Information as a product

Bridging the gap between BIM technical and social solutions in projects for O&M purposes

Thesis Project

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Construction Management and Engineering

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Abstract

The Architecture, Engineering, Construction and Operations (AECO) industry is in constant need of processes and standards that allow it to deliver projects within budget, time, and quality. A strategy that has helped to get closer to this goal is the implementation of Building Information Modelling (BIM). Adoption of BIM-related technologies is mostly limited to architecture, engineering, and construction (AEC) actors, who handover the collection of design and construction data for the client but retrieving data from BIM models for operations and maintenance (O&M) activities is not as common as desired but it offers great potential to perform and support activities such as *Assessment and Monitoring, Documentation, Emergency Management, Energy and Space Management,* and *Maintenance of Service Information*. Processes, standards, and formats for integrating information about Operations and Maintenance in the design phase have been conceptually developed with a technical dimension approach toward activities, information, and solutions. Given that BIM is a socio-technical system, solutions must also consider a social perspective. For this reason, Activity Theory is used to analyse maintenance activities, their origin, elements related, and processes involved in their performance and, more specifically, their definition. The established theoretical lens considers information as the main product to deliver instead of a by-product of the models' deliverables. Thus, it was determined, through a literature review, exploratory interviews, semi-structured interviews and the aforementioned analysis, that the integration of O&M personnel is not only usually late along the information lifecycle of an asset's life, but that the required attributes that provide the necessary information to asset managers to perform their tasks are not even considered early enough in the project, commonly when it is already handed over. Integration of these actors along the already established processes is encouraged to ensure the information will not only be produced and transferred as required, but it will also be useful for other purposes that are included in the documentation of the project.

Keywords: BIM, information, activity theory, handover

Preface

Since I started my bachelor's studies I found myself quite fond of the possibilities that technology provide to any given industry in which it is applied. Quite fast I was already immersed into the world of 2D design and 3D modelling, but I wanted to go further. When I started my studies at TU Delft I discovered an even deeper and more interesting relationship between the areas that are involved in construction projects, as well as within the built environment, and technology. And so I got myself, an architect, into the not so common world, for designers, of the Operations and Maintenance of assets. This took me into an almost 11-month period in which I developed a research on the idea to understand and go beyond current technical solutions for this lifecycle stage. What if we give more capabilities to the users to carry out their activities? More importantly, how can we actually provide them with those capabilities?

This research project represented one of the biggest challenges in my life and took me out of my comfort zone in numerous ways and, I got to admit, performing research in the middle of a pandemic was more difficult than I could have foreseen. That is why, despite having setbacks and circumstances preventing me to keep going as smoothly as I would have liked, I have many people to thank for to help me get through this process. First of all, my committee provided me with different tools to retrieve and analyse previous research information, as well as the data I got from my interviews. To my chairman, Profr.dr. Paul W. Chan for his dedication and availability to provide me specific feedback on how to improve my analysis and my presentations. To my first supervisor, Dr.ir. L.H.M.J. Lousberg, for his substantial feedback after every meeting held. To my second supervisor, Yan Liu, who worked with me to improve the content and the structure of both my proposal and my research project.

Additionally, the people from Netherlands Airport Consultants provided me with invaluable resources for the completion of this project. To my supervisor Gerard van der Veer, who facilitated my contact with the BIM Group of NACO and gave me important feedback through the different stages of the project. To my mentor, Radu Panaitescu, who provided me the contact with the rest of the BIM Group but also other colleagues whose input was essential for the development of the project. Special thanks to Mike dos Santos Freitas, for the many resources he helped me with.

I want to thank my parents and my sister, who have supported me and have been there always for me. Without them and their unconditional support I would have not achieved this, nor anything else before. I want to thank the rest of my family whose care, cheers and support come always in the perfect times whether they are aunts, uncles, or cousins. Last but not least, I want to thank my other family, which is dispersed among Australia, Mexico, Belgium, Canada, Greece, India, The Netherlands and the UK, whose origin and background is so diverse that I cannot thank enough for having all of you in my life. Special thanks to Pri, Adrián, Alex, Archie, Bernardo, Cintia, Delia, Dian, Fanny, Jesús, Lili, Lucía, Moni, Pris, Luis Fernando, Eilidh, Alice, Βασουλάκι, Μαριαλενακι, Gerardo, Mayra, Sebastián, Nikhil, my Latin family in the Netherlands, my Mexican family in the Netherlands, Araixchel, Marco, Azkary, Iván and Ana Karen. You have supported me and helped me in a lot of processes, to face numerous challenges and to grow for almost 16 years in some cases. I owe you a lot and love you even more.

Erick

Table of Contents

Extended Table of Contents

List of abbreviations and acronyms

3D	Three-dimensional
AEC	Architecture, Engineering, and Construction
AECO	Architecture, Engineering, Construction and Operations
BIM	Building Information Modelling
CAD	Computer Aided Design
CAFM	Computer Aided Facility Management
IFMA	International Facility Management Association
O&M	Operations and Maintenance

Part I

Chapter 1 – Introduction to the topic

Chapter Introduction

This chapter comprises the topic introduction as well as the problem definition. The latter sub-section includes why this is an area of relevance for the industry as well as the basis of the project including the scope of the project, its objective and research question to be addressed. This chapter includes an outline of how the thesis project divided and what each part entails.

Introduction

The Architecture, Engineering, Construction and Operations (AECO) industry is in constant need of processes and standards that allow it to deliver projects within budget, time, and quality. A strategy that has helped to get closer to this goal is the implementation of Building Information Modelling (BIM). Van Nederveen and Tolman (1992) developed the concept as models that contained all the necessary information required for design, structural and utilities activities. These serve for different perspectives and include numerous hierarchy levels for spaces and their components. For that purpose, software and platforms such as Autodesk Revit, Graphisoft ArchiCAD, Bentley OpenBuilds Designer have been developed, taking advantage of knowledge retrieved from 2D Computer Aided Design (CAD) tools usage to allow users to design and graphically experience the projects they are working on in a 3D environment before their actual construction, which eventually evolved into BIM.

Giel and Issa (2013) showed that BIM is not properly implemented to the entire lifecycle of projects. BIM-related technologies adoption is mostly limited to AEC actors for design, engineering, and coordination purposes, leaving aside the collection and implementation of data the client needs for operation and management (O&M) activities. Actors who have implemented BIM were aware they have not done it properly or that their knowledge and experience was not as high as their competitors (Gu and London, 2010). Differences in the level of BIM implementation relate directly to the maturity level, defined as “the quality, repeatability, and degree of excellence with which BIM services are executed” (Succar, 2009). Maturity levels are defined by the degree and form of collaboration among parties; the information and its formats, which are to be developed in the design and construction phases, and to be transferred in the handover process for operations and maintenance purposes.

1.1 Setting the scene

This thesis research project focuses on the practices that involve the creation, development, transfer, retrieval and use of the information contained in models developed during the design and construction phases in order to be used in the operations’ stage of the project’s lifecycle. These do not only involve the information within the models but also the workflows, processes followed, standards abided, requirements stated, personnel involved and contractual implications. Understanding these elements and the relations among them as a whole and not as single elements can improve O&M performance later in the project lifecycle and, even though some solutions have been suggested, the holistic approach has not been fully reached within projects corresponding to airports and their facilities.

Facility handover processes are held back by information exchange practices that have not changed much in decades. Information handover to facility management phase is commonly left until completion of construction and usually provided in a non-digital format, delivering to the owner a set of printed plans and documents (Patacas et al., 2015) that is not completely useful for virtual purposes (William East and Nisbet, 2019). This has developed a growing concern with the integration of information about Operations and Maintenance in the design phase instead of waiting until the handover of the project to the client.

Processes, standards, and formats for integrating information about Operations and Maintenance in the design phase have been conceptually developed with a technical dimension approach toward activities, information, and solutions for the handover process of the project to the client. Derived from format differences among the software employed by actors, interoperability has been one of the major problems (Farghaly et al., 2018) in the integration of Operations and Management stage to the already established Architecture, Engineering and Construction industry. Hence, two elements make it complex to deliver the correct information from AEC actors to the client or manager of the facilities: the physical set of information that has to be entered manually in the required software (e.g. Maximo), and data which might not be transferred completely or correctly from one software platform to another. Considering these difficulties, efforts have been put into developing standards (e.g. PAS 1192-2:2013, ISO 19650) and open formats (i.e. IFC and COBie) to ease the handover process. Disciplines have even opted for the development of their own Model View Definition (MVD) (Lee et al., 2019), which is a "subset of the overall IFC schema to describe a data exchange for a specific use or workflow" (buildingSMART International, 2018), containing definitions and requests for particular data for specific purposes.

However, despite the fact that opportunity areas have already been identified, how these processes, standards, and formats work in practice and develop within a social dimension is still under research. The format is part of the challenge, but so is the process. Information handover practices are inefficient and error prone (Cavka et al., 2015; Cavka et al., 2018). Details of the model elements and how they evolve throughout the project are important given that an FM BIM (or AIM) does not include necessarily the same information as a construction BIM (or PIM) (Cavka et al., 2018). That is why frameworks have been created to align to the paradigm shift that AECO industry is going through to develop a lifecycle-oriented BIM strategy (Giel and Issa, 2016). Even though a technical approach has been considered in research, involving formats, software developments and interoperability solutions, other authors have started looking at how the information is actually created, how it evolves and how it is transferred during the lifecycle of projects. BIM is not only a technical solution for the construction industry. It is conceived as a socio-technical system which adoption and use result in new practices (Harty et al., 2019). It encompasses both tools and social practices that develop and affect each other, shaping them together (Liu et al., 2017). Jupp and Awad (2017), determined that requirements of operations and FM need to be considered from the conception of the project. In addition, Dubas and Jerzy (2017) established that communication between stakeholders should be improved and customer requirements must be considered early in the project's development. Rodriguez-Trejo et al., (2017) suggest that structured information delivery prevents information loss, facilitates complete information, and increases its efficient use in operations. It has been noted that clients' requirements and priorities should be developed preliminarily. Although this would help the development of a BIM-enabled project delivery for exchanging information to support handover and Operations and Maintenance functions (Cavka et al., 2017), the projects in which BIM is employed as means to assist these activities, teams do not usually utilise models because they do not include the information they need or because they do not know how to transfer it to the software to be used (Cavka et al., 2017).

BIM has developed itself into a system that can support activities and processes through the entire lifecycle of a project, which has been established in what is known as the BIM Dimensions. Hence, BIM-based asset management is possible, but needs to identify the information required for this purpose (Munir et al., 2019), which relates to the lifecycle information integration and information requirements (Matarneh et al., 2019). This can be achieved with the social dimension covered by BIM Maturity Levels framework, which considers both the technology and the collaboration among actors in the development of a project. It ranges from a Level 0, meaning no collaboration, up to a Level 3, with the use of a central and unique model in which actors work at the same time (United BIM, 2020). Additional levels have been developed by Oesterreich and Teuteberg (2019), related to the degree of collaboration and technology used, given that the appropriation of tools drives innovations into new working, managing, and collaborating techniques (Harty et al. 2019). Because of this, I wanted to research about the factors preventing operators and maintenance staff from receiving the information required for their stage's activities. ***<u>Therefore</u>***, this research project proposes a research on collaboration, with an Activity Theory lens, instead of a technical approach, identifying the clients' information needs, (i.e. formats, requirements, information flows, and organisation structures), for the operations and maintenance stage of an airport project. The lens refers to the theory that people develop activities within a context, in which the elements used to perform them, the rules to abide by, subjects involved and the community they are part of, all have an influence into the final outcome of the activity itself. Given that BIM is a socio-technical system, it is important to note that technology is influenced by social interactions, needs and aspirations which will determine their uses. Hence, the process of how the information is built socially and contextually, differentiating it from data (units comprising facts, quantities and/or definitions), will be considered, as well as the level of information required, produced, and transferred to the client for their ultimate purpose.

1.2 Problem Definition

Design and construction related information is included in BIM models as a means to communicate and coordinate between actors and as the basis to provide information to the client. BIM, as a methodology, provides the contractor and other actors involved in the project development a platform to develop an information-rich model to generate 2D and 3D documentation and views that support the construction activities. The requirements for these are defined usually in the contract and further developed into a BEP and the intention to include elements' information for the operations stage is latent in the industry. However, in practice this is not reflected in the documentation provided and because of this, formats, specifications, and information flows are not thought to include the so-called second life of information of the projects. This graduation project addresses the challenge of bridging the gap between the already existing technical solutions and the social implications of their (non-)application in the construction and operations industry.

1.2.1 Relevance of the problem

Previous research developed in this field has focused on how the different technical solutions can ease the transfer of information to the client when it is required. In this sense, interoperability has had been one of the major obstacles to overcome in the industry when developing BIM-based projects, but once numerous alternatives have been designed to tackle this problem, it is required to identify the other elements involved in these systems. Considering BIM as a socio-technical system, it is inherently required to understand the human intervention and how it affects the development of information and why this has not been properly requested nor provided for the Operations and Maintenance lifecycle stage when it has been already solved and integrated in the design and construction phases. This graduation research focuses on the elements that intervene and affect the requisition, development, and transfer of information towards its application in the Operations and Maintenance stage, responding to the existing gap between the BIM technical solutions and the social impacts of human interactions in the actions that lead to the use of models in the mentioned lifecycle phase.

