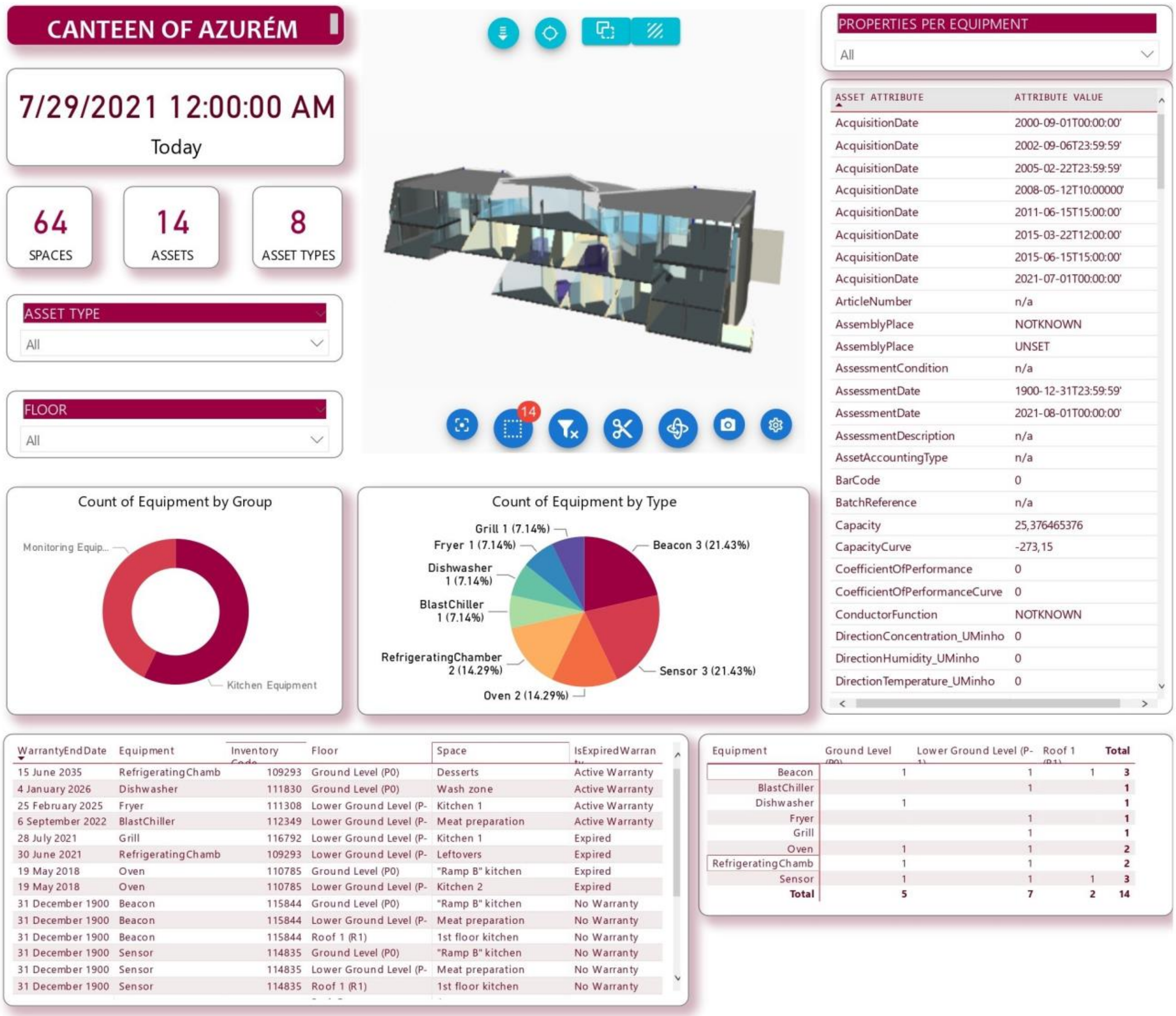


Figure 37: Dashboard created using Power BI

A warranty deadline date analysis was simulated, as shown on the left bottom corner of Figure 37. Fictitious warranty expiration dates were created for each appliance and inserted in the model inside the *WarrantyEndDate* property. Thus, the Power BI was configured to display the list of assets with respective inventory code, localization in the building, expiration dates of warranty, and, in addition, present a status message depending upon their warranties expiration dates when compared to the date the report was being analyzed.

As can be seen, the assets that had the neutral value (1900-12-31T23:59:59') in the *WarrantyEndDate* property received the status of "No Warranty" since those neutral values represent there is no available information for the property and, in that case, it is understood there is no warranty associated to the asset. The remaining assets received either an "Active Warranty" or "Expired Warranty" status, depending upon their defined warranty end dates. The simulation allows demonstrating that the business intelligence platform can visualize the information inserted in the AIM, but it can also manipulate it to allow FM analyses and assist maintenance and management decisions.

When observing more than one visual working together, it is possible to select just one type of equipment, and the whole dashboard will refresh and highlight the information applicable to it, including its group and quantity, and also the location of each appliance of the same type in the building (Figure 38). Additionally, when selecting just one floor, the automatic refreshment happens, and the dashboard presents the different groups and types of assets located on the selected floor, as well as the warranty information and status of those appliances (Figure 39).

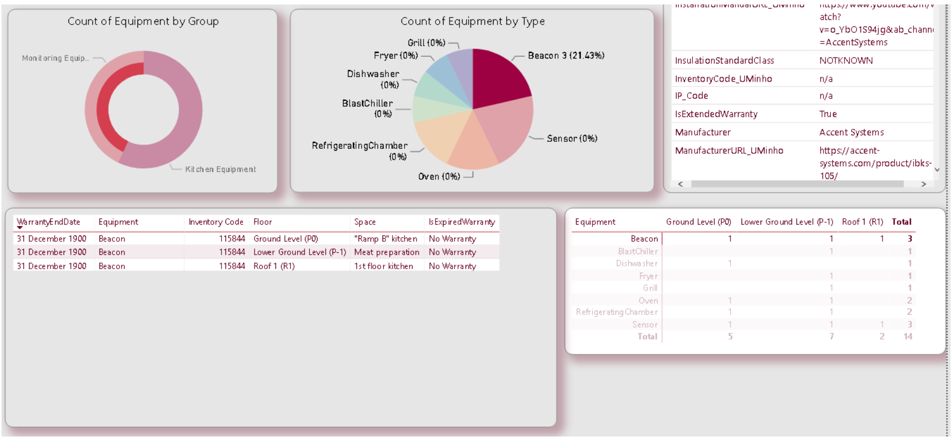


Figure 38: Power BI dashboard when a type of equipment is selected

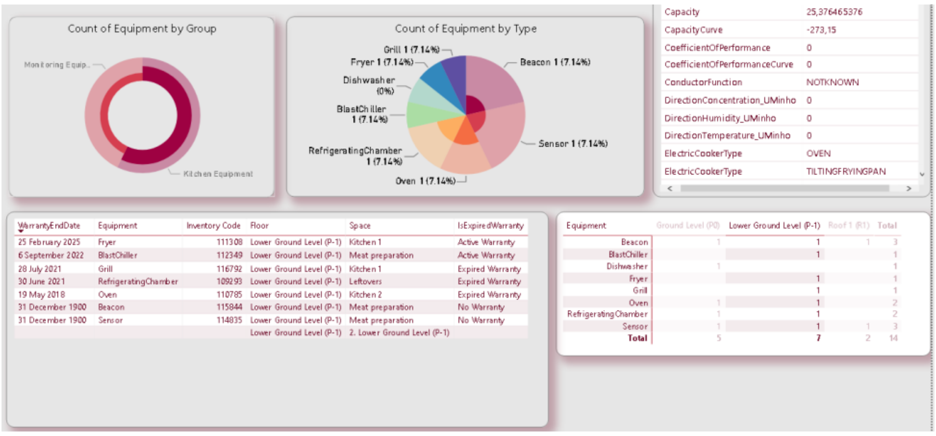


Figure 39: Power BI dashboard when a floor level is selected

During the process of creating the dashboard and interacting with its functions, it was confirmed that the completeness of information was corrected transferred from the model to the platform through the IFC file. Moreover, the chosen platform of analyses demonstrated to be a very useful and customizable tool, with the characteristic of having appealing visuals and allowing an extensive range of possibilities of analyses.

6 Conclusion

6.1 General conclusions

This dissertation presented the process of developing interoperability focused requirements in the form of an AIR to inform the development of a BIM model aiming at supporting FM processes for the operational phase of the Canteen of Azurém, a building part of the University of Minho campus. The work also encompassed modelling the building and its assets with posterior importation of the exported IFC file in a business intelligence platform that proves the viability of using the model as the primary source of information to allow analysis and procedures taken from the facility manager role.

The first step of the work was developing theoretical knowledge on the fields of FM and BIM, including the research for the most current studies on the subject. The extent of the literature included guidance, manuals and standardisation, which assisted the understanding of the concepts, regulations, and guidelines from these documents.

During the process of developing the requirements applied to the case study, the absence of detailed and specific guidance for creating those requirements was confirmed as a considerable difficulty for the process, as has already been foreseen by the literature review. This is aggravated by the fact that the procedure for specifying those requirements for a given use and asset also requires highly specific knowledge that may not always be part of a manager or owner expertise, hindering the process.

Even though the development of those requirements demands specific knowledge, the content of the ISO 19650 series consulted during the process assisted the understanding of the information management process. The standard must be considered for the efficient application of BIM during the various phases of an asset life cycle, helping the understanding of the actors involved in a project and the role of those actors. Thus, it was possible to create a complete set of requirements for the FM context of the existing building, resulting in an AIR that followed the standard recommendations.

Another essential reference for developing those requirements was the Level of Information Need framework from the European Standard EN 17412-1, which thoroughly covered the specification of the extent, granularity, and form of the required information. The framework proved to be a relevant regulation for requirements definition as it allows a lean process based on well-defined steps, concepts, and guidelines. An important perception derived from the process of developing the Level of Information Need is that it presents the posterior necessity of analysing the final set of requirements for the same

Information Delivery Milestone that may encompass different uses for the same asset. It requires a thorough analysis to determine the final amount of information (geometrical, alphanumerical and documentation) a specific asset will require when all the uses are interconnected in the same model.

Both the ISO series and the European Standard states the primary determination that information requirements definition must happen with a purpose-driven perspective. This critical definition was proved to be quite helpful in the process since this thread of thought assisted the decision-making process as for the relevance of requiring one or another level of complexity for each type of information. For the BIM-FM adoption context, the description of the process of developing the requirements as well as the decisions made during it, presented in this dissertation, can assist the implementation of the cited guidelines by other entities.

Besides the standards, the specifications from the IFC schema were used since the first steps of the requirements definition, and it was noted that the extent of the scope assisted the development of the requirements. The schema includes definitions that encompass diverse AECO industry topics, presenting pre-defined properties and properties sets for different use cases. The consultation of the IFC definitions since the beginning of the process also allows an interoperability-focused requirements definition.

For the modelling stage, the relevance of having previous knowledge about the authoring software characteristics was confirmed to be relevant. Considering Revit, the awareness about an essential aspect of the software regarding the association of built-in properties was essential to avoid information duplication. In addition, the characteristic of the non-exportation of empty properties was used to favour the project.

Aware of those particularities, it was possible to establish that all the hard-coded properties (those enforced by the authoring software to be associated with the objects) would be kept in the model, but only a portion of them would be exported. In addition, the empty properties could be applied for the specific case of Boolean properties for which there was no known value for its fulfilling. Those definitions guarantee the properties are available for future fulfilment in the authoring software if the SASUM requires a model update from the same Lead Appointed Party. It is essential to highlight the absence of guidelines about the neutral values to adopt for Boolean properties, which induced an assumption that contradicts the primary guidelines of avoiding empty properties in the model, leading to a final IFC file that does not contain the complete set of properties required.

The application of the model in a business intelligence platform allowed the confirmation of the potential of using BIM as a trustful information source while showing the potentialities of the chosen platform. The IFC schema was also proved to be efficient for the transportation of information from the BIM model to a platform that allows FM analysis since all the required information was able to be delivered seamlessly.

It is relevant to acknowledge the value of the work developed in this dissertation for the context of the strategic implementation of BIM-FM. For the current state of the art on the subject, the dissertation stands out and fits the gap of studies covering the process of BIM-FM implementation as a whole. The developed work explained the procedure step by step, summarizing the main path to take, always considering the applicable standardization, and commenting on the possible challenges to be faced. Therefore, the dissertation construction allows it to be consulted as an example for owners and managers aiming at developing information requirements. Any building operator can adapt its content to meet their business interests, generating useful sets of requirements for effective BIM-FM performance.

6.2 Future suggestions

The University of Minho and the SASUM do not have defined OIR and AIR. The first suggestion would be to improve the AIR created during the development of this dissertation for it to encompass other relevant uses for the BIM model and other range of assets that were not considered in this study. This would be the first step in creating a set of official documents for the BIM application in the university's facility management processes.

During the final stage of this dissertation development, a laser scanning was realized on the Canteen as one of the steps of the project Cognitive CMMS, generating a point cloud of the building's architecture. Therefore, the association of the model created in this dissertation with the point cloud resulted from the survey is a suggested future action that would improve the model's accuracy, allowing future uses as the "Augmented reality", and bringing more efficiency for the "Asset Tracking" and "Asset Maintenance" Uses.

For the few analyses developed during this study, Power BI potential for deep personalization and information organization was proved. A third suggestion would encompass the enhancement of the report created in the platform. Among the possibilities for future reports, the data collected by the Canteen sensors could be stored in dashboards and used for analysing its historical behaviour. Another option would be the analysis of the energy consumption of the building by accumulating the information monthly, allowing to keep a close perception of it historically.

Since the Power BI platform has diversified capabilities, to keep improving the FM process for the Canteen using the cited platform, it is suggested its connection with other information sources, in addition to the building model. The BIM model proved to be an efficient primary source of information to allow FM visualizations. It provides the initial information about the building and assets, representing the building physical form and allowing the localization of assets. However, the insertion of data from different sources relevant to the FM activities can potentially improve the possible analyses and activities to occur. A suggestion is to generate work orders directly from Power BI as this type of information is usually not associated with the BIM model, supporting maintenance activities.

In addition to improving the data analysis using the platform suggested previously, considering the context of the CMMS project, utilising the model as the source of information for the platform to be developed by Valuekeep is another step suggested. This study could reinforce the versatility of the BIM model as the primary information provider for a diverse range of FM platforms.

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8 Appendix I – General Modelling Manual

Generic Rules	
Nomenclature	The building file must be named as follow: Building_UMinho_NameOfTheBuilding
	The objects' files must be named as follow [67], [68]: Type_Manufacturer_Model
Assets	The assets to be modelled must be determined prior to any modelling activity and their selection must depend on the uses intended for the model.
	The assets should be organized within a breakdown structure. It is necessary to arrange the assets considering the semantic, functional and spatial decomposition of the project into objects (e.g. construction elements and spaces are identified). It is advised to consider the IFC schema structure during the arrangement of the objects to allow the link between them and the native classes of the IFC.
	All selected assets must be modelled following the guidelines of their respective Level of Information Need
Classification System	The assets should be classified using the newest version of the Uniclass 2015 classification system.
Architectural Levels	The model must be built considering the architectural finished floor levels.
	The modelling by level is crucial since most model-based analysis and facility management organization are performed by floor.
Coordination System	It is recommended that the coordination base of the project is determined in a way the entire building locates within the positive sides of the X-Y axis.
	In terms of the Z-axis, the building position should be the same as its actual elevation.
	The model should be georeferenced using the Coordinate System EPSG:3763.
Software	It is required to check the software exporting certificates to ensure their capability to export models in the IFC version agreed for the project.
	The project agreed version of the IFC schema must be the regulated most recent one. The list of official releases of the IFC specification can be check at: https://technical.buildingsmart.org/standards/ifc/ifc-schema-specifications/
IFC Native Classes	All elements must be modelled using the correspondent tool within the authoring software to guarantee the identification of the objects according to the native classes of objects from the IFC schema.
	If there is no specific tool in the BIM creation software to model a particular element, it can be modelled as a generic object. In this case, the element must be mapped to the appropriate IFC Entity and respective Predefined Types to allow a correct export.
	Invariably, it is imperative to guarantee the correct and appropriate definition of the properties to export the information about the IFC Entity and Predefined Type for all the elements modelled, according to the IFC schema version defined for the project.
Architectural Elements	
Walls	When creating the architectural model, the walls must be modelled per floor. Some BIM authoring software or IFC exporters have a setting option allowing the user to split multi-story walls per floor when exporting in the IFC format.
	There must be no overlap or gap between slabs and walls.
	Interior walls should be modelled from the top of the floor finish to the bottom surface of the above slab or beam.

Architectural Elements	
Walls	Floor slabs should be aligned with the inside surface of the outside walls if there is no other design orientation.
	If the wall layers and their materials are not relevant to any of the BIM uses defined for the project, the wall must have only one layer and present just the total thickness of the element.
Doors and Windows	Doors and windows must be contained within the wall elements.
	If windows are spaning more than one floor, they should be modelled as openings in the walls of each floor of the building.
Slab	Unless the floor is considered an asset to be managed or the definition of its layers is relevant to any of the BIM uses defined for the project, the slab must have only one layer. Its total thickness must encompass the structure and the cladding.
	The slabs must be properly connected to adjacent elements.
Stairs	Stairs must be modelled using the appropriate tool. If necessary, landings can be introduced using the another tool to allow their modelling, however considering the Ifc Entity is associated correctly.
Structural Elements	
Columns and beams	The structural elements are often not considered objects of the Facility Management activities unless the maintenance of the building structure is planned to happen. Nevertheless, it is relevant to model the beams and columns since their presence can interfere with other maintenance activities.
	Columns and beams should be modelled by their external dimensions, taking into account the structure and finish thickness.
	The columns must be modelled per floor.
Spaces	
Spaces	Spaces can usually be created automatically using the tools of the BIM software. They represent an area or volume bounded actually or theoretically with certain functions within a building.
	The definition of the limits and extension of the spaces can vary on a project basis since it depends upon the facility manager to delimitate how the spaces of the building will be categorized.
	IfcSpace class attributes are essential for building management and must be defined according to the organization inventory.
Furniture	
Furniture	The furniture shall be modelled if it is one of the assets to be managed or its position and volume interfere in one of the foreseen appointments to be taken place.
	Furniture must be modelled as objects, and the IfcElementType must be defined accordingly.
Equipment	
Electrical Appliance	All electrical appliances should be modelled with the correct type and position of connectors if it seems necessary to fulfill the purpose of the models.
	It is unnecessary to model the connectors if the building systems will not be modelled, since these appliances would not connect to anything.
Building Systems	
Building Systems	The various systems of the building must be modelled using different colours, allowing easy visual differentiation between them.
	The systems and the equipment served by them must be connected.

9 Appendix II – OIR, AIR, Purposes and Uses

OIR	AIR	PURPOSES	USES
Keep the university installations and infrastructure efficient and prepared to feed the occupants needs	Develop an accurate record of the final building design for use in future renovation projects	3D representation of the current building design	(1) Visual Communication; (3) Virtual Reality Simulation (VR)
		Tracking building and assets renovation or replacement and importing new information into model	(10) BIM/FM Integration (BIM-FMI)
	Adequate allocation of spaces to intended uses	Having a trustful and fast source to access space conditions and requirements	(8) Space Management; (7) Relocation Management
	Keep an accurate computerized record of the building's assets	Maintain up-to-date facility and equipment data including but not limited to maintenance schedules, warranties, cost data, upgrades, replacements, damages/deterioration, maintenance records, manufacturer's data, and equipment functionality	(5) Asset Maintenance
		Store operations, maintenance owner user manuals, and equipment specifications for faster access	(5) Asset Maintenance
	Decrease the occurrence of reactive maintenance and emergency maintenance repairs	Provide one comprehensive source for the maintenance record of a building's assets for the maintenance team	(5) Asset Maintenance
		Track maintenance history	(5) Asset Maintenance
Guarantee the safety, confort and health of the buildings' occupants	Improve the effectiveness of emergency response when needed	Pre-Disaster planning	Not Applicable
		Post-Disaster record	Not Applicable
	Minimize risks to first responders	Provide police, fire, public safety officials, and first responders access to critical building information in real-time	Not Applicable
	Assure the obedience of occupancy limits for the spaces	Having faster access to spaces dimensions and availability	(8) Space Management
	Guaranty air quality of the spaces	Monitoring of CO2, humidity and temperature levels using sensors	(9) Real-time Utilization
		Visually review lighting conditions	(10) BIM/FM Integration (BIM-FMI)

OIR	AIR	PURPOSES	USES
Guarantee a sustainable management of the buildings	Pursue energy efficiency	Improve the accuracy of building energy consumption assessment	(2) Energy Utilization
	Promote the mitigation of the environmental impact of the building utilization	Perform a Life Cycle Analysis (LCA) for the building	(4) Life Cycle Assessment (LCA)
		Keep documentation of environmental impacts for future uses	(4) Life Cycle Assessment (LCA)
Improve financial expenses management	Monitor life cycle costing	Provide quantitative results for energy use calculations	(2) Energy Utilization
	Increase the productivity of field installation, repair and maintenance	Minimize down-time by appropriately allocating maintenance staff by real time location of personnel and assets	(6) Asset Tracking
		Produce accurate quantity take-offs of current university assets which aid in financial reporting and estimating the future cost implications of upgrades or replacements of a particular asset	(10) BIM/FM Integration (BIM-FMI)
		Obtaining building and system information automatically from the building information model instead of inputting data manually	(10) BIM/FM Integration (BIM-FMI)
	Extend the service life of equipment	Provide one comprehensive source for tracking the use, performance, and maintenance of a building's assets for the financial department	(5) Asset Maintenance

10 APPENDIX III – LEVEL OF INFORMATION NEED

III.1 Architectural and Structural Elements Group

Information Delivery Milestone:	Handover		
Purposes/Uses:	Asset Maintenance Asset Tracking Relocation Management Space Management BIM/FM Integration (BIM-FMI)		
Asset:	Architectural and Structural Elements	Form	Format
Structured Information			
Geometrical Information			
Detail	The objects shall represent the simplified form and volume of the physical element's external boundary without providing any further details. The objects should be modelled with no layers or components.	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Object must have representative colours close to the reality but there is no need for textures.		
Parametric Behaviour	Explicit Geometry		
Alphanumerical Information			
Identification	Columns	n/a	n/a
	Doors		
	Slabs		
	Roofs		
	Stairs		
	Walls		
	Windows		
Information Content	Not Applicable	n/a	n/a
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

Information Delivery Milestone:	Handover		
Purposes/Uses:	Real-time Utilization		
Asset:	Architectural and Structural Elements	Form	Format
Structured Information			
Geometrical Information			
Detail	The objects shall represent the simplified form and volume of the physical element's external boundary without providing any further details. The objects should be modelled with no layers or components.	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Not Applicable		
Parametric Behaviour	Explicit Geometry		
Alphanumerical Information			
Identification	Columns	n/a	n/a
	Doors		
	Slabs		
	Roofs		
	Stairs		
	Walls		
	Windows		
Information Content	Not Applicable	Data Sheet	IFC
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

Information Delivery Milestone:	Handover		
Purposes/Uses:	Visual Communication		
Asset:	Architectural and Structural Elements	Form	Format
Structured Information			
Geometrical Information			
Detail	The object shall represent the real form of the physical elements' external boundary, including external detailing only when it can be differentiating. The objects should be modelled as single elements (with no layers).	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Symbolic appearance, with uniform real colour		
Parametric Behaviour	Explicit Geometry		
Alphanumerical Information			
Identification	Columns	n/a	n/a
	Doors		
	Slabs		
	Roofs		
	Stairs		
	Walls		
	Windows		
Information Content	Not Applicable	Data Sheet	IFC
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

Information Delivery Milestone:	Handover		
Purposes/Uses:	Virtual Reality Simulation (VR)		
Asset:	Architectural and Structural Elements	Form	Format
Structured Information			
Geometrical Information			
Detail	The object shall represent the real form of the physical elements' external boundary, including external detailing only when it can be differentiating. The objects should be modelled as single elements (with no layers).	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Realistic. Showing colours, textures and transparency of the materials.		
Parametric Behaviour	Explicit Geometry		
Alphanumerical Information			
Identification	Columns	n/a	n/a
	Doors		
	Slabs		
	Roofs		
	Stairs		
	Walls		
	Windows		
Information Content	Not Applicable	Data Sheet	IFC
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

Information Delivery Milestone:	Handover		
Purposes/Uses:	Life Cycle Assessment (LCA)		
Asset:	Architectural and Structural Elements	Form	Format
Structured Information			
Geometrical Information			
Detail	The object should contain all the layers and components from its real composition, in the correct sequence and position with their actual thickness. Its dimensions, volume, shape, and form must be equivalent to reality.	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Symbolic appearance, with uniform real colour		
Parametric Behaviour	Explicit Geometry		
Alphanumerical Information			
Identification	Columns	n/a	n/a
	Doors		
	Slabs		
	Roofs		
	Stairs		
	Walls		
	Windows		
Information Content	The information content is established at Tables IV.1 -IV.7	Data Sheet	IFC
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

Information Delivery Milestone:	Handover		
Purposes/Uses:	Energy Utilisation;		
Asset:	Architectural and Structural Elements	Form	Format
Structured Information			
Geometrical Information			
Detail	The object should contain all the layers and components from its real composition, in the correct sequence and position with their actual thickness. Its dimensions, volume, shape, and form must be equivalent to reality.	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Symbolic appearance, with uniform representative colour		
Parametric Behaviour	Explicit Geometry		
Alphanumerical Information			
Identification	Columns	n/a	n/a
	Doors		
	Slabs		
	Roofs		
	Stairs		
	Walls		
	Windows		
Information Content	Not Applicable	n/a	n/a
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