1.2.2 Problem Statement

Establishing what is required to be included in a BIM model impacts the design and the construction stage processes and information flows. When the Operations and Maintenance stage needs are included in the requirements for the contractors, a richer and more complete product can be developed to satisfy the client's information needs. With this, the intention is to reduce the amount of work required to produce again a model that could serve for the activities carried out during the Operations phase of the project. The interest in this lies in the challenge faced when carrying out operations and maintenance in facilities, where most of the information required is not available or it has not been provided in a viable format for its use in different CAFM systems, deriving in the creation of new databases and/or models of information that could have been already available at handover.

1.3 Research Domain and Scope

This graduation research is performed in partial fulfilment of the requirements for the degree of Master of Science in Construction Management and Engineering at Delft University of Technology. The research is conducted in collaboration with Netherlands Airport Consultants (NACO), an airport consultancy and engineering company that provides services of airport master planning, airport build design, airport civil engineering, special airport systems, and downtime works and maintenance.

The research focuses on the provision of Employer's Information Requirements (EIRs) and the development of the BIM Execution Plan (BEP) to include information to be used during the design, construction, and specially the operations stage since the beginning of the project. The interest lies in the elements that conform the practices of the information transmission such as the roles involved, their sources of information (documentation and requirements) and how it is handed in back to the client (information workflows and exchange formats).

1.4 Research Objective

The research considers the activity theory lens as opposed to the already established technical perspective in previous research. The purpose is *to determine how to provide the information that is required for O&M BIM-based purposes of an airport, from the design to the O&M stage, with a classification that serves for both construction and O&M, to fulfil the different operators' information needs for decision-making purposes.* understanding the information within the model as the product to be delivered to the client, instead of a by-product of the handed-in models. Therefore, to achieve this, sub-objectives have been defined as follows:

1: Identification of the level of information needed from the operator's team members to perform their activities.

2: Definition of the processes involved in the development and transfer of information to other actors for operations and maintenance activities in airport projects.

3: Identification of the airport asset manager's activities' context and the implication on its related processes.

4: Identification of the client's needs of information for operations and maintenance activities in airport projects.

1.5 Research Questions

Considering the objective and sub-objectives of this research project, the following research question has been established:

How can the handed-in BIM information model fulfil the information needs for operation and maintenance practices' purposes in an airport project?

This research question can be subdivided in order to respond to the sub-objectives formulated, considering the main elements to analyse, being them the level of detail of the information, the processes involved in its development and provision, the context in which the activities are performed. The basis for this is that these elements are required to develop an adequate response when referring to what needs to be defined to perform Operations and Maintenance activities.

1: How detailed does the information has to be to fulfil the client's needs to perform operation and maintenance activities in an airport project?

2: What are the processes followed to provide the information required for operations and maintenance activities in an airport project?

3: What are the elements that comprise the context of the airport's activities?

4: What is the client's ultimate purpose of information for operations and maintenance in an airport project?

These sub-questions are to provide the required information to answer the main research question and hence, achieving the objective of this research.

NOTE: Context elements refer to the characteristics that define the circumstances in which data develops, including discipline, stage, actors involved, divisions, team members, technology, software, formats.

1.6 Thesis Outline

This thesis report follows the structure of a design-aimed practice-oriented research as developed by Verschuren and Doorewaard (2010) and is divided into the next parts:

- **Part I**: This part comprises chapters one and two. The first one, introduces the research project and the second one, refers to the research methodology.

- **Part II**: Consists of the problem analysis, in which the theoretical background, Chapter 3, is included. The theoretical background provides an insight on the existing literature related to the research topic as well as the elements mentioned in the research sub-questions: the level of detail of the information, the processes involved in its development and provision, the context in which the activities are performed. Exploratory interviews are performed as a basis to support the relevant information to be considered both from the technical and the social perspectives, from an empirical point of view. This section provides an answer to the first and second sub-questions.

- **Part III**: This section consists of data collection in the Chapter 4 and the data analysis in Chapter 5. These sections narrow down the scope of the research as defined by Verschuren and Doorewaard (2010) in the Diagnosis phase of the research. This part complements the answers to the first and second sub-questions and responds to the third and fourth ones. The data collection is developed through a case study and semi-structured interviews.

- **Part IV**: The synthesis of the data is further elaborated into Chapter 6 - Process Map Design, Chapter 7 - Conclusions, and Chapter 8 - Recommendations. In this section, the answer to the main research question can be found as well as a final analysis and future research recommendations.

1.7 Chapter Conclusions

The AECO industry has been fragmented for most of its existence but continuous efforts have been made to overcome this to facilitate transition from one phase of the construction projects to the following one. From the perspective of technological development onto a more integrated industry, the implementation of methodologies such as BIM comes as an improvement for both the integration of the AEC industry and the diversification of usages on which the information contained in the BIM models can be employed for. However, the integration of the industry has not included the Operational part yet, which can translate into benefits for the manager of the facilities, especially when talking about an airport given the complexity, extension, and diversity of the assets it involves. The aim of this research is to identify how the information that is required for Operations and Maintenance purposes can be included within the previous stages' processes in order to make it available for the relevant parties when required; therefore, striving to conciliate the technical and social solutions that have been proposed so far in literature.

Chapter 2 – Research Methodology

Chapter Introduction

This chapter aims to describe the research methodology followed to retrieve the necessary information from different means which include a literature review and a case study. The selection of the research methods in accordance with the previous research objectives and research questions is described. Furthermore, the phasing of the project and its correspondence with the project stages and subsequent chapters of this report is elucidated.

2.1 Research Strategy

Considering the project addresses the gap that exists between practical, technical solutions to provide information through models during different stages of the lifecycle of a project and the social interactions that a socio-technical system like BIM entails, the proposed research method comprises a case study that is design-aimed and practice-oriented. The elements that conform this are described in the following sub-sections.

2.1.1 Case study

The decision to opt for a case study is to find parallels in the way information was required and how it was delivered. In this case, *Employer's Information Requirements, BIM Execution Plans, BIM team composition, roles, Level of Development*, *BIM processes, non-geometric information, documentation,* and *project specifics (i.e. key project contacts, project goals, information exchanges, data requirements, collaboration procedures, quality control procedures, infrastructure needs, model structure, and deliverables)* are analysed to identify these parallels. In order to favour the research, this method is selected above others in order to acquire more depth than breadth in the data retrieved. In addition to this, the study of documentation available from the cases as well as the semi-structured interviews, the research project will get a deeper insight into the requirements and processes involved in the requisition and provision of information through a BIM model for Operation and Maintenance activities. Verschuren and Doorewaard (2010) describe that in this type of study, qualitative research methods are frequently used, therefore the conduction of the semi-structured interviews. The characteristics of the use of a case study are outlined by Verschuren and Doorewaard (2010) as follows:

- Use of a small domain, suitable for the complexity of a large project and for the comparison and interpretation of the results.
- Intensive data generation regarding the interviews with the parties involved. This will provide input from different sources which will allow for triangulation.
- Depth, obtaining specific and detailed information about a single or a couple of selected projects.
- Strategic selection of the cases.
- Obtaining qualitative rather than quantitative data, suitable for the social analysis to be performed.

Cases were selected considering the documentation availability and the differences in the level in which BIM was implemented, demonstrating the influences that documentation has in the development of the project and future uses of the BIM models derived from them. To be able to draw similar conclusions, verify what is drawn from the literature review and gain an in-depth perspective of the research, two project cases have been analysed. To ensure the cases were comparable, the following criteria was established:

- Projects of similar characteristics
- Projects with available documentation to review
- Projects in which BIM was implemented
- Projects in which a BIM Execution Plan was developed
- Availability of team members involved in the project for an interview

During the exploratory interviews, interviewees were questioned about potential cases regarding information as the topic of main interest of the research and how it was developed and handed back to the client. From there, two potential cases were found.

2.1.2 Design-aimed practice-oriented research

Utilising a case study for the practice-oriented research has the advantage that is more flexible than other strategies (i.e. survey study). It provides the ability to change the desired path even if the situation in the studied case changes spontaneous and rapidly. In addition, if the case studied is specific enough, as it is intended (e.g. an airport project), the results will be more easily accepted in the concerning fields of information about Operations and Maintenance inclusion in the design phase, information management and handover because of rapid identification of the stakeholders involved. Other advantages include that it is not required to obtain a large number of viable projects, and it will be easier to maintain the project scope within the time that is appointed to it.

The sources from which the information will be retrieved and gathered will be individuals interviewed from different teams (i.e. design leads, project managers, clients), general information of documents generated by them for the BIM handover, and the literature reviewed for the desk study. This approach will provide input from different perspectives over the same topic as is bridging the gap between the technical solutions studied and their implementation in real life, which includes their development in a social context. It was decided to perform a series of interviews over a survey research because they will provide more and specific content regarding the information development and processes among team members and actors. The addition of a desk research in the analysis stage is due to the large amount of data available to study that will serve as a basis for the whole study as for the preparation of the mentioned interviews. The cases analysis has the advantage of not requiring a pre-structure of the study, it is more flexible than other strategies (as surveys) and the results will be accepted faster in the industry.

Additionally, the case study is intended to be *comparative* with a *hierarchic method*. This method has the characteristic of analysing the cases independently at first and comparing them in a subsequent step. This way, similarities and differences among the cases can be found and it will be possible to identify general issues or categories, making possible the recognition of the information that is required for the BIM handover, how it should be managed, shared, by/to whom it will be shared and when it should be delivered for decision-making or any other O&M purposes in airport projects.

The research project has been designed as a *design-aimed* (focusing on a scheme that considers the social approach for O&M information practices), *practice-oriented* (which purpose is to use the developed scheme in real life scenarios and projects), for which the strategy proposed is a hybrid between a practical and a theoretical approach. This is an overlapping process between the theoretical and the practical approach towards the same challenge faced by airports regarding the provision of the information required to perform activities during the Operations and Maintenance phase of their facilities. For this purpose, the study has been divided into three stages that will lead into the conclusions and recommendations section. These stages have been planned to identify and provide an answer for the four sub-questions developed in section 1.5 and are depicted in **Figure 01**.

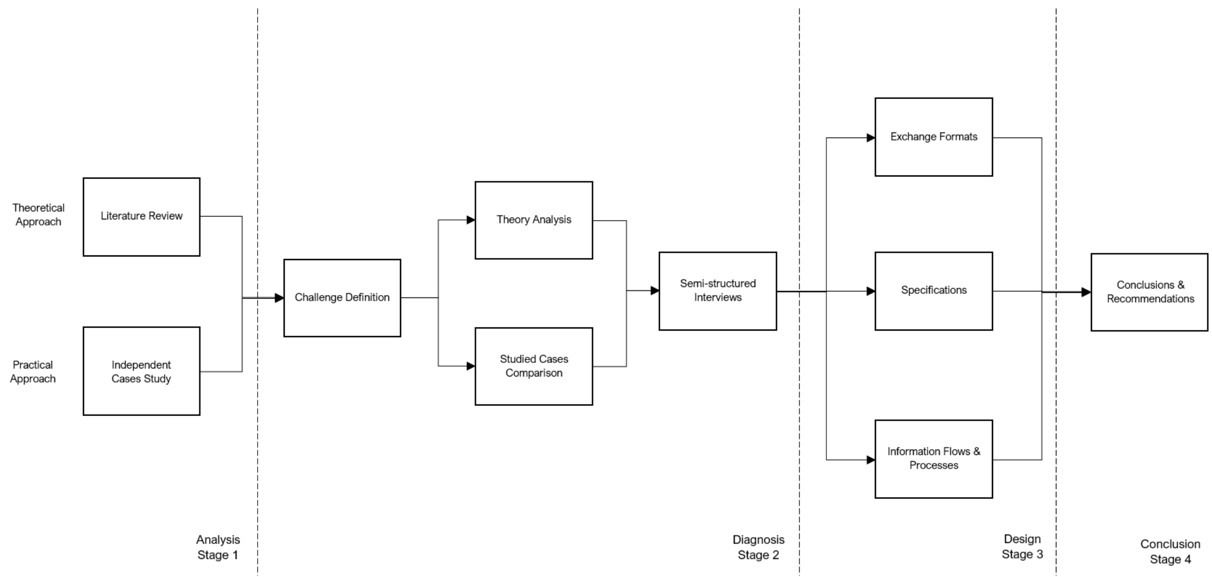

Figure 01 – Project planning and project stages

This method was selected to provide the knowledge retrieved from the research to the actors involved in this type of projects.

2.2 Project Phasing

The cycle of a research project of this type considers the following three phases to be developed, as Verschuren and Doorewaard (2010) describe it:

2.2.1 Problem analysis

The research project was narrowed down performing a literature review regarding how information, as a concept, is obtained, developed, transferred, and retrieved among actors in the construction industry, and how team members collaborate and intervene in information flows, before and during handover to the client. The aim of the literature review is to understand the social dimension of BIM, the influence it has on the development of information, and how information is developed and transferred among actors and through different phases of the lifecycle of the project, thus the *activity theory* lens.

The literature review was supported with exploratory interviews conducted to the consultant and engineering side of the project. With this approach, the gap between what the theory establishes, and the practices can be described. The gap not only considers the technical components but also the social elements, how the users utilise them and, therefore, the relation between both parts. For this, the candidates were considered to be from different areas with the intention of avoiding siloed information and perspectives, complementing what was retrieved from other colleagues.

This stage provides a broader panorama of how interactions from the same and from different teams shape information and their processes, as an aid to identify why there is a gap between the technical solutions provided by different software and technology companies, and their implementation in real life, when the social factor comes into scene and its interactions among personnel contribute to the evolution of both the Building Information Model, as well as the information contained in it.

This section entails the definition of core concepts for the research, such as *information* and *collaboration* and their related elements such as *context*, *data, granularity, relationships, means & temporality of communication, information flows, organisational structure, social context,* and *implicit/explicit elements of information.* For this reason, the literature review has been supported by a series of exploratory interviews to identify the specific methods, processes, workflows, and how information is treated by different teams from the same company towards its handover to the client in a pursuit of fulfilling their needs in later stages of the project lifecycle.

For this purpose, the exploratory interviews conducted intended to address, but not limit to, the following roles and their activities:

- BIM modeller / coordinator
- BIM manager
- Project manager
- Special Airport Systems team member
- Airport Building Design team member

The basic structure of the exploratory interviews can be found in **Appendix D**. Both the findings of the literature review and the exploratory interviews set the foundations of the theoretical framework which narrows down the scope of the case study and further interviews. From this part of the study, conclusions are made to provide an answer to the first research sub-question.

2.2.2 Diagnosis of the challenge

Narrowing down the research scope into information management components allows an in-depth and defined data gathering, considering the processes involved in the provision of information for the Operations and Maintenance activities to be performed within airport facilities. In order to identify both the processes and the implications of them in the provision of information for the Operations and Maintenance stage, it was decided to perform case studies. The conclusions derived from the case studies contribute to answer the first research sub-question and to provide answers to the second, third (and fourth) sub-questions.

2.2.2.1 Documentation Review

The interviewing process has been complemented with a review of available project documentation to understand the context in which the projects were carried out, the processes followed to provide the information, and the specifics of the information contained in the models as well as how it was requested.

2.2.2.2 Qualitative Interviews

In addition to the documentation reviewed, the main data collection method involves qualitative interviewing. The semi-structured interviews were conducted to different team members of the design contractor, the client, and consultant teams to understand how different perspectives affect the information reception/provision and what elements are considered to be the most important to pay attention to when dealing with data to be used for Operations and Maintenance activities. As a complement, the data gathered from the interviews will provide an insight into the different relations and interactions among the users, designers, and modelled elements towards the handover of this information back to the client. In addition, in order to understand what information is important depending on the user, the perspectives of a BIM consultant, an IDM/ Use Case Management specialist, a BIM Advisor, and Data Engineers have been considered. An outline of the semi-structured interviews can be found in the **Appendix E.**

2.2.2.3 Data Analysis with Activity Theory lens

Complementary to the document review of the case study, the interviews provide a richer in-depth insight about the current practices regarding information and how it is requested from the client's side to the contractor, in order to receive a model that will not only be useful for the construction but the operations phase. The data gathered from the interviews requires to be confirmed with the interviewees to avoid mistakes and/or misunderstandings regarding the topics discussed. Afterwards, the data is to be analysed using the Activity Theory lens to identify not only which elements are present in the perspective of each of the parties, but also to determine where the tensions (or contradictions) lay down, preventing the information to reach its final user for the intended purposes in the form it has to be developed. This will be performed by analysing each of the components involved in the development of the information required for the O&M lifecycle stage, as described in section 3.4: *subject, tools, community, rules, division of labour,* and *object*.

2.2.3 Proposed process map design

The empirical data retrieved from the case studies can be complemented and theoretically validated with the findings from the literature review. Performing a case study in addition to the reviewed literature provides a deeper insight into how information for Operations and Maintenance is requested and how it is provided to the client. Given that this type of study is not intended to be broad, the research method is qualitative rather than quantitative; therefore, the differences and similarities among the cases are analysed to generate findings that are to be contrasted with the ones derived from the literature.

During this stage, a strategy to bridge the gap found with the literature review and the semi-structured interviews will be developed. The intention is to propose an effective process to retrieve both the requirements and information the actors need as well as a complete list of requirements in order to make a useful information model for them. The aim is to exclude unnecessary practices from the actors' workflow, taking advantage of the information they already produced with a special interest in information flows, BIM processes, exchange formats, and requirements & specifications.

2.3 Chapter Conclusions

Defining the approach to be followed during this research project as a combination of case study and semi-structured interviews can help identify the parallelisms both of the administrative (through the existing documentation of the studied cases) and the practice (through the interviews conducted to different roles involved in the same type of projects and assets) perspectives, in comparison with the existing literature regarding the technical and social solutions explored to address the integration of Operations and Maintenance into the AEC industry. The obtained data is to be analysed with the Activity Theory case to understand the relationships between the factors involved in the performance of a Maintenance Activity within Airport's facilities, with a focus on civil infrastructure assets. The analysis of both the documentation and the semi-structured interviews is to be used as the basis for developing a process map that aims to integrate the required data into the information lifecycle, from the design stage, to be able to retrieve it when necessary to actually perform maintenance activities in the aforementioned assets.

Part II

Chapter 3 – Theoretical Background

Chapter Introduction

Before an analysis can be performed to generate in-depth knowledge on this topic, it is required to first establish the context in which the Employer's Information Requirements and the BIM Execution Plan are developed in matters of Operations and Maintenance activities for civil work. The aim of this chapter is to define and describe the perspectives toward the presented challenge in an effort to cover the project phases described in section 2.2. For this, the first stage of this research project is performed by a literature review and an independent analysis of the case studies selected. This chapter is developed as a literature study to define the existent lack of information and information requirements in this topic and the differences that exist between the construction and the operations' phase of an asset's lifecycle. Therefore, the approach taken considers the BIM adoption within the Asset Management industry, the current challenges the airport industry faces when working with BIM models, how these are being faced and practical (Use Case) and theoretical (Activity Theory) analyses to have a better insight into the gap existing between these approaches towards the same challenge. As an addition, a sub-section of this chapter goes deeper into literature about information needs, its relation to further BEP definition and Levels of Development for the models to be done during the design and construction of the project.

3.1 Current Situation

3.1.1 O&M Solutions and Benefits

A BIM model can provide different solutions to manage and maintain an asset through its operational stage. These can be provided in numerous ways: as further developed construction models, server-based solutions, and/or linked web tools that would retrieve the information from the models and provide the data that users and operators need in order to perform their activities. Re Cecconi et al. (2017, p. 1) established that BIM models can be used to store and access assets' information, and the same is described in PAS1192-3. However, it becomes more complex than that when numerous stakeholders are involved, which is commonly the case in large assets and facilities, such as airports. When these situations present, the interests of those stakeholders vary largely, deriving not only in different disciplines involved, but also in different data to be retrieved by different means to fulfil different purposes.

As Toledo et al. (2016, p. 4) described it, information technologies as BIM models and BIM-authoring tools support stakeholders in the production of documentation and the delivery of construction projects. Thus, BIM models can provide not only information about and for design and construction lifecycle stages, but they can foster the interaction and collaboration among the actors involved in a project. This is even supported with the usual thought that the more developed the BIM model, the better for the project and for the parties involved in it. This is partially true when the intention is to use that model for scheduling, estimations, sustainability analyses, and facilities management, known as the BIM 7D. Nonetheless, the conditions and information needs for the latter lifecycle stages are not necessarily the same ones as for other BIM applications performed during the design and construction phases. The reason behind this is that it is not necessarily required to develop with a high graphical detail an element for the Operations and Maintenance phase as much as it should be done for the Construction phase of a project, even though the information contained in it should be more extensive.

Despite the fact that most of the times clients are not aware of what BIM deliverables and processes to ask for when procuring these services, literature has established diverse ways in which the use of BIM could provide an added value to the processes held during the Operations and Maintenance stage (Liu & Gao, 2017, p. 137), such as:

- Assessment and monitoring
- Documentation
- Emergency management
- Energy and space management
- Maintenance of service information and warranties
- Retrofit planning

These categories can be even further developed into specific activities that can be supported by a BIM model during the Operation and Maintenance stage. An example of it is the Building Condition Assessment (BCA), which involves actions such as:

- Asset survey
- Filling documents (diagnostic forms, reports, etc.)
- Key Performance Indicators calculations (if needed)
- Pictures inclusion

While the possible activities and advantages that the use of BIM can provide to the Operations and Maintenance phase are numerous, so are the challenges. These can relate from the use of 2D CAD solutions for operations purposes, the lack of correlation of information provided by different means (printed or digital) with the actual as-built situation, onto inefficient coordination between disciplines and interoperability of used software by the different actors involved (Liu & Gao, 2017, p. 136). But these challenges can be extended to include an imperfect and incomplete information exchange, loss of information and data, and the reproduction of the lost information.

The personnel involved in the Operations and Maintenance stage of the lifecycle of airport assets face the challenge of retrieving information that may not be available in the models. This is related to how and when the information is collected and handed over to other actors during previous stages of the lifecycle of the project. Data of the different assets of airport facilities is produced regularly during their design and construction; hence, it should be acquired, stored and verified once it becomes available, avoiding its collection in a single transfer at the end of the project (Liu & Gao, 2017, p. 138). Following this line of reasoning, BIM could be used for the creation of inventory lists, which can be populated with the different attributes and properties required from different types of assets, and updated constantly as required, instead of retrieving the information in a major exchange or handover at the end of a predefined stage of the construction project, or at the end of a lifecycle phase. This activity can be further improved by providing the information in a suitable exchange format for its use or integration into a Computerised Maintenance Management System (CMMS), or the Computer-Aided Facility Management (CAFM) system used for the facilities management for an automated process.

Considering this, BIM models can be used to reduce the manual work and resources, such as time, that are required for the input of information into a different system for other purposes than only designing and construction. In addition, performing an analysis of the facilities can be eased by the use of BIM, considering it can provide information of the existing building condition. Moreover, information and documentation related to contracts, manuals, procurement, purchases, reports, and warranties can be either linked or integrated to the model. In this sense, asset managers can effectively use the information for decision-making purposes related to the preventive maintenance, reparation or even replacement of different elements or equipment within a system or an asset. Liu and Gao (2017, p. 139) found that, in relation to this, facilities operators that were not involved in projects where BIM was used had a lower satisfaction level regarding how useful was the information they received to begin their activities.

Utilisation of BIM models during the Operations and Maintenance stage is not as general as the uses aforementioned. It is required to establish the requirements for each activity's area as can be asset rating (for condition assessment), core and supporting data from the assets (for asset inventory), maintenance data (for maintenance management), space data (for space management), or work orders (for spare parts replacements). Additionally, specific details of these should be considered to provide the required information to the operators and maintenance personnel when working with the systems within the facilities. These can range from manufacturer data, location and description of the elements, systems or assets, to asset performance rating or level of maintenance rating (Liu and Gao, 2017, p. 140). The authors also establish that the usage of BIM in earlier phases of the project can simplify the input and further transfer of data in an efficient way to the intended personnel for the operations and maintenance of the facilities. Considering this, Liu and Gao (2017) established that certain data and information should be captured in the modelled elements during these phases for its future utilisation in the operations and maintenance stage, such as:

- **Data items**: Attributes, equipment information, asset information, equipment location, manufacturer information, and vendor information.
- **Supporting information and documentation**: certificates, instructions, manuals, specifications, test reports, warranties.

3.1.2 BIM Adoption in AM

BIM models have been conceived as storage files where information required for construction, operation, and maintenance of projects can be found. However, the stakeholders involved in an asset lifecycle do not use the same information elements, nor they need the same level of graphical detail of the elements involved in their activities. Despite this, a BIM model can prove itself as immensely helpful when used during the Operation and Maintenance stage. According to the Penn State Computer Integrated Construction Research Group (2019), these would include:

- Asset Management
- Building System Analysis
- Disaster Planning and Management
- Maintenance Scheduling
- Record Modeling
- Space Management

From the aforementioned BIM uses, activities such as surveys, diagnostic forms, reports and KPIs calculations are not always digitized, which prevents operators from exploiting the information that can be retrieved from them in further activities pertaining to the Operations and Maintenance phase. This information can be integrated to either the BIM model or fed to a Computer Aided Facility Management (CAFM) System. Despite the chosen solution, data has to be structured properly to offer a simple and practical option to perform the intended activities; same as with the tools used to perform the correspondent tasks. For this, it has been established that when the interface of a new-to-be implemented tool is intuitive, responsive and the users understand it easily, it is more likely they will adopt and embrace it (Dubas & Pasławski, 2017, p. 17; Merschbrock & Nordahl-Rolfsen, 2016, p. 6), as it will turn out to be more efficient than current available solutions (Re Cecconi et al., 2017, p. 10). Therefore, it can be inferred that when users, being them modellers, coordinators, managers, operators, or part of the client's team, understand what they are doing, how they are doing it, and how to use the tools to achieve their purpose, it is more likely they will adopt the proposed method, which is not limited to a technology; this can be applied to a process or workflow process such as BIM, which is a highly interrelated socio-technical methodology.

3.1.3 Current Challenges

It has been noticed that most of the problems final users of the Operation and Maintenance information face are when retrieving information and feeding back the model: it usually does not have the information needed to perform operations and maintenance to an asset, and it requires the use of a BIM authoring tool. This limits acutely the efficiency of personnel carrying out these activities in an airport facility given that they do not have the skills nor experience using these types of software. Furthermore, when performing only maintenance activities within airport facilities, the information provided by a BIM model, which was used and developed through previous stages as design and/or construction, is overwhelming for the intended purposes.