III.2 Equipment Group

III.2.1 Equipment

Information Delivery Milestone:	Handover		
Purposes/Uses:	Space Management		
Asset:	Equipment	Form	Format
Structured Information			
Geometrical Information			
Detail	Not Applicable	n/a	n/a
Dimensionality	3D		
Location	Relative Location		
Appearance	Not Applicable		
Parametric Behaviour	Not Applicable		
Alphanumerical Information			
Identification	Sensor	n/a	n/a
	Beacon		
	Oven		
	Fryer		
	Refrigerating Chamber		
	Grill		
	Dishwasher		
	Blast Chiller		
Information Content	Not Applicable	n/a	n/a
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

Information Delivery Milestone:	Handover		
Purposes/Uses:	Visual Communication		
Asset:	Equipment	Form	Format
Structured Information			
Geometrical Information			
Detail	The object shall represent the real form of the physical element's external boundary, including external detailing.	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Symbolic appearance, with uniform representative colour		
Parametric Behaviour	Explicit Geometry		
Alphanumerical Information			
Identification	Sensor	n/a	n/a
	Beacon		
	Oven		
	Fryer		
	Refrigerating Chamber		
	Grill		
	Dishwasher		
	Blast Chiller		
Information Content	Not Applicable	n/a	n/a
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

Information Delivery Milestone:	Handover		
Purposes/Uses:	Virtual Reality Simulation (VR)		
Asset:	Equipment	Form	Format
Structured Information			
Geometrical Information			
Detail	The object shall represent the real form of the physical elements' external boundary, including external detailing.	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Realistic. Showing colours, textures and transparency of the materials.		
Parametric Behaviour	Explicit Geometry		
Alphanumerical Information			
Identification	Sensor	n/a	n/a
	Beacon		
	Oven		
	Fryer		
	Refrigerating Chamber		
	Grill		
	Dishwasher		
	Blast Chiller		
Information Content	Not Applicable	n/a	n/a
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

Information Delivery Milestone:	Handover		
Purposes/Uses:	Asset Tracking		
Asset:	Equipment	Form	Format
Structured Information			
Geometrical Information			
Detail	Not Applicable	Drawing	IFC
Dimensionality	0D		
Location	Relative Location		
Appearance	Not Applicable		
Parametric Behaviour	Not Applicable		
Alphanumerical Information			
Identification	Sensor	n/a	IFC
	Beacon		
	Oven		
	Fryer		
	Refrigerating Chamber		
	Grill		
	Dishwasher		
	Blast Chiller		
Information Content	Not Applicable	n/a	n/a
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

Information Delivery Milestone:	Handover		
Purposes/Uses:	Life Cycle Assessment (LCA)		
Asset:	Equipment	Form	Format
Structured Information			
Geometrical Information			
Detail	The object shall represent the simplified form and volume of the physical element's external boundary without providing any further detail.	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Symbolic appearance, with uniform representative colour		
Parametric Behaviour	Explicit Geometry		
Alphanumerical Information			
Identification	Sensor	n/a	n/a
	Beacon		
	Oven		
	Fryer		
	Refrigerating Chamber		
	Grill		
	Dishwasher		
	Blast Chiller		
Information Content	The information content is established at Table IV.8 - IV.13	Data Sheet	IFC
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

III.2.2 Monitoring Equipment

Information Delivery Milestone:	Handover		
Purposes/Uses:	Real-time Utilization		
Asset:	Monitoring Equipment	Form	Format
Structured Information			
Geometrical Information			
Detail	The object shall represent the simplified form and volume of the physical element's external boundary without providing any further detail.	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Symbolic appearance, with uniform representative colour		
Parametric Behaviour	Explicit Geometry		
Alphanumerical Information			
Identification	Sensor	n/a	n/a
	Beacon		
Information Content	The information content is established at Tables IV.8 and IV.9	Data Sheet	IFC
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

Information Delivery Milestone:	Handover		
Purposes/Uses:	Asset Maintenance Relocation Management BIM/FM Integration (BIM-FMI)		
Asset:	Monitoring Equipment	Form	Format
Structured Information			
Geometrical Information			
Detail	The object shall represent the simplified form and volume of the physical element's external boundary.	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Symbolic appearance, with uniform representative colour		
Parametric Behaviour	Explicit Geometry		
Alphanumerical Information			
Identification	Sensor	n/a	n/a
	Beacon		
Information Content	The information content is established at Table IV.8 and IV.9	Data Sheet	IFC
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

III.2.3 Kitchen Equipment

Information Delivery Milestone:	Handover		
Purposes/Uses:	Asset Maintenance BIM/FM Integration (BIM-FMI)		
Asset:	Kitchen Equipment	Form	Format
Structured Information			
Geometrical Information			
Detail	The object shall represent the simplified form and volume of the physical element's external boundary, including the required volume of the operational and maintenance space (clearance zone) and without providing any further detail.	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Symbolic appearance, with uniform representative colour		
Parametric Behaviour	Explicit Geometry		
Alphanumerical Information			
Identification	Oven	n/a	n/a
	Fryer		
	Refrigerating Chamber		
	Grill		
	Dishwasher		
	Blast Chiller		
Information Content	The information content is established at Table IV.10 – IV.13	Data Sheet	IFC
Unstructured Information			
Documentation			
Set of documents	Primary information document	n/a	PDF

Information Delivery Milestone:	Handover		
Purposes/Uses:	Relocation Management		
Asset:	Kitchen Equipment	Form	Format
Structured Information			
Geometrical Information			
Detail	The object shall represent the simplified form and volume of the physical element's external boundary, including the required volume of the operational and maintenance space (clearance zone) and without providing any further detail.	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Symbolic appearance, with uniform representative colour		
Parametric Behaviour	Explicit Geometry		
Alphanumerical Information			
Identification	Oven	n/a	n/a
	Fryer		
	Refrigerating Chamber		
	Grill		
	Dishwasher		
	Blast Chiller		
Information Content	The information content is established at Table IV.10 - IV.13	Data Sheet	IFC
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

Information Delivery Milestone:	Handover		
Purposes/Uses:	Energy Utilisation;		
Asset:	Kitchen Equipment	Form	Format
Structured Information			
Geometrical Information			
Detail	The object shall represent the simplified form and volume of the physical element's external boundary without providing any further detail.	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Symbolic appearance, with uniform representative colour		
Parametric behaviour	Explicit Geometry		
Alphanumerical Information			
Identification	Oven	n/a	n/a
	Fryer		
	Refrigerating Chamber		
	Grill		
	Dishwasher		
	Blast Chiller		
Information Content	The information content is established at Table IV.10 - IV.13	Data Sheet	IFC
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

III.3 Spaces

Information Delivery Milestone:	Handover		
Purposes/Uses:	Asset Tracking; Relocation Management; Space Management; Real-time Utilization; BIM/FM Integration (BIM-FMI)		
Asset:	Spaces	Form	Format
Structured Information			
Geometrical Information			
Detail	Not Applicable	Drawing	IFC
Dimensionality	3D		
Location	Relative Location		
Appearance	Not Applicable		
Parametric Behaviour	Not Applicable		
Alphanumerical Information			
Identification	Spaces	n/a	n/a
Information Content	The information content is established at Table IV.14	n/a	n/a
Unstructured Information			
Documentation			
Set of documents	Not Applicable	n/a	n/a

11 APPENDIX IV – INFORMATION CONTENT

Table IV.1 – Walls' Data Template for Information Content

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							Reference	Pset_WallCommon	Character	Instance	n/a
			x							Status *1		Character	Instance	n/a
			x							FunctionalUnitReference	Pset_EnvironmentalImpactIndicators	Character	Type	n/a
			x							Unit		Character	Type	n/a
			x							LifeCyclePhase *2		Character	Type	n/a
			x							ExpectedServiceLife		Integer	Type	years
			x							TotalPrimaryEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							WaterConsumptionPerUnit		Decimal	Type	l/m^2
			x							HazardousWastePerUnit		Decimal	Type	kg/m^2
			x							NonHazardousWastePerUnit		Decimal	Type	kg/m^2
			x							ClimateChangePerUnit		Decimal	Type	kgCO2-eq/m^2
			x							AtmosphericAcidificationPerUnit		Decimal	Type	kgSO2-eq/m^2
			x							RenewableEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							NonRenewableEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							ResourceDepletionPerUnit		Decimal	Type	kgSb-eq/m^2
			x							InertWastePerUnit		Decimal	Type	kg/m^2
			x							RadioactiveWastePerUnit		Decimal	Type	kg/m^2
			x							StratosphericOzoneLayerDestructionPerUnit		Decimal	Type	kgCFC-R11-eq/m^2
			x							PhotochemicalOzoneFormationPerUnit		Decimal	Type	kgC2H4-eq/m^2
			x							EutrophicationPerUnit		Decimal	Type	kgPO4-eq/m^2
			x							TotalPrimaryEnergyConsumption	Pset_EnvironmentalImpactValues	Decimal	Instance	J
			x							WaterConsumption		Decimal	Instance	l
			x							HazardousWaste		Decimal	Instance	kg
			x							NonHazardousWaste		Decimal	Instance	kg
			x							ClimateChange		Decimal	Instance	kgCO2-eq
			x							AtmosphericAcidification		Decimal	Instance	kgSO2-eq
			x							RenewableEnergyConsumption		Decimal	Instance	J
			x							NonRenewableEnergyConsumption		Decimal	Instance	J

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							ResourceDepletion	Pset_EnvironmentalImpactValues	Decimal	Instance	kgSb-eq
			x							InertWaste		Decimal	Instance	kg
			x							RadioactiveWaste		Decimal	Instance	kg
			x							StratosphericOzoneLayerDestruction		Decimal	Instance	kgCFC-R11-eq
			x							PhotochemicalOzoneFormation		Decimal	Instance	kgC2H4-eq
			x							Eutrophication		Decimal	Instance	kgPO4-eq
			x							LeadInTime		Character	Instance	years
			x							Duration		Character	Instance	years
			x							LeadOutTime		Character	Instance	years

Table IV.2 – Slabs' Data Template for Information Content

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							Reference	Pset_SlabCommon	Character	Instance	n/a
			x							Status *[1]		Character	Instance	n/a
			x							FunctionalUnitReference	Pset_EnvironmentalImpactIndicators	Character	Type	n/a
			x							Unit		Character	Type	n/a
			x							LifeCyclePhase *[2]		Character	Type	n/a
			x							ExpectedServiceLife		Integer	Type	years
			x							TotalPrimaryEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							WaterConsumptionPerUnit		Decimal	Type	l/m^2
			x							HazardousWastePerUnit		Decimal	Type	kg/m^2
			x							NonHazardousWastePerUnit		Decimal	Type	kg/m^2
			x							ClimateChangePerUnit		Decimal	Type	kgCO2-eq/m^2
			x							AtmosphericAcidificationPerUnit		Decimal	Type	kgSO2-eq/m^2
			x							RenewableEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							NonRenewableEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							ResourceDepletionPerUnit		Decimal	Type	kgSb-eq/m^2
			x							InertWastePerUnit		Decimal	Type	kg/m^2
			x							RadioactiveWastePerUnit		Decimal	Type	kg/m^2
			x							StratosphericOzoneLayerDestructionPerUnit		Decimal	Type	kgCFC-R11-eq/m^2
			x							PhotochemicalOzoneFormationPerUnit		Decimal	Type	kgC2H4-eq/m^2
			x							EutrophicationPerUnit		Decimal	Type	kgPO4-eq/m^2
			x							TotalPrimaryEnergyConsumption	Pset_EnvironmentalImpactValues	Decimal	Instance	J
			x							WaterConsumption		Decimal	Instance	l
			x							HazardousWaste		Decimal	Instance	kg
			x							NonHazardousWaste		Decimal	Instance	kg
			x							ClimateChange		Decimal	Instance	kgCO2-eq
			x							AtmosphericAcidification		Decimal	Instance	kgSO2-eq
			x							RenewableEnergyConsumption		Decimal	Instance	J
			x							NonRenewableEnergyConsumption		Decimal	Instance	J
			x							ResourceDepletion		Decimal	Instance	kgSb-eq
			x							InertWaste		Decimal	Instance	kg
			x							RadioactiveWaste		Decimal	Instance	kg
			x							StratosphericOzoneLayerDestruction		Decimal	Instance	kgCFC-R11-eq

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							PhotochemicalOzoneFormation	Pset_EnvironmentalImpactValues	Decimal	Instance	kgC2H4-eq
			x							Eutrophication		Decimal	Instance	kgPO4-eq
			x							LeadInTime		Character	Instance	years
			x							Duration		Character	Instance	years
			x							LeadOutTime		Character	Instance	years

Table IV.3 – Columns' Data Template for Information Content

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							Reference	Pset_ColumnCommon	Character	Instance	n/a
			x							Status *[1]		Character	Instance	n/a
			x							FunctionalUnitReference	Pset_EnvironmentalImpactIndicators	Character	Type	n/a
			x							Unit		Character	Type	n/a
			x							LifeCyclePhase *[2]		Character	Type	n/a
			x							ExpectedServiceLife		Integer	Type	years
			x							TotalPrimaryEnergyConsumptionPerUnit		Decimal	Type	J/m^3
			x							WaterConsumptionPerUnit		Decimal	Type	l/m^3
			x							HazardousWastePerUnit		Decimal	Type	kg/m^3
			x							NonHazardousWastePerUnit		Decimal	Type	kg/m^3
			x							ClimateChangePerUnit		Decimal	Type	kgCO2-eq/m^3
			x							AtmosphericAcidificationPerUnit		Decimal	Type	kgSO2-eq/m^3
			x							RenewableEnergyConsumptionPerUnit		Decimal	Type	J/m^3
			x							NonRenewableEnergyConsumptionPerUnit		Decimal	Type	J/m^3
			x							ResourceDepletionPerUnit		Decimal	Type	kgSb-eq/m^3
			x							InertWastePerUnit		Decimal	Type	kg/m^3
			x							RadioactiveWastePerUnit		Decimal	Type	kg/m^3
			x							StratosphericOzoneLayerDestructionPerUnit		Decimal	Type	kgCFC-R11-eq/m^3
			x							PhotochemicalOzoneFormationPerUnit		Decimal	Type	kgC2H4-eq/m^3
			x							EutrophicationPerUnit		Decimal	Type	kgPO4-eq/m^3
			x							TotalPrimaryEnergyConsumption	Pset_EnvironmentalImpactValues	Decimal	Instance	J
			x							WaterConsumption		Decimal	Instance	l
			x							HazardousWaste		Decimal	Instance	kg
			x							NonHazardousWaste		Decimal	Instance	kg
			x							ClimateChange		Decimal	Instance	kgCO2-eq
			x							AtmosphericAcidification		Decimal	Instance	kgSO2-eq
			x							RenewableEnergyConsumption		Decimal	Instance	J
			x							NonRenewableEnergyConsumption		Decimal	Instance	J
			x							ResourceDepletion		Decimal	Instance	kgSb-eq
			x							InertWaste		Decimal	Instance	kg
			x							RadioactiveWaste		Decimal	Instance	kg
			x							StratosphericOzoneLayerDestruction		Decimal	Instance	kgCFC-R11-eq

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							PhotochemicalOzoneFormation	Pset_EnvironmentalImpactValues	Decimal	Instance	kgC2H4-eq
			x							Eutrophication		Decimal	Instance	kgPO4-eq
			x							LeadInTime		Character	Instance	years
			x							Duration		Character	Instance	years
			x							LeadOutTime		Character	Instance	years

Table IV.4 – Roofs' Data Template for Information Content

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							Reference	Pset_RoofCommon	Character	Instance	n/a
			x							Status *[1]		Character	Instance	n/a
			x							FunctionalUnitReference	Pset_EnvironmentalImpactIndicators	Character	Type	n/a
			x							Unit		Character	Type	n/a
			x							LifeCyclePhase *[2]		Character	Type	n/a
			x							ExpectedServiceLife		Integer	Type	years
			x							TotalPrimaryEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							WaterConsumptionPerUnit		Decimal	Type	l/m^2
			x							HazardousWastePerUnit		Decimal	Type	kg/m^2
			x							NonHazardousWastePerUnit		Decimal	Type	kg/m^2
			x							ClimateChangePerUnit		Decimal	Type	kgCO2-eq/m^2
			x							AtmosphericAcidificationPerUnit		Decimal	Type	kgSO2-eq/m^2
			x							RenewableEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							NonRenewableEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							ResourceDepletionPerUnit		Decimal	Type	kgSb-eq/m^2
			x							InertWastePerUnit		Decimal	Type	kg/m^2
			x							RadioactiveWastePerUnit		Decimal	Type	kg/m^2
			x							StratosphericOzoneLayerDestructionPerUnit		Decimal	Type	kgCFC-R11-eq/m^2
			x							PhotochemicalOzoneFormationPerUnit		Decimal	Type	kgC2H4-eq/m^2
			x							EutrophicationPerUnit		Decimal	Type	kgPO4-eq/m^2
			x							TotalPrimaryEnergyConsumption	Pset_EnvironmentalImpactValues	Decimal	Instance	J
			x							WaterConsumption		Decimal	Instance	l
			x							HazardousWaste		Decimal	Instance	kg
			x							NonHazardousWaste		Decimal	Instance	kg
			x							ClimateChange		Decimal	Instance	kgCO2-eq
			x							AtmosphericAcidification		Decimal	Instance	kgSO2-eq
			x							RenewableEnergyConsumption		Decimal	Instance	J
			x							NonRenewableEnergyConsumption		Decimal	Instance	J
			x							ResourceDepletion		Decimal	Instance	kgSb-eq
			x							InertWaste		Decimal	Instance	kg
			x							RadioactiveWaste		Decimal	Instance	kg
			x							StratosphericOzoneLayerDestruction		Decimal	Instance	kgCFC-R11-eq

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							PhotochemicalOzoneFormation	Pset_EnvironmentalImpactValues	Decimal	Instance	kgC2H4-eq
			x							Eutrophication		Decimal	Instance	kgPO4-eq
			x							LeadInTime		Character	Instance	years
			x							Duration		Character	Instance	years
			x							LeadOutTime		Character	Instance	years

Table IV.5 – Windows' Data Template for Information Content

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							Reference	Pset_WindowCommon	Character	Instance	n/a
			x							Status *1		Character	Instance	n/a
			x							FunctionalUnitReference	Pset_EnvironmentalImpactIndicators	Character	Type	n/a
			x							Unit		Character	Type	n/a
			x							LifeCyclePhase *2		Character	Type	n/a
			x							ExpectedServiceLife		Integer	Type	years
			x							TotalPrimaryEnergyConsumptionPerUnit		Decimal	Type	J/m²
			x							WaterConsumptionPerUnit		Decimal	Type	l/m²
			x							HazardousWastePerUnit		Decimal	Type	kg/m²
			x							NonHazardousWastePerUnit		Decimal	Type	kg/m²
			x							ClimateChangePerUnit		Decimal	Type	kgCO2-eq/m²
			x							AtmosphericAcidificationPerUnit		Decimal	Type	kgSO2-eq/m²
			x							RenewableEnergyConsumptionPerUnit		Decimal	Type	J/m²
			x							NonRenewableEnergyConsumptionPerUnit		Decimal	Type	J/m²
			x							ResourceDepletionPerUnit		Decimal	Type	kgSb-eq/m²
			x							InertWastePerUnit		Decimal	Type	kg/m²
			x							RadioactiveWastePerUnit		Decimal	Type	kg/m²
			x							StratosphericOzoneLayerDestructionPerUnit		Decimal	Type	kgCFC-R11-eq/m²
			x							PhotochemicalOzoneFormationPerUnit		Decimal	Type	kgC2H4-eq/m²
			x							EutrophicationPerUnit		Decimal	Type	kgPO4-eq/m²
			x							TotalPrimaryEnergyConsumption	Pset_EnvironmentalImpactValues	Decimal	Instance	J
			x							WaterConsumption		Decimal	Instance	l
			x							HazardousWaste		Decimal	Instance	kg
			x							NonHazardousWaste		Decimal	Instance	kg
			x							ClimateChange		Decimal	Instance	kgCO2-eq
			x							AtmosphericAcidification		Decimal	Instance	kgSO2-eq
			x							RenewableEnergyConsumption		Decimal	Instance	J
			x							NonRenewableEnergyConsumption		Decimal	Instance	J
			x							ResourceDepletion		Decimal	Instance	kgSb-eq
			x							InertWaste		Decimal	Instance	kg
			x							RadioactiveWaste		Decimal	Instance	kg
			x							StratosphericOzoneLayerDestruction		Decimal	Instance	kgCFC-R11-eq

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							PhotochemicalOzoneFormation	Pset_EnvironmentalImpactValues	Decimal	Instance	kgC2H4-eq
			x							Eutrophication		Decimal	Instance	kgPO4-eq
			x							LeadInTime		Character	Instance	years
			x							Duration		Character	Instance	years
			x							LeadOutTime		Character	Instance	years

Table IV.6 – Doors' Data Template for Information Content

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							Reference	Pset_DoorCommon	Character	Instance	n/a
			x							Status *[1]		Character	Instance	n/a
			x							FunctionalUnitReference	Pset_EnvironmentalImpactIndicators	Character	Type	n/a
			x							Unit		Character	Type	n/a
			x							LifeCyclePhase *[2]		Character	Type	n/a
			x							ExpectedServiceLife		Integer	Type	years
			x							TotalPrimaryEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							WaterConsumptionPerUnit		Decimal	Type	l/m^2
			x							HazardousWastePerUnit		Decimal	Type	kg/m^2
			x							NonHazardousWastePerUnit		Decimal	Type	kg/m^2
			x							ClimateChangePerUnit		Decimal	Type	kgCO2-eq/m^2
			x							AtmosphericAcidificationPerUnit		Decimal	Type	kgSO2-eq/m^2
			x							RenewableEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							NonRenewableEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							ResourceDepletionPerUnit		Decimal	Type	kgSb-eq/m^2
			x							InertWastePerUnit		Decimal	Type	kg/m^2
			x							RadioactiveWastePerUnit		Decimal	Type	kg/m^2
			x							StratosphericOzoneLayerDestructionPerUnit		Decimal	Type	kgCFC-R11-eq/m^2
			x							PhotochemicalOzoneFormationPerUnit		Decimal	Type	kgC2H4-eq/m^2
			x							EutrophicationPerUnit		Decimal	Type	kgPO4-eq/m^2
			x							TotalPrimaryEnergyConsumption	Pset_EnvironmentalImpactValues	Decimal	Instance	J
			x							WaterConsumption		Decimal	Instance	l
			x							HazardousWaste		Decimal	Instance	kg
			x							NonHazardousWaste		Decimal	Instance	kg
			x							ClimateChange		Decimal	Instance	kgCO2-eq
			x							AtmosphericAcidification		Decimal	Instance	kgSO2-eq
			x							RenewableEnergyConsumption		Decimal	Instance	J
			x							NonRenewableEnergyConsumption		Decimal	Instance	J
			x							ResourceDepletion		Decimal	Instance	kgSb-eq
			x							InertWaste		Decimal	Instance	kg
			x							RadioactiveWaste		Decimal	Instance	kg
			x							StratosphericOzoneLayerDestruction		Decimal	Instance	kgCFC-R11-eq

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							PhotochemicalOzoneFormation	Pset_EnvironmentalImpactValues	Decimal	Instance	kgC2H4-eq
			x							Eutrophication		Decimal	Instance	kgPO4-eq
			x							LeadInTime		Character	Instance	years
			x							Duration		Character	Instance	years
			x							LeadOutTime		Character	Instance	years

Table IV.7 – Stairs' Data Template for Information Content

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							Reference	Pset_StairCommon	Character	Instance	n/a
			x							Status *[1]		Character	Instance	n/a
			x							FunctionalUnitReference	Pset_EnvironmentalImpactIndicators	Character	Type	n/a
			x							Unit		Character	Type	n/a
			x							LifeCyclePhase *[2]		Character	Type	n/a
			x							ExpectedServiceLife		Integer	Type	years
			x							TotalPrimaryEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							WaterConsumptionPerUnit		Decimal	Type	l/m^2
			x							HazardousWastePerUnit		Decimal	Type	kg/m^2
			x							NonHazardousWastePerUnit		Decimal	Type	kg/m^2
			x							ClimateChangePerUnit		Decimal	Type	kgCO2-eq/m^2
			x							AtmosphericAcidificationPerUnit		Decimal	Type	kgSO2-eq/m^2
			x							RenewableEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							NonRenewableEnergyConsumptionPerUnit		Decimal	Type	J/m^2
			x							ResourceDepletionPerUnit		Decimal	Type	kgSb-eq/m^2
			x							InertWastePerUnit		Decimal	Type	kg/m^2
			x							RadioactiveWastePerUnit		Decimal	Type	kg/m^2
			x							StratosphericOzoneLayerDestructionPerUnit		Decimal	Type	kgCFC-R11-eq/m^2
			x							PhotochemicalOzoneFormationPerUnit		Decimal	Type	kgC2H4-eq/m^2
			x							EutrophicationPerUnit		Decimal	Type	kgPO4-eq/m^2
			x							TotalPrimaryEnergyConsumption	Pset_EnvironmentalImpactValues	Decimal	Instance	J
			x							WaterConsumption		Decimal	Instance	l
			x							HazardousWaste		Decimal	Instance	kg
			x							NonHazardousWaste		Decimal	Instance	kg
			x							ClimateChange		Decimal	Instance	kgCO2-eq
			x							AtmosphericAcidification		Decimal	Instance	kgSO2-eq
			x							RenewableEnergyConsumption		Decimal	Instance	J
			x							NonRenewableEnergyConsumption		Decimal	Instance	J
			x							ResourceDepletion		Decimal	Instance	kgSb-eq
			x							InertWaste		Decimal	Instance	kg
			x							RadioactiveWaste		Decimal	Instance	kg
			x							StratosphericOzoneLayerDestruction		Decimal	Instance	kgCFC-R11-eq