Re Cecconi et al. (2017, p. 1) mentioned that the National Institute of Standards and Technology (NIST) demonstrated that stakeholders within the public facilities sector spend a high amount of resources for the processes of validating and/or reproducing information of their facilities when it should have been available already, provided from previous lifecycle stages. Re Cecconi et al. (2017) mention that in the studied cases, the lost information generated costs of approximately the 12.4% of the total annual mean Operation and Maintenance costs of the facilities. This was identified before, which is why the PAS1192-2:2013 proposes using BIM models for accessing and storing information of different assets of facilities, reducing the aforementioned associated costs. As has been established before, this would strive to provide the stakeholders the information that is required by them in a way in which it can be usefully retrieved, consulted, and updated with ease. Hence, it is recognised that a BIM model has the same lifecycle as a physical building, which implies and ensures its continuous usage through the Operations and Maintenance phase and not only its use for coordination or visualization purposes during earlier phases.

The main barriers found in the utilisation of BIM models for Operations and Maintenance are related to the use of BIM authoring tools to access, manage, update, and distribute Operations and Maintenance information and that these do not support the performance of the aforementioned actions for the facilities management (i.e. Building Condition Assessment). Thus Re Cecconi et al. (2017) established that the BIM models are not further employed given three main reasons:

- Excessive costs to provide the employees the tools to properly work with them (i.e. licenses)
- Personnel require intensive training to adequately use the software and manipulate the models (incurring in other added costs).
- It is not useful considering the tasks that operations and maintenance employees perform.

Overcoming the previously mentioned BIM-related barriers has a direct connection with the performance of individuals in their jobs. Because of this, learning curves during workers' training can be improved if they learn faster meanwhile modifications in the information workflows and processes related to them are implemented with ease (Howard et al., 2017, p. 6). Thus, it becomes essential to understand the perceived usefulness and the ease of use of the actual practitioners to understand their attitude towards the application of BIM methodologies and model-related information into their activities. In this sense, these concepts are defined by Howard et al. (2017) as follows:

- Perceived usefulness: Extent to which a person believes a computer could improve his performance.
- Perceived ease of use: Extent to which a person believes using a computer is effortless.

Howard et al. (2017, p. 9) established that when specific settings are imposed, the practitioners' usage of the tools and processes will be up to the minimum level required to actually carry out the minimum needed activities; beyond that point, anything else that is produced either in terms of usage of the BIM models for O&M in this case or the activities performed during the O&M phase with it, is strictly voluntary. This was supported by their conclusion that firms that want to implement BIM can steer their employees' perception by demonstrating that their corresponding managers believe the BIM methodology that is used is worthy and provide them the required support while the BIM methodology itself is being implemented within the different actors' companies. The authors suggested that at an individual level, BIM can be reduced to a modification in the workflow procedures, which in this project can be identified between the individuals; between individuals and the tools used, and the actual information workflows followed during the asset lifecycle for information transfer, including the design and operation phases as well. That is why the emphasis in this study is put into the development and flow of information since its requisition until it is handed over to the client for further operations and maintenance use.

Considering this perspective, it becomes also important to identify how and where the issues associated with the communication and transfer of information developed and gathered in the design and construction phases, to be delivered for the operations and maintenance phase, are generated. Dubas and Pasławski (2017, p. 15) established that the problems within the construction industry are related to communication, establishing that it was because of the failure of the involved actors to communicate their intentions to others, what produced misunderstandings and all the problems associated to them (Emmitt & Gorse, 2009). This was further related to the implication on the quality of future works because of the lack of information transfer from previous projects or stages onto the following ones (Singh et al., 2018).

This serves as the basis for establishing what are the most important things to consider in the infrastructure and civil works. As Hijazi and Omar (2017, p. 143) establish it, the gap between these industries and BIM is bigger than between BIM and the built environment; hence, it is necessary to implement defined standards to address this. These standards could be included in object data attributes or properties to allow stakeholders to work with different LOD specifications and classifications. In addition, the file format is another challenge to be overcome by engineering contractors. The research conducted by Hijazi and Omar (2017, p.

145) demonstrated that challenges relate to processes, specifications, and standards. In their case study, the BIM team was working with a model with over a thousand parameters and elements concerning MEP utilities, roads, and services. All of them became a problem when dealing with the 4th (scheduling) and 5th (costs) dimensions of BIM. Thus, the main issue was that the model was overloaded with information that, for instance, would not be used during O&M phase in its entirety. The authors also mention that most of the studies in this field were related to the integration of BIM with CityGML and GIS models, although they considered the main challenge was the need to develop a platform that could support BIM for both infrastructure and building projects (Hijazi & Omar, 2017, p. 145), which is the case for airport projects given they include both buildings' and infrastructure elements.

Another concern that has been mentioned both by researchers and practitioners (Hijazi & Omar, 2017, p. 147), has been the inability to work on IFC federated models. Even though the information that is included within them is good and vast, it is worth to notice that these models and the entities included in them, are not able to be modified. In addition to this, it was noticed that IFC file format needs to be expanded to include and support other infrastructure elements such as those present in airports, which can include runways, taxiways and roads' entities. An important challenge that BIM coordinators faced was to design and work with tools especially for landscape design, another important asset within airport facilities, given that standards do not cover these areas. Part of this problem became evident when there was a need to build the federated BIM models based on standards and these did not include the aforementioned areas.

Considering this, the problem is not only related to the coordination of information coming from different departments, but the fact that their platforms are completely different. In this sense, platforms and information related to the development of civil and infrastructure face a rather different challenge than architectural or utilities design areas. The standards created have not considered the development of information of the former as closely as the latter ones. The lack of classification and information can be extended to include the operations and maintenance of assets as for these, operations can vary from type, size, decomposition and even operator. Hijazi & Omar (2017, p. 149) consider that the main challenge is how to implement the Employer's Information Requirements plan as part of the BIM standards. This includes exchange file formats, exchange processes, requirements, and organisation structures, especially when more than one party is working on the same BIM project, being this the common practice when carrying out infrastructure projects such as airports and within their facilities.

Hijazi & Omar (2017, p. 152) concluded that it is important to establish a clear master information delivery plan that is part of the documentation used for BIM governance. Moreover, the authors determined that it is necessary to extend the IFC file format to include data related to other O&M activities' related attributes, such as safety, quality and risks; besides, this file format (and for that case, any other) should be developed to cover the entire project lifecycle on a basis of PAS1192-2 and LODs. Hence, the effort to create a seamless information workflow from the conceptual stage right onto operations and maintenance (and even further decommissioning), should include not only the actors for these stages and the relevant areas involved but also software developers that can cooperate for the improvement and creation of standards and specifications along with the software solutions they provide. This approach was also determined by Sun et al. (2015, p. 774), who established that BIM-authoring tools should focus on the creation of seamless interoperability processes among actors given that they could be using different platforms, as well as on the development of data exchange standards. As for the workflows and processes, it is necessary to adapt to new technologies and to act towards changes in the workflows instead of reacting to them (Sun et al., 2015, p. 774), which would limit the potential benefits of the use of the tools and workflows.

3.2 Information Needs

Airports comprise numerous assets on which the O&M activities mentioned in the previous section are to be performed, which include not only buildings, but also include spaces, systems, lands (Kim et al., 2015, p. 807), roads, runways and taxiways. These assets are classified depending on the intended purpose of the activities related to them. Either by components, systems, operations, or activities, a classification is helpful to narrow down the information to include only the one that concerns certain user(s) during a specific moment. To manage them properly, it is necessary for the O&M staff to have a source of information not only efficient but reliable. When performing operations and maintenance in an airport, in most of the cases, the information on which operators rely is based on 2D CAD files or even printed drawings and documentation that was handed-in to the client by the contractor after the completion of the project (Kim et al., 2015, p. 809). In addition to this, the information contained in these documents is not always enough, so the operators have to rely on different sources and information repositories, and even carry out surveys that consume many resources such as time and personnel. In extreme cases, this could entail contacting manufacturers to get the necessary information to operate and maintain the installed equipment, components, and systems of the premises.

On the other hand, BIM can be used as a support to avoid the aforementioned problems and to foster collaboration (Liu & Gao, 2017, p. 136) not only among actors but also through stages of the lifecycle of the project as has been done between design and construction phases. Since BIM can be used as a platform that could provide the necessary information for activities related to the operation and maintenance of assets, the ideal situation would be to establish a common ground for these to be named and developed. As Liu and Gao (2017, p. 137) describe it, for this to be plausible, it is necessary that the client establishes its information requirements, not only describing the data needs, but also understanding the standards and classifications to be considered for their development. Thus, all the actors involved would be “speaking the same language” making it easier for contractors and consultants to understand what is required and expected from them and what exactly they have to provide to the owner that can be useful for him and for the final user. A proposed solution for this, which is the path that buildingSMART International is following, is to use open standard file formats such as IFC, which is the data exchange standard considering its advantages of being vendor-independent as well as an open data format for both transfer and integration of information between models and systems.

But information has to be ordered and classified before it can be retrieved seamlessly, successfully and with ease to perform any activity related to the operations and management of an airport project. That is why Liu and Gao (2017, p. 137) also consider it can be further improved with the use of OmniClass, the object-oriented standard for data exchange and UniFormat, the classification structure for building information mostly used in digital models. The establishment of these standards and other guidelines to follow up has become usual as part of the requirements clients ask for when referring to BIM implementation and, even though this scene is seen more and more as a common practice, the provision of guidelines and requirements that should be included in a BIM Execution Plan in an integral way go back to 2009, when Pennsylvania State University published its own guide.

3.2.1 Information Management

The International Facility Management Association (IFMA) defines facility management as “the field that plans and manages physical workspaces associated with the personnel and work of an organisation” (Kim et al., 2015, p. 809). Managing dispersed information of the assets present in airport facilities to perform an activity during the Operation and Management phase is costly and inefficient. An option to increase the efficiency of the works performed has been the provision of an element that can be actively used by the personnel. This does not only reduce resistance to change to a different system or work methodology as can be with the BIM implementation for O&M purposes, but also increases chances of performing with a better quality and faster results, especially when speaking about an information model in comparison to CAD and/or printed files solutions. Even though Building Information Models have been used successfully to integrate design and construction activities, this has not been the case for the asset Operation and Maintenance phase. The challenge is not only present in building projects, but also in infrastructure ones.

In the so called “vertical infrastructure”, different modelling software and exchange file formats have been employed and have demonstrated the complexity of coming to a standard solution that could serve all the intended purposes (Perumpilly et al., 2019, p. 2). During design and construction phase, these have been solved by different “exports” updates within the software solutions to produce an extract with the precise graphical model with the desired non-graphical properties so that it can be used in another software. For infrastructure projects such as an airport, the information is not so easily retrieved and exchanged with other software. The main reasons behind this are that the data used for designing the buildings is in different formats than that of civil infrastructure elements, given the interests of both architectural and civil engineering purposes, and that the scales required for both are often completely different. This can be noticed when dealing with information about a runway and comparing it to a hydraulic installation that is located within a bathroom in the passenger terminal building (PTB) or within any other building.

3.2.2 BEP Requirements

So, how to actually establish what is needed to be provided during project realisation? Not only the client has to become an active party during the project realisation. When the other stakeholders align their goals and work together towards their achievement, it is easier for them to foster a collaborative approach regarding the information to be shared and distributed among their team members. The notion of including the Operations and Maintenance phase within this collaborative approach has received a limited attention in comparison to the design and construction stages. Therefore, a holistic approach has to be considered in order to include the required information for all the intended purposes to be not only carried out during Operations and Maintenance but also for future expansions of the airport assets and premises, having a whole lifecycle perspective. When the client gets involved in the project, it can be established why certain specific information is required for determined stages and in what way it should be delivered (Walsh et al., 2017).

Technology has become a tool that can support communication and coordination, but it cannot solve problems by itself (Walsh et al., 2017). There is a constant need of interaction between technology and its users and the development of this is influenced by the project delivery method chosen for the projects. Even more, the documentation related to it affects the whole process of information transfer during the whole lifecycle of the project, not only during the design and construction stages. This even includes the BIM Execution Plan (BEP) previous to the contract award and its continuous improvement: the document has to be considered a living document and a work in progress. During the lifecycle stages of the project and after the information delivery milestones, the BEP (or BXP) should be improved to fit and comply with the information requirements for the next phase. Hence, it is required that the client participates actively to create a whole building information lifecycle (Walsh et al., 2017).

Because of this, it is necessary to establish the specifications that the BIM model will have to abide by. The set of these specifications is usually described in the BIM Execution Plan (BEP). This document establishes the responsibilities related to the implementation of BIM into the project workflow, for each actor involved in the project. As described in the BIM Project Execution Planning Guide v2.2 (Messner et al., 2019), the BEP defines the uses for BIM on a project, as well as clearly denoting the design and documentation of the process workflow for implementing BIM during the lifecycle of the project. The authors identify four main steps:

1. Identify high-value BIM uses for all the project phases.
2. BIM execution process design (i.e. through process maps).
3. BIM deliverables definition (i.e. information exchanges).
4. Structure development (i.e. contracts, communication procedures, technology, and quality control) to support the implementation.