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							PhotochemicalOzoneFormation	Pset_EnvironmentalImpactValues	Decimal	Instance	kgC2H4-eq
			x							Eutrophication		Decimal	Instance	kgPO4-eq
			x							LeadInTime		Character	Instance	years
			x							Duration		Character	Instance	years
			x							LeadOutTime		Character	Instance	years

Table IV.8 – Sensor's Data Template for Information Content

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x	x		x		x	x	Status *[1]	Pset_SensorTypeCommon	Character	Instance	n/a
				x				x	x	TemperatureSensorType *[6]	Pset_SensorTypeTemperatureSensor	Character	Type	n/a
				x				x	x	SetPointTemperature		Decimal	Type	°C
				x				x	x	SetPointHumidity	Pset_SensorTypeHumiditySensor	Decimal	Type	n/a
				x				x	x	SetPointConcentration	Pset_SensorTypeCO2Sensor	Decimal	Type	n/a
				x		x			x	RatedCurrent	Pset_ElectricalDeviceCommon	Decimal	Type	A
				x		x			x	RatedVoltage		Decimal	Type	V
				x		x			x	NominalFrequencyRange		Decimal	Type	Hz
				x		x			x	PowerFactor		Decimal	Type	n/a
				x		x			x	ConductorFunction *[3]		Character	Type	n/a
				x		x			x	NumberOfPoles		Integer	Type	n/a
				x		x			x	HasProtectiveEarth		Boolean	Type	n/a
				x		x			x	InsulationStandardClass *[7]		Character	Type	n/a
				x		x			x	IP_Code		Character	Type	n/a
				x		x			x	IK_Code		Character	Type	n/a
				x					x	AssessmentDate	Pset_Condition	Date	Instance	n/a
				x					x	AssessmentCondition		Character	Instance	n/a
				x					x	AssessmentDescription		Character	Instance	n/a
			x							FunctionalUnitReference	Pset_EnvironmentalImpactIndicators	Character	Type	n/a
			x							Unit		Character	Type	n/a
			x							LifeCyclePhase *[2]		Character	Type	n/a
			x							ExpectedServiceLife		Integer	Type	years
			x							TotalPrimaryEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							WaterConsumptionPerUnit		Decimal	Type	l/Ud
			x							HazardousWastePerUnit		Decimal	Type	kg/Ud
			x							NonHazardousWastePerUnit		Decimal	Type	kg/Ud
			x							ClimateChangePerUnit		Decimal	Type	kgCO2-eq/Ud
			x							AtmosphericAcidificationPerUnit		Decimal	Type	kgSO2-eq/Ud
			x							RenewableEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							NonRenewableEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							ResourceDepletionPerUnit		Decimal	Type	kgSb-eq/Ud
			x							InertWastePerUnit		Decimal	Type	kg/Ud

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							RadioactiveWastePerUnit	Pset_EnvironmentalImpactIndicators	Decimal	Type	kg/Ud
			x							StratosphericOzoneLayerDestructionPerUnit		Decimal	Type	kgCFC-R11-eq/Ud
			x							PhotochemicalOzoneFormationPerUnit		Decimal	Type	kgC2H4-eq/Ud
			x							EutrophicationPerUnit		Decimal	Type	kgPO4-eq/Ud
			x							TotalPrimaryEnergyConsumption	Pset_EnvironmentalImpactValues	Decimal	Instance	J
			x							WaterConsumption		Decimal	Instance	l
			x							HazardousWaste		Decimal	Instance	kg
			x							NonHazardousWaste		Decimal	Instance	kg
			x							ClimateChange		Decimal	Instance	kgCO2-eq
			x							AtmosphericAcidification		Decimal	Instance	kgSO2-eq
			x							RenewableEnergyConsumption		Decimal	Instance	J
			x							NonRenewableEnergyConsumption		Decimal	Instance	J
			x							ResourceDepletion		Decimal	Instance	kgSb-eq
			x							InertWaste		Decimal	Instance	kg
			x							RadioactiveWaste		Decimal	Instance	kg
			x							StratosphericOzoneLayerDestruction		Decimal	Instance	kgCFC-R11-eq
			x							PhotochemicalOzoneFormation		Decimal	Instance	kgC2H4-eq
			x							Eutrophication		Decimal	Instance	kgPO4-eq
			x							LeadInTime		Character	Instance	years
			x							Duration		Character	Instance	years
			x							LeadOutTime		Character	Instance	years
				x					x	AcquisitionDate	Pset_ManufacturerOccurrence	Date	Instance	n/a
				x					x	BarCode		Character	Instance	n/a
				x					x	SerialNumber		Character	Instance	n/a
				x					x	BatchReference		Character	Instance	n/a
				x					x	GlobalTradeItemNumber	Pset_ManufacturerTypeInformation	Character	Type	n/a
				x					x	ArticleNumber		Character	Type	n/a
				x					x	ModelReference		Character	Type	n/a
				x					x	ModelLabel		Character	Type	n/a
				x					x	Manufacturer		Character	Type	n/a
				x					x	ProductionYear		Integer	Type	n/a
				x					x	AssemblyPlace		Character	Type	n/a
				x					x	ServiceLifeDuration	Pset_ServiceLife	Integer	Type	years
				x					x	MeanTimeBetweenFailure		Integer	Type	years

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
				x		x			x	WarrantyIdentifier	Pset_Warranty	Character	Instance	n/a
				x		x			x	WarrantyStartDate		Date	Instance	n/a
				x		x			x	WarrantyEndDate		Date	Instance	n/a
				x		x			x	IsExtendedWarranty		Boolean	Instance	n/a
				x		x			x	WarrantyPeriod		Integer	Instance	years
				x		x			x	WarrantyContent		Character	Instance	n/a
				x		x			x	PointOfContact		Character	Instance	n/a
				x		x			x	Exclusions		Character	Instance	n/a
				x					x	AssetAccountingType	Pset_Asset	Character	Type	n/a
				x		x			x	GrossWeight	Qto_SensorBaseQuantities	Decimal	Type	kg
				x					x	ReplacementCost_UMinho	UMinho_TypeInventory	Decimal	Type	Euros
				x					x	SustainabilityPerfomance_UMinho		Character	Type	n/a
				x		x			x	ProductURL_UMinho		Hyperlink	Type	n/a
				x		x			x	TechnicalDescriptionURL_UMinho		Hyperlink	Type	n/a
				x		x			x	InstallationManualURL_UMinho		Hyperlink	Type	n/a
				x		x			x	ManufacturerURL_UMinho		Hyperlink	Type	n/a
				x					x	InstallationDate_UMinho	UMinho_Inventory	Date	Instance	n/a
			x	x		x		x	x	InventoryCode_UMinho		Character	Instance	n/a
				x					x	AcquisitionCost_UMinho		Decimal	Instance	Euros
				x				x	x	ValueTemperature_UMinho	UMinho_SensorHistory	Decimal	Instance	°C
				x				x	x	DirectionTemperature_UMinho		Decimal	Instance	degrees
				x				x	x	QualityTemperature_UMinho		Character	Instance	n/a
				x				x	x	StatusTemperature_UMinho		Character	Instance	n/a
				x				x	x	ValueHumidity_UMinho		Decimal	Instance	n/a
				x				x	x	DirectionHumidity_UMinho		Decimal	Instance	degrees
				x				x	x	QualityHumidity_UMinho		Character	Instance	n/a
				x				x	x	StatusHumidity_UMinho		Character	Instance	n/a
				x				x	x	ValueConcentration_UMinho		Decimal	Instance	n/a
				x				x	x	DirectionConcentration_UMinho		Decimal	Instance	degrees
				x				x	x	QualityConcentration_UMinho		Character	Instance	n/a
				x				x	x	StatusConcentration_UMinho		Character	Instance	n/a

Table IV.9 – Beacon's Data Template for Information Content

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x	x		x		x	x	Status *[1]	Pset_SensorTypeCommon	Character	Instance	n/a
				x		x			x	RatedCurrent	Pset_ElectricalDeviceCommon	Decimal	Type	A
				x		x			x	RatedVoltage		Decimal	Type	V
				x		x			x	NominalFrequencyRange		Decimal	Type	Hz
				x		x			x	PowerFactor		Decimal	Type	n/a
				x		x			x	ConductorFunction *[3]		Character	Type	n/a
				x		x			x	NumberOfPoles		Integer	Type	n/a
				x		x			x	HasProtectiveEarth		Boolean	Type	n/a
				x		x			x	InsulationStandardClass *[7]		Character	Type	n/a
				x		x			x	IP_Code		Character	Type	n/a
				x		x			x	IK_Code		Character	Type	n/a
				x					x	AssessmentDate	Pset_Condition	Date	Instance	n/a
				x					x	AssessmentCondition		Character	Instance	n/a
				x					x	AssessmentDescription		Character	Instance	n/a
			x							FunctionalUnitReference	Pset_EnvironmentalImpactIndicators	Character	Type	n/a
			x							Unit		Character	Type	n/a
			x							LifeCyclePhase *[2]		Character	Type	n/a
			x							ExpectedServiceLife		Integer	Type	years
			x							TotalPrimaryEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							WaterConsumptionPerUnit		Decimal	Type	l/Ud
			x							HazardousWastePerUnit		Decimal	Type	kg/Ud
			x							NonHazardousWastePerUnit		Decimal	Type	kg/Ud
			x							ClimateChangePerUnit		Decimal	Type	kgCO2-eq/Ud
			x							AtmosphericAcidificationPerUnit		Decimal	Type	kgSO2-eq/Ud
			x							RenewableEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							NonRenewableEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							ResourceDepletionPerUnit		Decimal	Type	kgSb-eq/Ud
			x							InertWastePerUnit		Decimal	Type	kg/Ud
			x							RadioactiveWastePerUnit		Decimal	Type	kg/Ud
			x							StratosphericOzoneLayerDestructionPerUnit		Decimal	Type	kgCFC-R11-eq/Ud
			x							PhotochemicalOzoneFormationPerUnit		Decimal	Type	kgC2H4-eq/Ud
			x							EutrophicationPerUnit		Decimal	Type	kgPO4-eq/Ud

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							TotalPrimaryEnergyConsumption	Pset_EnvironmentalImpactValues	Decimal	Instance	J
			x							WaterConsumption		Decimal	Instance	l
			x							HazardousWaste		Decimal	Instance	kg
			x							NonHazardousWaste		Decimal	Instance	kg
			x							ClimateChange		Decimal	Instance	kgCO2-eq
			x							AtmosphericAcidification		Decimal	Instance	kgSO2-eq
			x							RenewableEnergyConsumption		Decimal	Instance	J
			x							NonRenewableEnergyConsumption		Decimal	Instance	J
			x							ResourceDepletion		Decimal	Instance	kgSb-eq
			x							InertWaste		Decimal	Instance	kg
			x							RadioactiveWaste		Decimal	Instance	kg
			x							StratosphericOzoneLayerDestruction		Decimal	Instance	kgCFC-R11-eq
			x							PhotochemicalOzoneFormation		Decimal	Instance	kgC2H4-eq
			x							Eutrophication		Decimal	Instance	kgPO4-eq
			x							LeadInTime		Character	Instance	years
			x							Duration		Character	Instance	years
			x							LeadOutTime		Character	Instance	years
				x					x	AcquisitionDate	Pset_ManufacturerOccurrence	Date	Instance	n/a
				x					x	BarCode		Character	Instance	n/a
				x					x	SerialNumber		Character	Instance	n/a
				x					x	BatchReference		Character	Instance	n/a
				x					x	GlobalTradeItemNumber	Pset_ManufacturerTypeInformation	Character	Type	n/a
				x					x	ArticleNumber		Character	Type	n/a
				x					x	ModelReference		Character	Type	n/a
				x					x	ModelLabel		Character	Type	n/a
				x					x	Manufacturer		Character	Type	n/a
				x					x	ProductionYear		Integer	Type	n/a
				x					x	AssemblyPlace		Character	Type	n/a
				x					x	ServiceLifeDuration	Pset_ServiceLife	Integer	Type	years
				x					x	MeanTimeBetweenFailure		Integer	Type	years
				x		x			x	WarrantyIdentifier	Pset_Warranty	Character	Instance	n/a
				x		x			x	WarrantyStartDate		Date	Instance	n/a
				x		x			x	WarrantyEndDate		Date	Instance	n/a
				x		x			x	IsExtendedWarranty		Boolean	Instance	n/a

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
				x		x			x	WarrantyPeriod	Pset_Warranty	Integer	Instance	years
				x		x			x	WarrantyContent		Character	Instance	n/a
				x		x			x	PointOfContact		Character	Instance	n/a
				x		x			x	Exclusions		Character	Instance	n/a
				x					x	AssetAccountingType	Pset_Asset	Character	Type	n/a
				x		x			x	GrossWeight	Qto_SensorBaseQuantities	Decimal	Type	kg
				x					x	ReplacementCost_UMinho	UMinho_TypeInventory	Decimal	Type	Euros
				x					x	SustainabilityPerfomance_UMinho		Character	Type	n/a
				x		x			x	ProductURL_UMinho		Hyperlink	Type	n/a
				x		x			x	TechnicalDescriptionURL_UMinho		Hyperlink	Type	n/a
				x		x			x	InstallationManualURL_UMinho		Hyperlink	Type	n/a
				x		x			x	ManufacturerURL_UMinho		Hyperlink	Type	n/a
				x					x	InstallationDate_UMinho	UMinho_Inventory	Date	Instance	n/a
			x	x		x		x	x	InventoryCode_UMinho		Character	Instance	n/a
				x					x	AcquisitionCost_UMinho		Decimal	Instance	Euros

Table IV.10 – Oven's, Fryer's and Grill's Data Template for Information Content

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
	x		x	x		x			x	Status *[1]	Pset_ElectricApplianceTypeCommon	Character	Instance	n/a
				x		x			x	ElectricCookerType *[4]	Pset_ElectricApplianceTypeElectricCooker	Character	Type	n/a
	x			x		x			x	PowerState	Pset_ElectricAppliancePHistory	Boolean	Instance	n/a
	x			x		x			x	RatedCurrent	Pset_ElectricalDeviceCommon	Decimal	Type	A
	x			x		x			x	RatedVoltage		Decimal	Type	V
	x			x		x			x	NominalFrequencyRange		Decimal	Type	Hz
	x			x		x			x	PowerFactor		Decimal	Type	n/a
	x			x		x			x	ConductorFunction *[3]		Character	Type	n/a
	x			x		x			x	NumberOfPoles		Integer	Type	n/a
	x			x		x			x	HasProtectiveEarth		Boolean	Type	n/a
	x			x		x			x	InsulationStandardClass *[7]		Character	Type	n/a
	x			x		x			x	IP_Code		Character	Type	n/a
	x			x		x			x	IK_Code		Character	Type	n/a
	x			x					x	AssessmentDate	Pset_Condition	Date	Instance	n/a
	x			x					x	AssessmentCondition		Character	Instance	n/a
	x			x					x	AssessmentDescription		Character	Instance	n/a
			x							FunctionalUnitReference	Pset_EnvironmentalImpactIndicators	Character	Type	n/a
			x							Unit		Character	Type	n/a
			x							LifeCyclePhase *[2]		Character	Type	n/a
			x							ExpectedServiceLife		Integer	Type	years
			x							TotalPrimaryEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							WaterConsumptionPerUnit		Decimal	Type	l/Ud
			x							HazardousWastePerUnit		Decimal	Type	kg/Ud
			x							NonHazardousWastePerUnit		Decimal	Type	kg/Ud
			x							ClimateChangePerUnit		Decimal	Type	kgCO2-eq/Ud
			x							AtmosphericAcidificationPerUnit		Decimal	Type	kgSO2-eq/Ud
			x							RenewableEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							NonRenewableEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							ResourceDepletionPerUnit		Decimal	Type	kgSb-eq/Ud
			x							InertWastePerUnit		Decimal	Type	kg/Ud
			x							RadioactiveWastePerUnit		Decimal	Type	kg/Ud
			x							StratosphericOzoneLayerDestructionPerUnit		Decimal	Type	kgCFC-R11-eq/Ud

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							PhotochemicalOzoneFormationPerUnit	Pset_EnvironmentalImpactIndicators	Decimal	Type	kgC2H4-eq/Ud
			x							EutrophicationPerUnit		Decimal	Type	kgPO4-eq/Ud
			x							TotalPrimaryEnergyConsumption	Pset_EnvironmentalImpactValues	Decimal	Instance	J
			x							WaterConsumption		Decimal	Instance	l
			x							HazardousWaste		Decimal	Instance	kg
			x							NonHazardousWaste		Decimal	Instance	kg
			x							ClimateChange		Decimal	Instance	kgCO2-eq
			x							AtmosphericAcidification		Decimal	Instance	kgSO2-eq
			x							RenewableEnergyConsumption		Decimal	Instance	J
			x							NonRenewableEnergyConsumption		Decimal	Instance	J
			x							ResourceDepletion		Decimal	Instance	kgSb-eq
			x							InertWaste		Decimal	Instance	kg
			x							RadioactiveWaste		Decimal	Instance	kg
			x							StratosphericOzoneLayerDestruction		Decimal	Instance	kgCFC-R11-eq
			x							PhotochemicalOzoneFormation		Decimal	Instance	kgC2H4-eq
			x							Eutrophication		Decimal	Instance	kgPO4-eq
			x							LeadInTime		Character	Instance	years
			x							Duration		Character	Instance	years
			x							LeadOutTime		Character	Instance	years
				x					x	AcquisitionDate	Pset_ManufacturerOccurrence	Date	Instance	n/a
				x					x	BarCode		Character	Instance	n/a
				x					x	SerialNumber		Character	Instance	n/a
				x					x	BatchReference		Character	Instance	n/a
				x					x	GlobalTradeItemNumber	Pset_ManufacturerTypeInformation	Character	Type	n/a
				x					x	ArticleNumber		Character	Type	n/a
				x					x	ModelReference		Character	Type	n/a
				x					x	ModelLabel		Character	Type	n/a
				x					x	Manufacturer		Character	Type	n/a
				x					x	ProductionYear		Integer	Type	n/a
				x					x	AssemblyPlace		Character	Type	n/a
				x					x	ServiceLifeDuration	Pset_ServiceLife	Integer	Type	years
				x					x	MeanTimeBetweenFailure		Integer	Type	years
				x		x			x	WarrantyIdentifier	Pset_Warranty	Character	Instance	n/a
				x		x			x	WarrantyStartDate		Date	Instance	n/a

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
				x		x			x	WarrantyEndDate	Pset_Warranty	Date	Instance	n/a
				x		x			x	IsExtendedWarranty		Boolean	Instance	n/a
				x		x			x	WarrantyPeriod		Integer	Instance	years
				x		x			x	WarrantyContent		Character	Instance	n/a
				x		x			x	PointOfContact		Character	Instance	n/a
				x		x			x	Exclusions		Character	Instance	n/a
				x					x	AssetAccountingType	Pset_Asset	Character	Type	n/a
				x		x			x	GrossWeight	Qto_ElectricApplianceBaseQuantities	Decimal	Type	kg
				x					x	ReplacementCost_UMinho	UMinho_TypeInventory	Decimal	Type	Euros
				x					x	SustainabilityPerfomance_UMinho		Character	Type	n/a
				x		x			x	ProductURL_UMinho		Hyperlink	Type	n/a
				x		x			x	TechnicalDescriptionURL_UMinho		Hyperlink	Type	n/a
				x		x			x	InstallationManualURL_UMinho		Hyperlink	Type	n/a
				x		x				ManufacturerURL_UMinho		Hyperlink	Type	n/a
				x					x	InstallationDate_UMinho	UMinho_Inventory	Date	Instance	n/a
	x		x	x		x			x	InventoryCode_UMinho		Character	Instance	n/a
				x					x	AcquisitionCost_UMinho		Decimal	Instance	Euros

Table IV.11 – Dishwasher's Data Template for Information Content

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
	x		x	x		x			x	Status *[1]	Pset_ElectricApplianceTypeCommon	Character	Instance	n/a
				x		x			x	DishwasherType *[5]	Pset_ElectricApplianceTypeDishwasher	Character	Type	n/a
	x			x		x			x	PowerState	Pset_ElectricAppliancePHistory	Boolean	Instance	n/a
	x			x		x			x	RatedCurrent	Pset_ElectricalDeviceCommon	Decimal	Type	A
	x			x		x			x	RatedVoltage		Decimal	Type	V
	x			x		x			x	NominalFrequencyRange		Decimal	Type	Hz
	x			x		x			x	PowerFactor		Decimal	Type	n/a
	x			x		x			x	ConductorFunction *[3]		Character	Type	n/a
	x			x		x			x	NumberOfPoles		Integer	Type	n/a
	x			x		x			x	HasProtectiveEarth		Boolean	Type	n/a
	x			x		x			x	InsulationStandardClass *[7]		Character	Type	n/a
	x			x		x			x	IP_Code		Character	Type	n/a
	x			x		x			x	IK_Code		Character	Type	n/a
	x			x					x	AssessmentDate	Pset_Condition	Date	Instance	n/a
	x			x					x	AssessmentCondition		Character	Instance	n/a
	x			x					x	AssessmentDescription		Character	Instance	n/a
			x							FunctionalUnitReference	Pset_EnvironmentalImpactIndicators	Character	Type	n/a
			x							Unit		Character	Type	n/a
			x							LifeCyclePhase *[2]		Character	Type	n/a
			x							ExpectedServiceLife		Integer	Type	years
			x							TotalPrimaryEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							WaterConsumptionPerUnit		Decimal	Type	l/Ud
			x							HazardousWastePerUnit		Decimal	Type	kg/Ud
			x							NonHazardousWastePerUnit		Decimal	Type	kg/Ud
			x							ClimateChangePerUnit		Decimal	Type	kgCO2-eq/Ud
			x							AtmosphericAcidificationPerUnit		Decimal	Type	kgSO2-eq/Ud
			x							RenewableEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							NonRenewableEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							ResourceDepletionPerUnit		Decimal	Type	kgSb-eq/Ud
			x							InertWastePerUnit		Decimal	Type	kg/Ud
			x							RadioactiveWastePerUnit		Decimal	Type	kg/Ud
			x							StratosphericOzoneLayerDestructionPerUnit		Decimal	Type	kgCFC-R11-eq/Ud

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							PhotochemicalOzoneFormationPerUnit	Pset_EnvironmentalImpactIndicators	Decimal	Type	kgC2H4-eq/Ud
			x							EutrophicationPerUnit		Decimal	Type	kgPO4-eq/Ud
			x							TotalPrimaryEnergyConsumption	Pset_EnvironmentalImpactValues	Decimal	Instance	J
			x							WaterConsumption		Decimal	Instance	l
			x							HazardousWaste		Decimal	Instance	kg
			x							NonHazardousWaste		Decimal	Instance	kg
			x							ClimateChange		Decimal	Instance	kgCO2-eq
			x							AtmosphericAcidification		Decimal	Instance	kgSO2-eq
			x							RenewableEnergyConsumption		Decimal	Instance	J
			x							NonRenewableEnergyConsumption		Decimal	Instance	J
			x							ResourceDepletion		Decimal	Instance	kgSb-eq
			x							InertWaste		Decimal	Instance	kg
			x							RadioactiveWaste		Decimal	Instance	kg
			x							StratosphericOzoneLayerDestruction		Decimal	Instance	kgCFC-R11-eq
			x							PhotochemicalOzoneFormation		Decimal	Instance	kgC2H4-eq
			x							Eutrophication		Decimal	Instance	kgPO4-eq
			x							LeadInTime		Character	Instance	years
			x							Duration		Character	Instance	years
			x							LeadOutTime		Character	Instance	years
				x					x	AcquisitionDate	Pset_ManufacturerOccurrence	Date	Instance	n/a
				x					x	BarCode		Character	Instance	n/a
				x					x	SerialNumber		Character	Instance	n/a
				x					x	BatchReference		Character	Instance	n/a
				x					x	GlobalTradeItemNumber	Pset_ManufacturerTypeInformation	Character	Type	n/a
				x					x	ArticleNumber		Character	Type	n/a
				x					x	ModelReference		Character	Type	n/a
				x					x	ModelLabel		Character	Type	n/a
				x					x	Manufacturer		Character	Type	n/a
				x					x	ProductionYear		Integer	Type	n/a
				x					x	AssemblyPlace		Character	Type	n/a
				x					x	ServiceLifeDuration	Pset_ServiceLife	Integer	Type	years
				x					x	MeanTimeBetweenFailure		Integer	Type	years
				x		x			x	WarrantyIdentifier	Pset_Warranty	Character	Instance	n/a
				x		x			x	WarrantyStartDate		Date	Instance	n/a

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
				x		x			x	WarrantyEndDate	Pset_Warranty	Date	Instance	n/a
				x		x			x	IsExtendedWarranty		Boolean	Instance	n/a
				x		x			x	WarrantyPeriod		Integer	Instance	years
				x		x			x	WarrantyContent		Character	Instance	n/a
				x		x			x	PointOfContact		Character	Instance	n/a
				x		x			x	Exclusions		Character	Instance	n/a
				x					x	AssetAccountingType	Pset_Asset	Character	Type	n/a
				x		x			x	GrossWeight	Qto_ElectricApplianceBaseQuantities	Decimal	Type	kg
				x					x	ReplacementCost_UMinho	UMinho_TypeInventory	Decimal	Type	Euros
				x					x	SustainabilityPerfomance_UMinho		Character	Type	n/a
				x		x			x	ProductURL_UMinho		Hyperlink	Type	n/a
				x		x			x	TechnicalDescriptionURL_UMinho		Hyperlink	Type	n/a
				x		x			x	InstallationManualURL_UMinho		Hyperlink	Type	n/a
				x		x				ManufacturerURL_UMinho		Hyperlink	Type	n/a
				x					x	InstallationDate_UMinho	UMinho_Inventory	Date	Instance	n/a
	x		x	x		x			x	InventoryCode_UMinho		Character	Instance	n/a
				x					x	AcquisitionCost_UMinho		Decimal	Instance	Euros