Concerning the first step (1), the main focus for the project will be on the high-value BIM uses for the Operation and Maintenance phase of an airport project. The “uses” will be the bases for the definition of the Employer’s Information Requirements (EIRs) which in turn, when written down in a request for proposal (RFP), are the foundation for the BIM Execution Plan. When thinking about the complete lifecycle of a project, this approach would in turn take the form of a diagram as shown in the PAS1192-2:2013 as depicted in Figure 02, which is a general definition of the processes involved in the information lifecycle (2), of what is expected to be developed for each asset lifecycle phase (3). Additional requirements are to be established, described, and included in the BEP to establish the communication methods, frequency, roles, and staff involved, software to be used and how the quality of the deliverables will be assured and controlled (4).

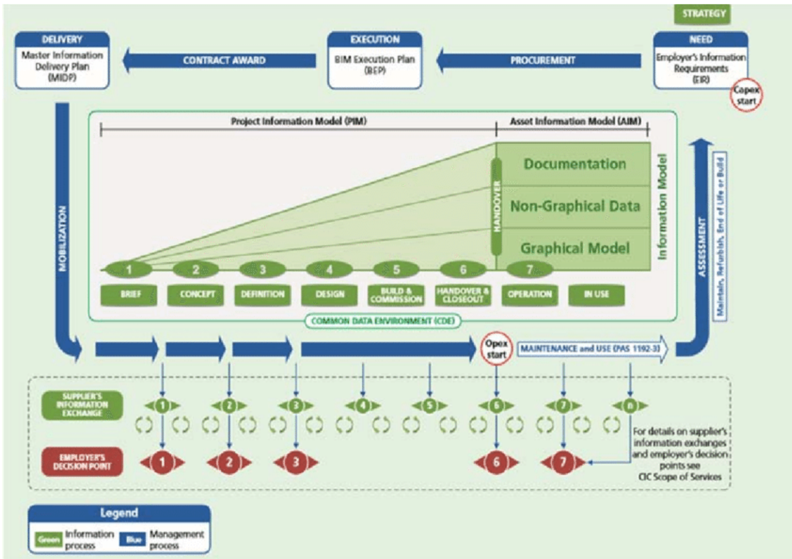

Figure 02 – Information Lifecycle, retrieved from PAS1192-2:2013

Only after the goals have been aligned and set, the information requirements can be described. Once the information required has been established, it can then be understood by all the actors involved whether they are architects, contractors, sub-contractors, engineers, operators, or the client. That is why it is important to understand the activities to be developed and performed during the Operations and Maintenance phase, so the actors can deliver the precise information that is required as it happens during the design and construction phases. It is in this type of situations where BIM becomes a tool that supports the definition and extent of the requirements throughout the lifecycle until handover (Walsh et al., 2017) and possibly, beyond that point, into the O&M stage. Furthermore, if the information that is contained within the models has an established standard and classification for its organisation, it can ease several activities during Operations and Maintenance phase by reducing review times and facilitating the required information in a single location. The performance can be further enhanced by means of implementing additional technologies (such as QR codes), to equipment and systems and linking that information and status to the information contained in the BIM model that, for the Operation and Maintenance stage, is no longer consider a Project Information Model (PIM) but an Asset Information Model (AIM).

The BEP is an important document which deals not only with the model itself, but also with business and managerial concerns, for which the intended purposes and processes to achieve them are defined for each project. Hadzaman et al. (2016, p. 31) established that the following four elements are derived from BEP processes:

1. BIM goals
2. BIM uses
3. Responsible parties
4. Decision making

The authors defined that BIM is a tool that would serve to overcome inefficiencies of the construction industry while capturing and storing information in an organised way, avoiding process interruptions while implemented in the project. For this purpose, the BEP is conceived as the written communication tool that describes how BIM will be executed throughout the project; therefore, it is important not only to prepare a well-structured BEP but also to define properly the information exchange processes captured within (Hadzaman et al., 2016, p. 30). In addition to this, as well as closely related, the responsible actors, level of development of the model and the collaboration procedures to follow are also of an essential nature to the development and application of the BEP within an airport project. For these factors to be implemented correctly and efficiently, it is important that actors and team members of the different parties understand the elements involved in the BIM processes:

- Disciplines involved
- Information transfer moments
- Inputs and outputs
- Level of development (LOD)
- Model element breakdown
- Asset decomposition
- Responsible parties

3.2.3 LOD for O&M

Large and complex airport projects require a high degree of communication and collaboration among the actors involved, which all belong to different disciplines and require different information to perform their tasks. Thus, there is a constant process of development and transfer of information from one actor to another. This could lead to inconsistent modelling, which is one of the deficiencies that limit the BIM model development. Even more, the high Level of Development is opposed to current time and cost restrictions within the AECO industry (Hu et al., 2016, p. 216) in its different components: architecture, engineering, construction, and facilities operations and management. This Level of Development refers to the detail of a model, describing a BIM component from a conceptual design to the highest as-built detail level. BIM Forum conceives Level of Development as the “degree to which the element’s geometry and attached information has been thought through” and it establishes the following main distinctions in their levels:

- LOD 100: Information or symbols indicate the existence of a component.

- LOD 200: Elements are only represented by generic placeholders.

- LOD 300: Quantity, size, shape, location, and orientation of element as designed can be measured directly from the model. Therefore, there is no need to refer to non-modelled information (i.e. dimension call-outs or notes).

- LOD 350: Parts necessary for coordination of the element with nearby or attached elements are modelled, including supports and connections.

- LOD 400: Element is modelled with enough detail and accuracy for fabrication.

- LOD 500: Does not indicate progress to a higher level of model element geometry or non-graphic information. Related only to a field verification of the elements.

For construction purposes, LOD is usually defined at a 350 level, given that it provides necessary information to the contractor about the position, size, shape, quantity, orientation, and the immediate context of the elements, so it is useful for coordination. However, the definitions of these elements are mainly established for building elements and not for civil infrastructure ones which, as mentioned before, are not required to be developed to the same extent and which scale is completely different from those elements within a building. Because of this, Hu et al. (2016, p. 228) developed a multi-scale BIM model of the terminal of Kunming Changshui International Airport, based on what they identified as the main challenges for the modelling of MEP elements at these scales, being them:

- Contents, details, and workload of modelling efforts are out of control: Authors identified that it is not necessary to develop all the modelled elements to an LOD500, which becomes not only a challenge and an unnecessary burden for the modellers' team but also demands too much resources of the BIM authoring tools used for creation and development of those models, as well as for the software packages required for visualisation purposes.

- Construction is much more complicated than normal MEP projects: Not only related to MEP modelling; however, defining and including all the details required for the whole model is an activity that consumes both much time and human resources. In addition, not all these details are appreciated by everyone, given that different actors and team members will consider different elements as valuable from what is contained within the models.

- It is difficult to retrieve valuable information with strict requirements during Facilities Management: While this was considered strictly from the MEP perspective, it is certainly difficult to get the right information from the model when required to perform different operations and maintenance in an asset. When the latter is required, the personnel has to work promptly to solve any presented issues according to the manual of the component, element and/or system. Therefore, it is important to consider the final usage of the information, so it can be either stored in the model or linked to it and easily retrieved afterwards to perform the required activities. It is even more important to define this when considering not all employees will have the same background or knowledge, even though they will have to work with the same input information.

When referring to specific areas or rooms where maintenance and operations activities are going to be performed, it is preferred to have a higher level of development of the components and systems involved. This would facilitate actions such as emergency handling, equipment repair, and regular maintenance (Hu et al., 2016, p. 218) because these activities do not only require a high level of detail but other additional information as historic records of the maintenance provided or manuals of the involved equipment. That is why the information that is related to the individual elements cannot be managed nor manipulated separately from them, as should be when referring to them both from a Construction Management or from an Asset Management approach. On the other hand, when related to civil infrastructure elements, the high level of detail does not provide an added value for the maintenance to be carried out, becoming a challenge to overcome because the elements, which can be larger than the terminal building (i.e. runway, taxiway), when detailed to those levels, make it difficult for the software to handle that amount of graphical information and detail, reducing the efficiency of the activities to be performed.

3.3 Information Needs Definition and Implementation

3.3.1 Use Case

In order to establish the information that is required by the final users, which in this case is the O&M staff of the airport facilities, its proper definition is mandatory. As shown in the Figure 03 by Hu et al. (2016, p. 220), “Architecture of the MEP information model”, the process of development of the information model starts with the object definition, feeding the information to the design stage. However, this study goes a step beyond that, understanding what defines those objects, and how they are defined which, in turn, relates directly to the intended purposes of the elements and the information they will contain. As explained by Hu et al. (2016, p. 228), during the Operations and Maintenance phase, the personnel is usually familiar with 2D platforms with which the models could defer, considering the LOD to which they were developed or to what phase they were taken. Given this, a model that was not developed until the as-built stage could present deviations from the actual state of a system or could lack important information related to elements’ performance, KPIs, spare parts or even manuals which might become essential for performing certain operations or maintenance activities. Even more, the information that is handed-in for the Operations and Maintenance period has to be validated, and it is this stage in which elemental information could be lost if not stored or distributed in the correct format.

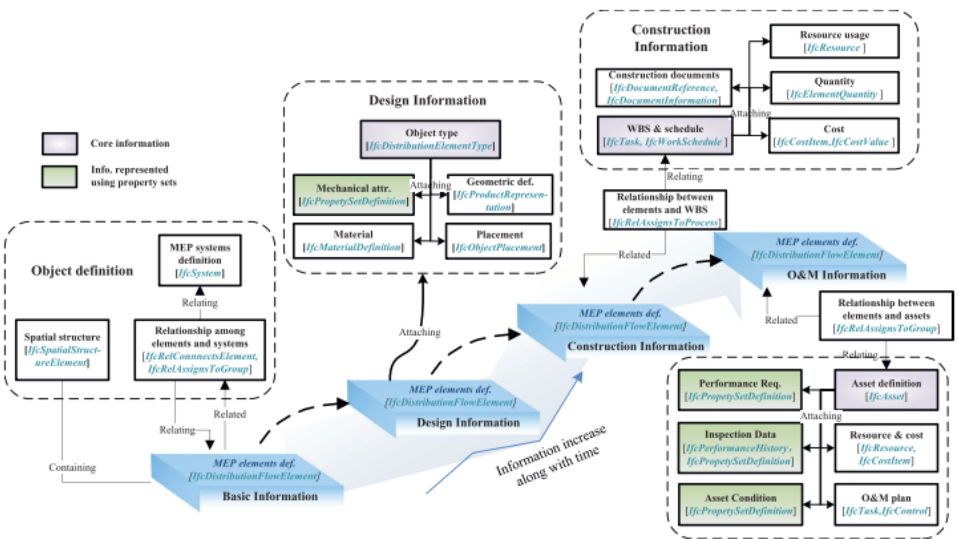

Figure 03 – Architecture of the MEP information model, retrieved from Hu et al. (p. 220, 2016)

Hu et al. (2016, p. 228), establish that the contents of each model depend on the ultimate purpose of the model. This, in turn, should be given by the Employer’s Information Requirements to properly determine the Level of Development and the Level of Information Needed of the model and its elements per discipline. As seen above, the distinct purposes will determine the system definition, the spatial structure and the relationship with other elements and systems. Since there exists a different definition of asset per system, these relationships will differ from one to another; therefore, it is necessary as well to establish them early in the project, as per the design stage.

The ideal situation would be to establish procedures that are meant to be used with digital models with a low level of graphical detail and a high level of information content. This way, a digital model of the assets of any airport project can be created with ease and will make it prepared to be used for usual activities performed by the operators and managers of the airport assets (Re Cecconi et al., 2017, p. 2). As for Asset and Facilities Management and as expressed before, these processes are expected to be towards a proactive management of the airport assets instead of a reactive one; therefore, activities considered to be supported by the models include (Re Cecconi et al., 2017, p. 3):

- Inventory-related activities.
- Maintenance, repairments, and replacements planning.
- Storage of customised parameters and Key Performance Indicators
- Management of maintenance plans
- Track performed maintenance operations
- Track components' installation dates and related issues (i.e. warranties, end of life)
- Data update after maintenance operations
- Service orders preparation
- Additional implementation and management of the information system.

In order to provide the correct information for the Operations and Management stage, an insight into how BIM models are perceived for this phase and their potential is suggested. Re Cecconi et al. (2017, p. 3) describe a series of elements that define the perception of the actors involved towards the usage of BIM models for this stage activities. One of the main challenges to overcome is that BIM models for existing buildings are commonly considered as an end instead of a Work In Progress (WIP) tool or a starting point, so their further development and update is not considered. In contrast, the perspective of having the models as a starting point can provide numerous advantages for the management of the facilities, organising their information, creating asset portfolios, and used for expansions and not only during refurbishments of the facilities. From there, other advantages can be added up. The effort required to maintain the models updated would be considerably less than when using printed documentation and, with this, the access to the model information is eased both in time and effort. Re Cecconi et al. (2017, p. 4) determined that an optimal BIM asset management system is that which is based in the Employer's Information Requirements and that is continuously tested and updated to ensure it has the correct and required data to perform the desired operations and maintenance activities on the airport civil infrastructure assets.

Given this, Re Cecconi et al. (2017, p. 13) concluded that considering the final purpose of the model is basic for BIM adoption within Asset Management and, therefore, in the Operation and Maintenance stage. This adoption enhances the information that can be obtained from the models and increases the uses and activities in which the models can be used. However, it is important to note that the authors also clarify it is a great advantage and that it is even feasible, economically speaking, only if it is considered in early stages of the asset's lifecycle. This brings up an important dissonance within the aforementioned modelling purposes: Project Information Model (for construction purposes) and Asset Information Model (for O&M purposes).