Table IV.12 – Refrigerating Chamber's Data Template for Information Content

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
	x		x	x		x			x	Status *1	Pset_ElectricApplianceTypeCommon	Character	Instance	n/a
	x			x		x			x	PowerState	Pset_ElectricAppliancePHistory	Boolean	Instance	n/a
	x			x		x			x	RatedCurrent	Pset_ElectricalDeviceCommon	Decimal	Type	A
	x			x		x			x	RatedVoltage		Decimal	Type	V
	x			x		x			x	NominalFrequencyRange		Decimal	Type	Hz
	x			x		x			x	PowerFactor		Decimal	Type	n/a
	x			x		x			x	ConductorFunction *3		Character	Type	n/a
	x			x		x			x	NumberOfPoles		Integer	Type	n/a
	x			x		x			x	HasProtectiveEarth		Boolean	Type	n/a
	x			x		x			x	InsulationStandardClass *7		Character	Type	n/a
	x			x		x			x	IP_Code		Character	Type	n/a
	x			x		x			x	IK_Code		Character	Type	n/a
	x			x					x	AssessmentDate	Pset_Condition	Date	Instance	n/a
	x			x					x	AssessmentCondition		Character	Instance	n/a
	x			x					x	AssessmentDescription		Character	Instance	n/a
			x							FunctionalUnitReference	Pset_EnvironmentalImpactIndicators	Character	Type	n/a
			x							Unit		Character	Type	n/a
			x							LifeCyclePhase *2		Character	Type	n/a
			x							ExpectedServiceLife		Integer	Type	years
			x							TotalPrimaryEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							WaterConsumptionPerUnit		Decimal	Type	l/Ud
			x							HazardousWastePerUnit		Decimal	Type	kg/Ud
			x							NonHazardousWastePerUnit		Decimal	Type	kg/Ud
			x							ClimateChangePerUnit		Decimal	Type	kgCO2-eq/Ud
			x							AtmosphericAcidificationPerUnit		Decimal	Type	kgSO2-eq/Ud
			x							RenewableEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							NonRenewableEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							ResourceDepletionPerUnit		Decimal	Type	kgSb-eq/Ud
			x							InertWastePerUnit		Decimal	Type	kg/Ud
			x							RadioactiveWastePerUnit		Decimal	Type	kg/Ud
			x							StratosphericOzoneLayerDestructionPerUnit		Decimal	Type	kgCFC-R11-eq/Ud
			x							PhotochemicalOzoneFormationPerUnit		Decimal	Type	kgC2H4-eq/Ud

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							EutrophicationPerUnit	Pset_EnvironmentalImpactIndicators	Decimal	Type	kgPO4-eq/Ud
			x							TotalPrimaryEnergyConsumption	Pset_EnvironmentalImpactValues	Decimal	Instance	J
			x							WaterConsumption		Decimal	Instance	l
			x							HazardousWaste		Decimal	Instance	kg
			x							NonHazardousWaste		Decimal	Instance	kg
			x							ClimateChange		Decimal	Instance	kgCO2-eq
			x							AtmosphericAcidification		Decimal	Instance	kgSO2-eq
			x							RenewableEnergyConsumption		Decimal	Instance	J
			x							NonRenewableEnergyConsumption		Decimal	Instance	J
			x							ResourceDepletion		Decimal	Instance	kgSb-eq
			x							InertWaste		Decimal	Instance	kg
			x							RadioactiveWaste		Decimal	Instance	kg
			x							StratosphericOzoneLayerDestruction		Decimal	Instance	kgCFC-R11-eq
			x							PhotochemicalOzoneFormation		Decimal	Instance	kgC2H4-eq
			x							Eutrophication		Decimal	Instance	kgPO4-eq
			x							LeadInTime		Character	Instance	years
			x							Duration		Character	Instance	years
			x							LeadOutTime		Character	Instance	years
				x					x	AcquisitionDate	Pset_ManufacturerOccurrence	Date	Instance	n/a
				x					x	BarCode		Character	Instance	n/a
				x					x	SerialNumber		Character	Instance	n/a
				x					x	BatchReference		Character	Instance	n/a
				x					x	GlobalTradeItemNumber	Pset_ManufacturerTypeInformation	Character	Type	n/a
				x					x	ArticleNumber		Character	Type	n/a
				x					x	ModelReference		Character	Type	n/a
				x					x	ModelLabel		Character	Type	n/a
				x					x	Manufacturer		Character	Type	n/a
				x					x	ProductionYear		Integer	Type	n/a
				x					x	AssemblyPlace		Character	Type	n/a
				x					x	ServiceLifeDuration	Pset_ServiceLife	Integer	Type	years
				x					x	MeanTimeBetweenFailure		Integer	Type	years
				x		x			x	WarrantyIdentifier	Pset_Warranty	Character	Instance	n/a
				x		x			x	WarrantyStartDate		Date	Instance	n/a
				x		x			x	WarrantyEndDate		Date	Instance	n/a

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
				x		x			x	IsExtendedWarranty	Pset_Warranty	Boolean	Instance	n/a
				x		x			x	WarrantyPeriod		Integer	Instance	years
				x		x			x	WarrantyContent		Character	Instance	n/a
				x		x			x	PointOfContact		Character	Instance	n/a
				x		x			x	Exclusions		Character	Instance	n/a
				x					x	AssetAccountingType	Pset_Asset	Character	Type	n/a
				x		x			x	GrossWeight	Qto_ElectricApplianceBaseQuantities	Decimal	Type	kg
				x					x	ReplacementCost_UMinho	UMinho_TypeInventory	Decimal	Type	Euros
				x					x	SustainabilityPerfomance_UMinho		Character	Type	n/a
				x		x			x	ProductURL_UMinho		Hyperlink	Type	n/a
				x		x			x	TechnicalDescriptionURL_UMinho		Hyperlink	Type	n/a
				x		x			x	InstallationManualURL_UMinho		Hyperlink	Type	n/a
				x		x				ManufacturerURL_UMinho		Hyperlink	Type	n/a
				x					x	InstallationDate_UMinho	UMinho_Inventory	Date	Instance	n/a
	x		x	x		x			x	InventoryCode_UMinho		Character	Instance	n/a
				x					x	AcquisitionCost_UMinho		Decimal	Instance	Euros

Table IV.13 – Blast Chiller's Data Template for Information Content

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
	x		x	x		x			x	Status *1	Pset_ChillerTypeCommon	Character	Instance	n/a
				x					x	NominalCapacity		Decimal	Type	kW
				x					x	NominalEfficiency		Decimal	Type	n/a
				x					x	NominalCondensingTemperature		Decimal	Type	°C
				x					x	NominalEvaporatingTemperature		Decimal	Type	°C
				x					x	NominalHeatRejectionRate		Decimal	Type	(W, J/s)
	x			x					x	NominalPowerConsumption		Decimal	Type	kW
				x					x	CapacityCurve		Decimal	Type	kW
				x					x	CoefficientOfPerformanceCurve		Decimal	Type	°C
				x					x	FullLoadRatioCurve		Decimal	Type	n/a
				x					x	Capacity	Pset_ChillerPHistory	Decimal	Type	°C
	x			x					x	EnergyEfficiencyRatio		Decimal	Type	BTU/h,W
				x					x	CoefficientOfPerformance		Decimal	Type	n/a
	x			x		x			x	RatedCurrent	Pset_ElectricalDeviceCommon	Decimal	Type	A
	x			x		x			x	RatedVoltage		Decimal	Type	V
	x			x		x			x	NominalFrequencyRange		Decimal	Type	Hz
	x			x		x			x	PowerFactor		Decimal	Type	kW
	x			x		x			x	ConductorFunction *3		Character	Type	n/a
	x			x		x			x	NumberOfPoles		Integer	Type	n/a
	x			x		x			x	HasProtectiveEarth		Boolean	Type	n/a
	x			x		x			x	InsulationStandardClass *7		Character	Type	n/a
	x			x		x			x	IP_Code		Character	Type	n/a
	x			x		x			x	IK_Code		Character	Type	n/a
	x			x					x	AssessmentDate	Pset_Condition	Date	Instance	n/a
	x			x					x	AssessmentCondition		Character	Instance	n/a
	x			x					x	AssessmentDescription		Character	Instance	n/a
			x							FunctionalUnitReference	Pset_EnvironmentalImpactIndicators	Character	Type	n/a
			x							Unit		Character	Type	n/a
			x							LifeCyclePhase *2		Character	Type	n/a
			x							ExpectedServiceLife		Integer	Type	years
			x							TotalPrimaryEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							WaterConsumptionPerUnit		Decimal	Type	l/Ud

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
			x							HazardousWastePerUnit	Pset_EnvironmentalImpactIndicators	Decimal	Type	kg/Ud
			x							NonHazardousWastePerUnit		Decimal	Type	kg/Ud
			x							ClimateChangePerUnit		Decimal	Type	kgCO2-eq/Ud
			x							AtmosphericAcidificationPerUnit		Decimal	Type	kgSO2-eq/Ud
			x							RenewableEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							NonRenewableEnergyConsumptionPerUnit		Decimal	Type	J/Ud
			x							ResourceDepletionPerUnit		Decimal	Type	kgSb-eq/Ud
			x							InertWastePerUnit		Decimal	Type	kg/Ud
			x							RadioactiveWastePerUnit		Decimal	Type	kg/Ud
			x							StratosphericOzoneLayerDestructionPerUnit		Decimal	Type	kgCFC-R11-eq/Ud
			x							PhotochemicalOzoneFormationPerUnit		Decimal	Type	kgC2H4-eq/Ud
			x							EutrophicationPerUnit		Decimal	Type	kgPO4-eq/Ud
			x							TotalPrimaryEnergyConsumption	Pset_EnvironmentalImpactValues	Decimal	Instance	J
			x							WaterConsumption		Decimal	Instance	l
			x							HazardousWaste		Decimal	Instance	kg
			x							NonHazardousWaste		Decimal	Instance	kg
			x							ClimateChange		Decimal	Instance	kgCO2-eq
			x							AtmosphericAcidification		Decimal	Instance	kgSO2-eq
			x							RenewableEnergyConsumption		Decimal	Instance	J
			x							NonRenewableEnergyConsumption		Decimal	Instance	J
			x							ResourceDepletion		Decimal	Instance	kgSb-eq
			x							InertWaste		Decimal	Instance	kg
			x							RadioactiveWaste		Decimal	Instance	kg
			x							StratosphericOzoneLayerDestruction		Decimal	Instance	kgCFC-R11-eq
			x							PhotochemicalOzoneFormation		Decimal	Instance	kgC2H4-eq
			x							Eutrophication		Decimal	Instance	kgPO4-eq
			x							LeadInTime		Character	Instance	years
			x							Duration		Character	Instance	years
			x							LeadOutTime		Character	Instance	years
				x					x	AcquisitionDate	Pset_ManufacturerOccurrence	Date	Instance	n/a
				x					x	BarCode		Character	Instance	n/a
				x					x	SerialNumber		Character	Instance	n/a
				x					x	BatchReference		Character	Instance	n/a
				x					x	GlobalTradeItemNumber	Pset_ManufacturerTypeInformation	Character	Type	n/a

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
				x					x	ArticleNumber	Pset_ManufacturerTypeInformation	Character	Type	n/a
				x					x	ModelReference		Character	Type	n/a
				x					x	ModelLabel		Character	Type	n/a
				x					x	Manufacturer		Character	Type	n/a
				x					x	ProductionYear		Integer	Type	n/a
				x					x	AssemblyPlace		Character	Type	n/a
				x					x	ServiceLifeDuration	Pset_ServiceLife	Integer	Type	years
				x					x	MeanTimeBetweenFailure		Integer	Type	years
				x		x			x	WarrantyIdentifier	Pset_Warranty	Character	Instance	n/a
				x		x			x	WarrantyStartDate		Date	Instance	n/a
				x		x			x	WarrantyEndDate		Date	Instance	n/a
				x		x			x	IsExtendedWarranty		Boolean	Instance	n/a
				x		x			x	WarrantyPeriod		Integer	Instance	years
				x		x			x	WarrantyContent		Character	Instance	n/a
				x		x			x	PointOfContact		Character	Instance	n/a
				x		x			x	Exclusions		Character	Instance	n/a
				x					x	AssetAccountingType	Pset_Asset	Character	Type	n/a
				x					x	GrossWeight	Qto_ChillerBaseQuantities	Decimal	Type	kg
				x					x	ReplacementCost_UMinho	UMinho_TypeInventory	Decimal	Type	Euros
				x					x	SustainabilityPerfomance_UMinho		Character	Type	n/a
				x		x			x	ProductURL_UMinho		Hyperlink	Type	n/a
				x		x			x	TechnicalDescriptionURL_UMinho		Hyperlink	Type	n/a
				x		x			x	InstallationManualURL_UMinho		Hyperlink	Type	n/a
				x		x				ManufacturerURL_UMinho		Hyperlink	Type	n/a
				x					x	InstallationDate_UMinho	UMinho_Inventory	Date	Instance	n/a
	x		x	x		x			x	InventoryCode_UMinho		Character	Instance	n/a
				x					x	AcquisitionCost_UMinho		Decimal	Instance	Euros