Even though there exist many differences between the uses and, eventually, purposes for the models that are created for an airport project, whether they are for construction or asset management, models should be seen as the main information storage for the complete lifecycle of an asset (Howard et al., 2017, p. 3). While BIM models have been widely adopted through the design and construction phases, their application during operations has been almost disregarded. This phase of the lifecycle of projects is still siloed and information required to perform most of the activities belonging to this phase is not completely embedded within the models. Now, the disparity of experience and skills of the operators in comparison to the BIM authoring tools used to create the models makes it almost impossible for them to adopt these technologies. Howard et al. (2017, p. 4) established that perceptions towards collaborative BIM (when overcoming the siloed situation), are critical for the technology's adoption.

3.3.2 Civil Infrastructure Application

To perform any desired activity with information contained in the BIM models, their data has to be organised and structured in relation to the modelled objects, despite of them being components, spaces, or systems (Re Cecconi et al., 2017, p. 2); the appropriate data linked to the objects helps to identify and request them in an efficient way when using the BIM models instead of 2D CAD data and printed documents. This has been seen within the design and construction phases of the AECO industry for the building elements. On the other side, civil infrastructure elements do not have this distinction, so it has been a challenge to query them in a unique way. As aforementioned, this is observed in the Level of Development (LOD) Specification Part I and Commentary, For Building Information Models and Data, developed by BIM FORUM (2019), in which building elements geometry have been divided, according to the CSI Uniformat 2010, into classes and subclasses that extend to a fourth and even fifth level "to provide detail and clarity to the element definitions". Contrary to this, Civil elements have identified only four objects, namely precast structural concrete and steel girders for highway bridges and railroads. Given that most elements are not defined it becomes especially difficult to identify the elements and related data that has to be included in objects that pertain to the civil infrastructure category within an airport project.

In the study by Hijazi and Omar (2017), the authors made a review of LOD standards for civil works, file format, land development and sites' concepts following the information management requirements established in projects under PAS1192-2. Within the study, the authors considered BIM as 3D physical properties with graphical, non-graphical and documentation data for the phases of concept, design, and construction. The definition of BIM is apparently limited until the construction phase. However, the development of BIM models and the information contained in them have the potential to be used in further phases of the lifecycle of the projects. In this case, during the Operations and Maintenance stage, the term most referred to is that of Asset Information Model (AIM). The authors describe that when referring to infrastructure projects, challenges usually start with communication among stakeholders, with the information means, and that these are dealt using numerous platforms.

Given this, it becomes evident that most of the actors involved could be experiencing issues when referring to the LOD of the models developed for the civil infrastructure elements. The reason behind it is that these stakeholders must have the same understanding regarding LODs to be used in the project. However, it is important to establish that LOD extends to all project phases, areas, and specifications in the project. Hijazi and Omar (2017) also mention that dealing with information in infrastructure projects is somehow different from the building environment, given that the latter is being developed more and more around IFC file format, which improves the interoperability among software packages used by different actors and in different phases of the project. On the other hand, for civil infrastructure assets this is not the case, which results in problems in the transfer of information, especially when numerous actors are involved.

3.4 Theoretical Lens

To be able to identify what is required and how to provide it, it is necessary to analyse the different actions that intervene in the process of information delivery for O&M purposes, that is why Activity Theory is selected as the approach to the mentioned tasks' study. Activity Theory suggests that every human activity can be both described and analysed. These have a structure and are carried out under certain circumstances, performed with specific tools in order to achieve an objective (McAvinia, 2016, p. 59). Given that activities have a conscious intention, it is also considered that an automatic action cannot be identified as an activity. Activity Theory strives to describe the relationship among the previously mentioned elements: individual, artefact, and the circumstances under which the activity is performed. As an advantage, Activity Theory is not dependant on a predefined or specific research method, providing a flexibility and versatility of its usage in many different scenarios. Other advantage of its use is mentioned by Kuutti (1995), who establishes that it is a "cross-disciplinary framework for studying different human practices with individual and social levels interlinked". McAvinia (2016, p. 61) also describes that one of the attributes of this theory is that it provides the researcher with a holistic approach to the context of an activity, as well as the relationships among the participants and elements involved in the studied activity. In this case, the Activity Theory is used to identify specifically those components related to the Operations and Maintenance stage of Civil infrastructure elements in airport projects, with special attention to the missing elements and details about the relationships among them to understand why the information that is required for the activities during this phase is not available when and how it should be provided. This will provide a sense of awareness of what can be done to overcome this challenge, apart from what can be considered as obvious, as has been suggested by Engeström (1999) and McAvinia (2016, p. 61).

The basic model of the Activity Theory consists only of three nodes:

- (Human) Subject
- (Used) Tools
- (Achievable) Object/objective

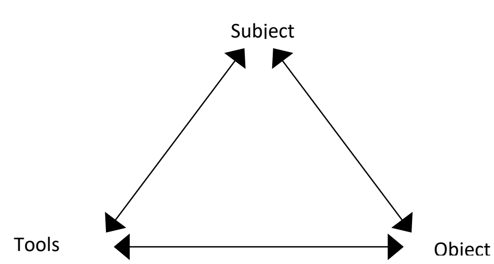

Figure 04 – Activity Theory's Basic Model

From this model, it is derived that the subject performing something related to an object using the tool, generates an outcome, whether this is intended or not. However, Engeström and Miettinen (1999) considered the activity study as more complex, with many more elements intertwined among them, which were conceived by Leont'ev (1981) and integrated to the previous diagram elaborated based on Vygotsky's work back in the 20's and 30's decades. Hence, the Engeström's extension considers the following elements as a more complete approach towards the activities to be studied:

- Instrument
- Object
- Subject
- Community
- Division of Labour
- Rules

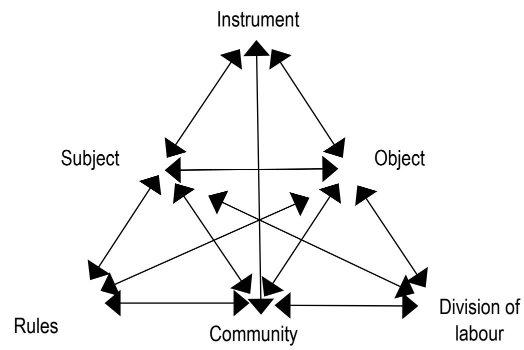

Figure 05 – Activity Theory Engeström's Extension Model

This diagram depicts the detail onto which an activity can be analysed and described. In it, a Subject is striving towards an Object through the use of Instruments. However, the activity is moderated with other factors as the Community of which the subject is part of; the Rules to abide as regulations, laws or, in this case, standards; and the Labour Division, being this the activity distributed among the individuals of the community for their specialization. For the purposes of this research project, the analysis performed on the collected data will follow the structure of a potentially shared object, in this case the asset information, which determines a shared understanding of what is required to be achieved by the different parties for Operations and Maintenance activities for civil works in airport facilities. The following diagram by CRADLE (2011) depicts how these shared object relations are established:

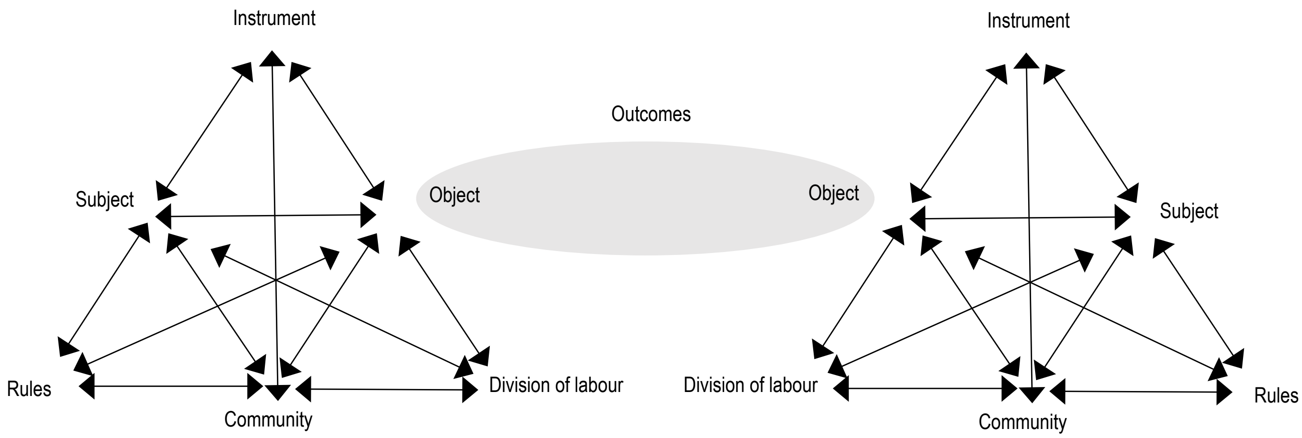

Figure 06 – CRADLE's Activity Theory Shared Object Model

3.5 Chapter Conclusions

A vast series of activities (such as assessment, monitoring, documentation, energy and space management, maintenance of service information, and retrofit planning) as well as tasks that support them (i.e. surveys, documentation filling, KPIs calculation) can be supported by the use of BIM models during the Operations and Maintenance lifecycle stage of an asset. The process to establish the information requirements to actually perform those operations goes back to the documentation used both pre- and post- contract award. In a first instance, the development of the Employer's Information Requirements (EIR) sets the basic requirements for the project to be carried out.

As a second step, the development of the BIM Execution Plan (BEP) will be determined by the requirements established in the EIRs. This document can go from a general paraphrase of the requirements the client required the contractor to fulfil, or it can be a comprehensive definition of all the actions to be performed, how they will be performed and through what channels the information created, as well as the documentation developed, will be transferred between parties during the project, as well as how it will be handed back to the client so the Operations and Maintenance lifecycle stage can be initiated. To accomplish this in a smooth transition, the ideal scenario has to consider the classification of the information on the same basis not only for design and construction, but also for later lifecycle phases as Operations and Maintenance. Although this ideal situation has been considered, one of the problems preventing a full integration of the AECO industry is the fact that currently there is not a single classification system that covers that assets' lifespan.

As an addition to the aforementioned, the differences present between elements in the built environment of an airport and the civil infrastructure ones has made it almost impossible to conciliate the differences. Attempts to achieve this have fostered the development of open standards such as IFC and CityGML, which can amend some of the differences, but it is still not possible to achieve interoperability between both worlds. Other challenges that prevent the integration of Operations and Maintenance into the AEC industry are related to the scale of the assets presents within an airport facility. Elements within buildings are usually measured in scales of metres, centimetres and even millimetres when dealing with specific elements of the systems involved (as can be MEP or IT systems) while, when referring to land, runways and taxiways, the scale of the elements can reach kilometres. The final difference is related to the maintenance of the elements involved in both environments. When dealing with elements of systems existent within the buildings of the airports' facilities, maintenance activities usually only involve the element of the system that is affected. On the contrary, when dealing with land or asphalt layers, to maintain those assets it is required to have information of the elements around them and their detail does not necessarily have to be the same as the elements inside the buildings.

Therefore, it has been suggested that in order to fulfil the information needs for the maintenance activities to be performed in the assets of the airports' facilities, the object-oriented BIM models can be complemented with the approach suggested by Hu et al. (2016) in which the objects are fed with information through the lifecycle of the asset. However, this straight-forward process has the risk of overloading the BIM models with information that eventually will not be used during the latter stages of the lifecycle of the assets. Additionally, the interests of operators and maintenance staff might not be considered in time, affecting the development of the information, which can lead to the transfer of data that is not useful for their purposes. So, to bring the requirements of these actors earlier into the design stage, the Activity Theory lens has been proposed in order to analyse current practices, identifying the processes of transfer and requisition of information during the design and construction lifecycle stages, determining actions that can foster the integration of the AECO industry. The advantage of the selected theory resides in covering the complete context in which an individual is performing an activity, which involves the usage of certain tools to achieve it, is based on certain regulations, and is performed within a community of actors that directly and/or indirectly, contribute to the development of the activity with other actions that support it or provide necessary input for it to be carried out.

Part III

Chapter 4 – Data Collection

Chapter Introduction

As a complement from the previous chapter literature review on the current situation of BIM implementation during the Operations and Maintenance phase, as well as the specific information needs during this asset's lifecycle stage, data collection from a set of exploratory interviews was carried out to have the perspective of the airport industry in real life applications and how these challenges are being solved or which solutions have been suggested to overcome them. This chapter aims to identify the information needs in practice and how they are requested to fulfil their demands to perform the activities described in the previous chapter. For this, the study cases offer a more in-depth knowledge about how the information requirements for Operations and Maintenance activities are established and transferred from the appointing parties to the appointed parties. The documentation to be reviewed for this considers the Employer's Information Requirements and the BEP of the selected cases. In addition, all the appendices corresponding to these documents are to be analysed as well, identifying information needs such as *BIM team composition, roles, Level of Development*, *BIM processes, non-geometric information, documentation,* and *project specifics (i.e. key project contacts, project goals, information exchanges, data requirements, collaboration procedures, quality control procedures, infrastructure needs, model structure, and deliverables)*. To identify the elements relevant to the activity theory analysis to be conducted in this research study, the data collection is set into two different steps. The first of these refers to reviewing documentation available from cases that involved the development of a BIM Execution Plan. As a second step, interviews with employees from the appointing party's side are conducted to retrieve case-specific and discipline-specific related information.