Table IV.14 – Spaces' Data Template for Information Content

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
						x	x	x	x	IsExternal	Pset_SpaceCommon	Boolean	Instance	n/a
							x		x	PubliclyAccessible		Boolean	Instance	n/a
						x	x		x	HandicapAccessible		Boolean	Instance	n/a
							x		x	FireExit	Pset_SpaceFireSafetyRequirements	Boolean	Instance	n/a
							x		x	OccupancyType	Pset_SpaceOccupancyRequirements	Character	Instance	n/a
							x		x	OccupancyNumber		Integer	Instance	Ud
							x		x	OccupancyNumberPeak		Integer	Instance	Ud
							x		x	OccupancyTimePerDay		Decimal	Instance	s
							x		x	AreaPerOccupant		Decimal	Instance	m^2
							x		x	MinimumHeadroom		Decimal	Instance	m
							x		x	IsOutlookDesirable		Boolean	Instance	n/a
							x	x	x	SpaceTemperature	Pset_SpaceThermalRequirements	Decimal	Instance	°C
							x	x	x	SpaceTemperatureMax		Decimal	Instance	°C
							x	x	x	SpaceTemperatureMin		Decimal	Instance	°C
							x	x	x	SpaceTemperatureSummerMax		Decimal	Instance	°C
							x	x	x	SpaceTemperatureSummerMin		Decimal	Instance	°C
							x	x	x	SpaceTemperatureWinterMax		Decimal	Instance	°C
							x	x	x	SpaceTemperatureWinterMin		Decimal	Instance	°C
							x	x	x	SpaceHumidity		Decimal	Instance	n/a
							x	x	x	SpaceHumidityMax		Decimal	Instance	n/a
							x	x	x	SpaceHumidityMin		Decimal	Instance	n/a
							x	x	x	SpaceHumiditySummer		Decimal	Instance	n/a
							x	x	x	SpaceHumidityWinter		Decimal	Instance	n/a
							x		x	DiscontinuedHeating		Boolean	Instance	n/a
							x		x	NaturalVentilation		Boolean	Instance	n/a
							x		x	NaturalVentilationRate		Decimal	Instance	m^3/h
							x		x	MechanicalVentilationRate		Decimal	Instance	m^3/h
							x		x	AirConditioning		Boolean	Instance	n/a
							x		x	AirConditioningCentral		Boolean	Instance	n/a
						x	x		x	Height	Qto_SpaceBaseQuantities	Decimal	Instance	m
						x	x		x	FinishCeilingHeight		Decimal	Instance	m
						x	x		x	FinishFloorHeight		Decimal	Instance	m

BIM Uses										PropertyName	PsetName	Data Type	Instance or Type	Unit
1	2	3	4	5	6	7	8	9	10					
						x	x		x	GrossPerimeter	Qto_SpaceBaseQuantities	Decimal	Instance	m
						x	x		x	NetPerimeter		Decimal	Instance	m
						x	x		x	GrossFloorArea		Decimal	Instance	m^2
						x	x		x	NetFloorArea		Decimal	Instance	m^2
						x	x		x	GrossWallArea		Decimal	Instance	m^2
						x	x		x	NetWallArea		Decimal	Instance	m^2
						x	x		x	GrossCeilingArea		Decimal	Instance	m^2
						x	x		x	NetCeilingArea		Decimal	Instance	m^2
						x	x		x	GrossVolume		Decimal	Instance	m^3
						x	x		x	NetVolume		Decimal	Instance	m^3

Table IV.15 – List of enumerated values for specific properties fulfilling

*1
PEnum_ElementStatus
NEW
EXISTING
DEMOLISH
TEMPORARY
OTHER
NOTKNOWN
UNSET
*2
PEnum_LifeCyclePhase
ACQUISITION
CRADLETOSITE
DECONSTRUCTION
DISPOSAL
DISPOSALTRANSPORT
GROWTH
INSTALLATION
MAINTENANCE
MANUFACTURE
OCCUPANCY
OPERATION
PROCUREMENT
PRODUCTION
PRODUCTIONTRANSPORT
RECOVERY
REFURBISHMENT
REPAIR
REPLACEMENT
TRANSPORT
USAGE
WASTE
WHOLELIFECYCLE
USERDEFINED
NOTDEFINED
*3
PEnum_ConductorFunctionEnum
PHASE_L1
PHASE_L2
PHASE_L3
NEUTRAL
PROTECTIVEEARTH
PROTECTIVEEARTHNEUTRAL
OTHER
NOTKNOWN
UNSET
*4
PEnum_ElectricApplianceElectricCookerType
STEAMCOOKER
DEEPFRYER
STOVE
OVEN
TILTINGFRYINGPAN
COOKINGKETTLE
OTHER
UNKNOWN
UNSET
*5
PEnum_ElectricApplianceDishwasherType
POTWASHER
TRAYWASHER
DISHWASHER
BOTTLEWASHER
CUTLERYWASHER
OTHER
UNKNOWN
UNSET
*6
PEnum_TemperatureSensorType
HIGHLIMIT
LOWLIMIT
OUTSIDETEMPERATURE
OPERATINGTEMPERATURE
ROOMTEMPERATURE
OTHER
NOTKNOWN
UNSET
*7
PEnum_InsulationStandardClass
CLASS0APPLIANCE
CLASS0IAPPLIANCE
CLASSIAPPLIANCE
CLASSIIAPPLIANCE
CLASSIIIAPPLIANCE
OTHER
NOTKNOWN
UNSET

12 Appendix V – User defined properties and their definition

Pset Name	Property Name	Description
UMinho_TypeInventory	ReplacementCost_UMinho	The cost for the replacement of the asset
	SustainabilityPerfomance_UMinho	The sustainability performance of the asset and the method used for the assessment. It should be filled if the asset manufacturer already assessed its sustainability performance.
	ProductURL_UMinho	The hyperlink of the product's website
	TechnicalDescriptionURL_UMinho	The hyperlink for the technical description of the product
	InstallationManualURL_UMinho	The hyperlink for the installation manual of the product
	ManufacturerURL_UMinho	The hyperlink for the website of the product manufacturer
UMinho_Inventory	InstallationDate_UMinho	The date the asset was installed
	InventoryCode_UMinho	The asset code according to the University inventory
	AcquisitionCost_UMinho	The cost of the asset on the date it was purchased
UMinho_SensorHistory	ValueTemperature_UMinho	Indicates sensed temperature values over time.
	DirectionTemperature_UMinho	Indicates sensed direction for sensors capturing magnitude and direction measured from True North (0 degrees) in a clockwise direction.
	QualityTemperature_UMinho	Indicates the quality of temperature measurement or failure condition, which may be further qualified by the Status. True: measured values are considered reliable; False: measured values are considered not reliable (e.g., a fault has been detected); Unknown: reliability of values is uncertain.
	StatusTemperature_UMinho	Indicates an error code or identifier, whose meaning is specific to the automation system. It refers to the temperature measurement.
	ValueHumidity_UMinho	Indicates sensed humidity values over time.
	DirectionHumidity_UMinho	Indicates sensed direction for sensors capturing magnitude and direction measured from True North (0 degrees) in a clockwise direction.
	QualityHumidity_UMinho	Indicates the quality of humidity measurement or failure condition, which may be further qualified by the Status. True: measured values are considered reliable; False: measured values are considered not reliable (e.g., a fault has been detected); Unknown: reliability of values is uncertain.
	StatusHumidity_UMinho	Indicates an error code or identifier, whose meaning is specific to the automation system. It refers to the humidity measurement.
	ValueConcentration_UMinho	Indicates sensed CO2 concentration values over time.

Pset Name	Property Name	Description
UMinho_SensorHistory	DirectionConcentration_UMinho	Indicates sensed direction for sensors capturing magnitude and direction measured from True North (0 degrees) in a clockwise direction.
	QualityConcentration_UMinho	Indicates the quality of CO2 concentration measurement or failure condition, which may be further qualified by the Status. True: measured values are considered reliable; False: measured values are considered not reliable (e.g., a fault has been detected); Unknown: reliability of values is uncertain.
	StatusConcentration_UMinho	Indicates an error code or identifier, whose meaning is specific to the automation system. It refers to the cCO2 concentration measurement.

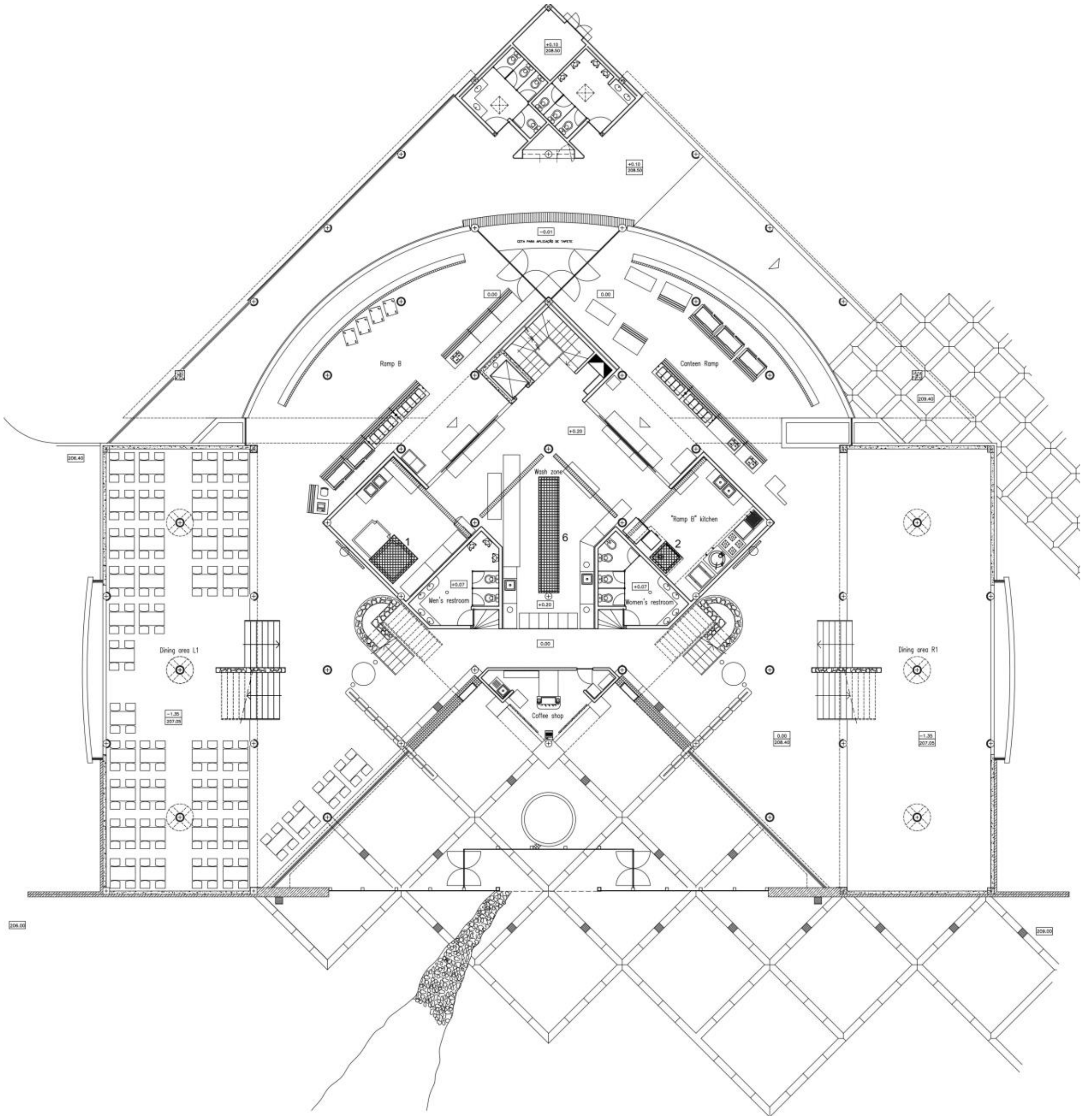
13 APPENDIX VI – LOCATION OF SELECTED KITCHEN EQUIPMENT

Figure VI.I – Pieces of Equipment on Floor P-1

LABEL

1- Refrigerating chamber
2- Oven
3- Fryer
4- Grill
5- Blast chiller

Figure VI.II – Pieces of Equipment on Floor P0



LABEL

1- Refrigerating chamber
2- Oven
6- Dishwasher