4.1 Exploratory Interviews Findings

The first approach towards the objective of this research project, in addition to the literature review, was a set of exploratory interviews to understand what the main issues and challenges within airport facilities are when dealing with projects related to their Operation and Maintenance. These exploratory interviews were conducted with a Civil 3D / BIM specialists, a BIM coordinator, and a Project Manager-BIM manager. All of them have been working in the airport industry for at least four years and were involved in different projects in that period of time. Therefore, the information gathered from the exploratory interviews comprises insight of up to three different airport projects around the world and, during these meetings, information needs were considered as the main topic of discussion.

Derived from the exploratory interviews, some elements were found to be important and have to be considered when facing a project that requires to have information related to the Operations and Maintenance stage. It is important to establish as much as possible the O&M information needs to be addressed from the beginning of the project. The reason for this is to avoid over working on elements that could have been delivered earlier on the project. In addition, a classification system was considered necessary for the information to have a common ground so users could refer to the same elements whether they are referring to them in the same or in a different language. However, a classification system for civil or infrastructure elements has not been developed, which is in line to what the literature review demonstrates. An ideal situation to which companies and governments are aiming at, is to develop a standardised approach, so classifications are not needed anymore.

Several actions have been taken facing the standardised approach to be reached. That is why projects are now being delivered in IFC file formats that include the geometry and some non-graphic information related to the elements contained in them. This is not only applicable to BIM models but also to GIS ones, so the whole facilities are included in a sole federated model despite the fact the information present corresponds to buildings or infrastructure elements. Even though the gaps in this area are being closed, there are still other challenges to overcome. One of the main ones would be the inclusion of the information requirements for the Operations and Maintenance stage in the Employer's Information Requirements. Mostly, models are being used only for design and construction purposes that include coordination and visualisation, while the operator needs are considered either later in these stages or even after handover.

IFC files provide a high versatility of uses in which the models can be utilised for. But these file formats were considered as not developed enough given that elements that were specific to the airport industry -strictly speaking about design, construction, and operation- did not have the properties' fields required to provide the complete information requested by the client. In addition, a great amount of elements were missing from the IFC schema, which limits the ability of BIM modelers, BIM coordinators and BIM managers of providing the information as was requested. However, the challenge becomes even bigger when referring to the area of civil works given that the elements of this have not been developed as much as the building ones. One of the most important takeaways from the exploratory interviews was the fact that there is a large disparity in the knowledge about potential BIM uses and benefits during Operations and Maintenance of the facilities within an airport from client to client.

4.2 Case A

This case project concerns a design consultancy for an expansion and redevelopment of an airport in the region of Central America and the Caribbean. The passenger terminal building is topped, hence the required expansion. NACO is involved as a design leader in this project, which is not limited to the mentioned expansion but to provide what is needed to allow the airport a continuous growth in the upcoming future, including:

- Customer experience
- Relieve of capacity constraints
- Sustainability

The most important systems considered in the project are the baggage handling system (BHS) and sorting system, check-in facilities and several upgrades required for the screening process to comply with TSA standards. As for the sustainability goals, the project was registered for a LEED Silver level accreditation. In order to achieve this, solar panels are considered to provide green energy to the facilities and to include an automated building management system which will regulate both the temperature and lighting of spaces depending on the occupancy of these.

4.2.1 Employer's Information Requirements

4.2.1.1 Request for Proposal

The Employer's Information Requirements were established only as part of the Request for Proposal. The *Building Information Modelling (BIM)* section included a brief description of what BIM is, the main purposes of the model (*design and coordination*), the need of a BIM Execution Plan, a general definition of the Levels of Development to work with in each phase and limits regarding existing buildings and areas of the project. The RFP includes the phasing of the project.

4.2.1.2 Technical Bid

The *Building Information Modelling (BIM)* section includes a paraphrasing of the BIM section included in the RFP. This includes the benefits and brief description of what BIM is, the main purposes of the model, the setup of a BIM protocol, the need to establish a BIM Execution Plan, subsequent reports to define the quality of the model, the information required per design phase and the simplification of certain areas of the project.

4.2.2 BIM Execution Plan - BEP

The *BIM Execution Plan* of this project is divided into nine sections and includes numerous appendices. The level of development of the document is high in comparison to the information requested to the designer; however, the BIM implementation it entails can be considered as a medium-level. On the first part, the Introduction, the BEP establishes the purpose and the scope of the document in which standards, methods, procedures, technical requirements, roles, and responsibilities are included. The scope goes into a more detail about the project and establishes further actions to consider as implementation and revisions of the document to ensure its alignment to the project requirements. As a first approach, it is established on which documents it is based on from the client's side and what information is considered from the design team's side. The project's specific information is included as well as how the appointed party's team is structured.

The second section entails the requirements related to BIM, including a general description of the phases of the project and a general description of the deliverables by the end of each phase, as established by the client. Furthermore, the objectives and analysis to be carried out with the model are established as well as in which stages these are to be done, in what formats and what type of model they are based on. The third section corresponds to the BIM processes. In this part, the roles and responsibilities for specific team members are described in great detail. This is followed by the organisation followed for the models' subdivision, corresponding disciplines, and software to be used for their development. In addition, each discipline's model structure is defined, the naming convention to follow for these is specified, as well as the workflow relative to the federated model. Specifications are established for different milestones. A clear definition of the limits of the model is described and is divided into existing situation, areas to be demolished and which of them are to be reused.

The fourth section refers to how data is to be treated during the project, including moments in which it will be transferred, what is to be transferred, by whom and to whom. The formats for the diverse deliverables is specified and a QA/QC sub-section can be found for specific checks. A general description of the handover process is described, differentiating between areas, and specifying the information to be handed-in. Afterwards, a communication section describes how the information exchange is to be done internally and externally, using the Common Data Environment specified by the appointed party. Within the established CDE, different rights are established depending on the team members of the appointing and appointed parties. Additionally, a detailed chart depicts the meetings to be scheduled, the frequency, the attendees, and their content. The provision of the model is established to be defined at specific moments during the project and uses of this are described.

The subsequent section of the BEP concerns the Level of Development (LOD) of the Building Information Model. For this, the LOD approach is defined and its application onto the project is described. Additional definitions and descriptions concern the graphical model of different disciplines, what is not to be modelled in the project, non-graphical information, spaces and how they are to be identified. Information about interferences is available in this section, in which different levels of severity are described and exemplified. Later, project specific standards related to the origin of the models and orientation are established. Conventions for levels, grids, annotations, naming, templates are described, followed by the element classification to abide by as well as the model phases. Descriptions on how to share information within the CDE, what exports should be shared, and additional information related to modelling techniques are included in this section. Further, specifications related to IT, security and privacy concerning the project, models and their information is found. Finally, a disclaimer specifies the purposes for which the BIM model is to be developed, followed by appendices with more detailed information of previous sections or subsections of the BEP document.

4.3 Case B

The project of this case entails part of the expansion of an airport in Western Europe. The airport consists of one sole terminal and is facing a situation in which it is about to reach its limit regarding flight movements per year and is an important hub within continental Europe for air traffic. Current expansion of the airport includes an additional pier with eight extra gates and a high sustainability grade given the elements included in the design as insulating glass and use of biomaterials. However, the expansion does not consider only this but extends to other areas of concern such as land use, noise, and pollution which are extremely important to the stakeholders involved.

4.3.1 Employer's Information Requirements

4.3.1.1 Employer's Information Requirements

The document is an extensive definition of the information requirements. As it has been established before, information considers three different elements: geometry, non-geometry, and documentation. The three elements are present in the document with enough definition detail to prepare a complete BEP. This document also includes general information regarding BIM, organisation structures to be used in the project and references to the Information Delivery Cycle, part of the PAS1192 standard.

Moreover, the document establishes the aim of the protocol, providing a clear delineation of the approach and expectations of the quality of the results to be delivered per phase of the project. Additionally, information considering data ownership, data transfer is further developed. The BEP section includes a list of the things to consider for the preparation of a complete document, including process, geometry, non-geometry, documents, and project specifics. For its fulfilment, a different section considers the roles and responsibilities of team members, as well as how consultation with the team should be carried out.

The model geometry-related section of the document includes the naming rules for the models, limits/demarcations, and coding are defined. The quality of the model is defined for every stage of the design process and how it should be delivered on each milestone to be achieved. For this, even the cut-outs of elements through primary, secondary, tertiary, and even quaternary elements' priorities are defined. The non-geometry-related section considers the quality of these elements, the coding to be followed (NL-SfB) and a list of parameters specific to the appointing party (Information Delivery Manual - IDM) with which the objects have to be verified.

As for the documentation, it is established that the responsibility of what documentation and when it is to be delivered, lies with the contractor. The section establishes what needs to be developed within the BEP. Project specifics refer to members, phases, software, planning, and simulations, providing a baseline for their development both in the BEP and the project development. Lastly, an appendix is included with the terms and definitions to be used, based on the ILS document.

4.3.1.2 Terms and Definitions Appendix

The document expresses a list of the most important terms to be considered from the *Employer's Information Requirements* and included in the BEP, as well as further references during project execution. In addition, tasks, and responsibilities of different roles within the BIM team are included and serve as a reference for the differentiation of these roles and contacts when the BEP is set up.

4.3.1.3 Information Delivery Manual (IDM)

The document expresses in more detail what is established in the *Employer's Information Requirements*. It provides a main objective regarding the information delivery during the project, the general purposes for which the information provided for Asset Management will be employed, scope, application of the document, and what it is based on. As a baseline, the Information Delivery Cycle referred in the PAS1192 and it also offers flowcharts of how the information should be provided in alignment with the BEP in order to comply with the requirements of a BIM (model) and an AIM (model).

The schema of the process of information delivery is provided in comparison with other standards such as DNR-STB 2014, NEN 2574 which facilitates comprehension by other actors and aligns the understanding and provision of information either from the asset manager to the contractor or vice versa. Every information delivery milestone is defined as well as the deliverables to be handed in. Provision of information is delineated by schemas specific for both the client and the contractor.

The transfer of digital files is more detailed than in the previous document. Specific information to be handed in is listed and includes, but does not limit to drawings, lists, extracts, and documentation. In addition and to ease the organisation of the information, naming conventions and folder structures are determined and exemplified.

The specifications include the principles and standards to be followed by the contractor and other parties involved in the development of the models. GUID, model structure, drawing standards, geographic orientation, positioning, location decomposition and spaces are considered and described in further sections. Systems' groupings are also specified and the object classification to be followed is described (and detailed in the Appendix C of the IDM document). The information related to any asset is further categorised and detailed, becoming the link between the project to be executed and the already existing Asset Information System. As supporting documentation, the ILS has eight different appendices concerning the following topics:

Document	Description
Appendix A	Categorisation of elements to be handed in depending the discipline, corresponding area, project phase, type of asset and to whom it should be delivered. Includes a section for general products to be delivered and the formats in which the information should be transferred.
Appendix B	Description of each information product included in the Appendix A.
Appendix C	Technical Decomposition of objects, up to a fourth level of specificity. Based in the NL/SfB, the classification has been extended to fulfil Schiphol internal information needs.
Appendix D	Definition of generic master data and specific asset master data.
Appendix E	List of space functions and names within the airport facilities.
Appendix F	Fire compartments and location within the airport facilities.
Appendix G	Specifics of the system and type designations as well as coding of systems used at the airport facilities.
Appendix H	List of previous versions and modifications effected in the documentation.

Table 01 – Case B IDM Appendices

4.3.2 BIM Execution Plan - BEP

The BIM Execution Plan of this case is divided into six different sections with five additional appendices. The content of the overall document has a high-degree of detail in the topics covered; therefore, it can be considered as a high-level BIM. The first section entails the introduction of the document, where the purpose and the scope of the BEP are described, as well as what documents it is based on. A synthesized reading guide provides a general overview of all the appendices listed. The second section concerns the process. For this, the project team structure between the appointed and the appointing party is established. Furthermore, roles, tasks and responsibilities for the most important roles are established. After this, a consultation structure is provided, establishing the attendees and the topics to be covered in each of them. This is followed by the model exchange process, concerning the Common Data Environment; the validation process for the models; the demarcation of the models; and naming conventions to be used for the files' names.

The third section of the document entails the geometry included in the model. This includes the structure of the models, conventions for its positioning, naming, levels, spaces, and groupings. The geometry quality is provided in terms of the Level of Development (LOD) for the different elements included in the models, even considering those of other parties. Specifications concerning cut-outs, intersections, and how to define clashes are provided.

The fourth section is related to the non-geometrical information. This part includes as well a definition of how the model quality is to be ensured, structure of models (including IFC parameters), under which document the elements are coded, parameters' list and the implications of working with a Global Unique Identifier (GUID) when elements are exported using certain tools. The subsequent section refers to the documents, where they are derived from and to which other documentation refer when looking for specific details about digital files.

The sixth section encompasses all the specific information of the project. This includes contact information of the project members and the phasing of the project (considering the different areas to be included in the project as a whole). In addition, the project software to be used as well as the files used are defined in a general manner (specifics are included in one of the appendices provided). A guide to export information in an IFC format and the limitations of this are included and described with detail. Then, general information about the planning of the project, simulations, deliverables, and model transfer is included. As for the appendices, they describe the following information:

Document	Description
Appendix I	Refers to a document where the BIM deliverables are described and specified.
Appendix II	Refers to a document where the BIM process workflow is described.
Appendix III	Refers to a document where the limits of the project are established.
Appendix IV	Describes the differences between disciplines' models and specifies the methodology followed to create previous versions.
Appendix V	Notes concerning the existing installations in the project.

Table 02 – Case B BEP Appendices

4.4 Case Study Comparison

4.4.1 Employer's Information Requirements Comparison

The analysis conducted on the documentation available has the intention not only to understand how complete and useful these tools are but also how they affect the development and implementation of the naming conventions in the Operations and Maintenance activities of civil infrastructure assets. The EIRs, while establishing what has to be implemented into the BEP to be used throughout the project also lays down the organisation needs, which are aligned to its purposes and goals in the long run.

Content Categories	*Case A*	*Case B*
General	A general description of BIM requirements and phasing of the project was delivered. *BIM model (PIM) is not considered a deliverable in the project.	- Information regarding the main purposes and processes for the Asset Management stage are described. - Regulations to be followed are included and property of the expected documentation to be produced is defined. - Transferral of the digital information produced is specified, concerning source files and the extracts that could be derived from them.
Processes	General requisition to the contractor about when to provide information is established.	- The BIM process is described in general terms, specifying the main information handover moments. - The protocol establishes specific requirements for the different phases of the project. - It is established that a BEP is necessary for the project, to which party this is a responsibility, and the general elements to be included in the BEP are listed. - Roles required, their definition, and organisation structure is established. - Different consultation tools (meetings) are established and what will be dealt in each of them. - Naming conventions of the models are established, following a specific structure that helps its identification for further uses.
Geometry	General requisition of the LOD of the model is presented.	- IFC formats and standards are specified for the models to be developed.

		- Position and orientation of the models within the CDE are established. - Model quality to be achieved on each phase of the project is established. - Tolerances between the elements present in the models are defined, considering the hierarchy of the systems involved.
Non-geometric information	No specifics nor details were provided.	- Model quality to be achieved on each phase of the project is established. - Classification to be followed is established. - Naming convention for the assets involved in the project are established. - Naming convention for the different levels of the buildings are established. - Naming convention for the spaces are established. - Naming convention for the groupings are established.
Documentation	Even though the BIM model (PIM) was not considered a deliverable, 2D documentation was expected to be produced and extracted from it.	- General requirements for the contractor to be met including what and when is to be delivered.
Project specifics	N/A	- General requirements for the contractor related to the members, phases, software, planning, and simulations is established.
Appendices	N/A	- Additional information regarding terms and definitions employed through the document is described.

Table 03 – Employer's Information Requirements Comparison

NOTE: The mark "N/A" (Not applicable) is established for those items in which the listed information was not existent in the analysed documentation.

The differences between both cases are not only related to the presence or absence of a formal document about the Employer's Information Requirements but also to the purpose of using BIM within the project. While in the Case A the BIM model (PIM) was only intended to be used for the development of 2D documentation, in Case B, the BIM model had the intentions to be further used for Asset Management purposes (AIM). Given that for Case A the main purpose was to retrieve the 2D documentation for the project, the BIM model characteristics were not defined nor detailed in the EIR and the use of BIM was barely described for the project. In comparison, when the BIM model has been considered to serve future operations (as can be seen in Case B), the requisition for BIM is more detailed. Not only the description of its intended use in the project is present, but also there is a higher level of development of the requirements in relation to the processes to follow, the geometry or graphical elements, non-geometric information, and the documentation. It can be seen a further definition of the concepts and elements present in the main document, proving that the client is both aware of the future uses of the model requested, and knowledgeable of the terms and information related to the requests made. From the Employer's Information Requirements, takeaways can be described as follows:

- The requisition of geometry and graphical specifications is closely related to the format of the extracts to retrieve from the models which, in turn, will be used for other activities, mostly related to the maintenance of the assets.
- The quality to be delivered in each milestone must be defined.
- A hierarchy has to be defined for the elements and systems to be present in the model; therefore, input from the different disciplines will be required.
- Naming conventions must be requested or defined for elements or assets, levels, spaces, groupings for future tasks and common knowledge among the project parties and within the organisation.

4.4.2 BIM Execution Plan (BEP) Comparison

The BEP in addition to establishing how the processes are to be implemented during the project, reflects the EIRs. If the latter establishes that certain information is required to perform a specific activity or to achieve a certain BIM goal, the BEP document will be more developed towards this instead to other potential BIM uses that can be fulfilled with the model and its information. The specification of the components of the models will provide a more fit-for-purpose result than a generic BEP. Naming conventions can be specified either by the appointing party or by the appointed party, even by both of them. However, if an appointing party has experience working with BIM models, information retrieved from them and also with Asset Management, it is more likely to provide a whole guideline on naming assets, files or even elements present within the BIM model to be delivered.

Content Categories	*BIM Project Execution Planning Guide (Reference)*	*Case A*	*Case B*
BIM Project Execution Plan Overview	Establishes why it is required to create the Project Execution Plan.	- Definition of the purpose and scope of the BEP includes standards, methods, procedures, technical requirements, roles, and responsibilities.	- Definition of the purpose and scope of the BEP including its relation and references to other documents included in the package provided to the contractor.
Project Information	Describes the basic data that defines the project as description, location, and important dates/milestones.	- Description of the project to be performed. - General information of the project is listed.	- Detailed description of the project to be undertaken in a specific asset - Detailed description of the project through different phases

Key Project Contacts	Contact information of the key personnel involved in the project.	- Lead roles are listed, including the responsible and the contact information.	- Lead roles from each party involved in the project are listed, including the responsible and the contact information.
Project Goals / BIM Objectives	Definition of the added value of the specific uses of BIM. In this case, the Use covered entails the Asset Management, which is one of the numerous included in the Guide.	- Listed succinctly including modelling existing situation, coordination purposes, producing 2D documentation, schedules (4D), costs (5D), analysis (partly 6D and Operational purposes)	- Definition of the implementation of the BEP in an asset project during a specific phase of the project, mainly for coordination purposes.
Organisational Roles and Staffing	Establishes the coordination roles in charge of the planning and execution throughout the different project phases.	- Described in detail. - Differentiation from other roles. - Main responsibilities listed.	- Roles described in detail. - Differentiation from other roles.
BIM Process Design	This category should describe in detail how the process is to be implemented. The use of process maps to depict this is encouraged.	- Model workflow schemes to be followed for different milestones during the project.	- Information workflow on the exchange platform. - Information exchange during the design phase for the different model types and considering the information handover from the client to the contractor.
BIM Information Exchanges	Elements to be included in the models and their level of development for the BIM Uses have to be established.	Differentiation between: - Software used. - Disciplines involved. - Native formats. - Exchange formats for coordination purposes. - Frequency of QC. - LOD.	- LOD. - Disciplines involved. - IFC parameters - Detailed exports set-up
BIM and Facility Data Requirements	Inclusion of the client's requirements. These have to be clear and understood.	Client's BIM requirements are described and used for the development of the BEP document.	Client's BIM requirements are described, and the documentation provided is thoroughly used for the development of the BEP document.
Collaboration Procedures	Procedures described in this section include	- Coordination and information workflows are described	- Coordination and information workflows are described

	agendas, meeting schedules ad model management.	- Use description of the Common Data Environment for Information Exchange. - Frequency of Information Exchange. - Tools (meetings) are described and differentiated according to their scope and purpose.	- Use description of the Common Data Environment for Information Exchange. - Tools (meetings) are described and differentiated according to their scope and purpose.
Model Quality Control Procedures	Procedure(s) to follow to ensure project members will meet the requirements and how this will be supervised during the project.	- Different quality controls are defined, a responsible party is appointed, software to be used is defined and their frequency is established.	- Geometric model quality considering different LOD levels depending on the party involved. - Validation reports are established to be discussed during meetings. - Non-geometric quality is assured through IFC parameters, depending on the discipline and party involved.
Technology Infrastructure Needs	Elements required to execute the BEP, including hardware, software, and network infrastructure.	Software and CDE is described thoroughly	Software and CDE is described thoroughly
Model Structure	Definition of the coordinate system to be used, model structure, modeling standards, and naming conventions.	- Coordinates system - Orientation - Levels - Classification system - Naming conventions (files) - LOD	- Naming conventions (buildings, levels, spaces, groupings, files) - Classification system - LOD descriptions per party involved - Positioning and orientation
Project Deliverables	Detailed description of the deliverables to be handed over to the client.	Handover content is described including: - Models - 2D drawings - Shared Parameters files - Sheets - Schedules - Single line diagrams	Handover content is described including: - Permits, assignments - Calculations - Certificates of approval - Lists - Material/supplier information - Models - Multimedia - Plans - Project documents - Reports (inspections, measurements, controls)

			- Technical diagrams - Technical drawings
Delivery Strategy / Contracts	This section refers to the Project Delivery Model used for the project, which directly affects the implementation and language used in contractual documentation to guarantee the correct BIM implementation.	Project Delivery Model followed: FIDIC White Book	Not mentioned in the document.

Table 04 – BIM Execution Plan Comparison

The differences between both cases are reduced, considering what the requests included in the EIR (or related documentation) were. Even though the differences were less, the deliverables still differ because of the intended uses of the model. Given that requisitions were more specific in Case B, the deliverables to be handed back to the client are more activity driven than the general deliverables in Case A, which mainly includes 2D documentation. Despite this, the communication and information exchanges were established in both cases, providing a high importance to them, describing the frequency of the information provision for the client and the contractor. Additionally, in the two cases analysed, different types of meetings are established and the personnel to be involved is also described. From the documentation analysed, it can be defined that despite the lack of information presented to the contractor in the EIR or RFP for a project that considers the usage of BIM, the contractor is still able to steer the development of the documentation to be used throughout the project considering its expertise and previous knowledge. However, establishing only general uses for the model derives in providing only general guidelines for the development of the model and related extracts to be handed-in back to the client.

4.5 Preliminary Case Study Conclusion

Drawing up documentation for the development of the models and the information to be used for O&M stages of the assets is essential for the clients to receive what they need. Even in the case they do not provide a full and detailed EIR document, the contractor can still develop a general version of a BEP, leading to the provision of general and broad information of the project. However, this might not be useful for the client at all and therefore it is still required that the client participates more actively in the development of these tools and documentation. Regarding the Employer's Information Requirements, differences among the documentation provided to the client can be the result of reasons as the following:

- Intended uses of the BIM model: A model that is required only for the production of 2D documentation does not require the same detailing and LOD as a model that is required for coordination purposes.

A BIM model that is required for the maintenance of civil infrastructure elements does not require its elements to be developed to the same level as the elements in a building model.

- Possible future uses of the BIM model: If the future intentions of use of the BIM model are not limited to a PIM but to an AIM, their development would require additional tasks. Definition of parameters, extracts and exchange formats is required for the interoperability of the models and their information with other parties and platforms.
- Interest in the client to follow a BIM methodology: When the clients do not have an interest into following the BIM methodology, they can be influenced by BIM being a more and more common practice in the construction industry but may not request specific information; thus, only to receive a model, which will not be useful after it is handed-in to them.
- Knowledge of the client regarding the BIM methodology: Clients that have more knowledge and experience of the BIM methodology and possible uses of the information contained in the models, ask for more specific requirements to be fulfilled, driven by their interests and activities that they are already practicing or intend to practice.
- Awareness of Naming conventions importance in the development of the project (not only for files, but for elements within the models): This will affect directly the availability and ease to identify the required information not only within the models but also in the extracts generated, having a direct impact in the efficiency of the activities to be performed with that information.

Regarding the BIM Execution Plan, differences in the documentation provided are not as big as with the EIRs. However, the following can be determined:

- Contractors' knowledge plays an important role in the creation of the documentation for the execution plan. The lack of experience from the client's side can be solved but any specifics will not be developed, given the missing goals from the appointing party.
- Even though the requirements communicated by the client might be limited, the contractor can influence and steer the future uses of the model. For this, previous experience of the appointed party is essential which, in turn, does not only relate to the organisation itself, but the personnel involved in the project.
- Deliverables differ considerably depending on the intended use of the models. It is necessary to define the BIM uses of the model to properly define the deliverables. This will influence the processes, workflows, specifications of extracts, documentation and LOD of the models. As mentioned, for a 2D documentation it is not necessary to develop the model as much as when it is intended to be used for stakeholder meetings, documentation, scheduling, costs analysis, or sustainability analysis.
- Even though the contractor can influence the development of the BEP if required, the lack of a defined EIR document results in a not so complete BEP. This will influence the information and deliverables mentioned in the previous point. Additionally, the missing definition of the personnel involved in the processes could derive in a bad project coordination and a poor exploitation of the information present in the models.
- Meetings and workshops are important tools that foster collaboration among users. Community can be built up from them and division of labour can be reduced by avoiding siloed work and decisions.

- Even though meetings foster collaboration, they could establish a dissonance: only certain personnel is designed to be present in them, which could in turn become a source of siloed thinking that will lead to coordination problems in the project.

4.6 Semi-structured Interviews Candidates

To address the approaches desired and the areas to be covered which include BIM uses, information for Operations and Maintenance, missing airport and civil works IFC entities, IFC schema challenges, standards and classifications, BIM Execution Plans and Employer's Information Requirements, the following roles and perspectives were considered for the semi-structured interviews:

- BIM manager (client's side)
- Operations and Maintenance specialist
- Missing entities specialist
- Civil team member (BIM/engineer)
- Use Case specialist

As for this roles, it is worth to notice that the interviewees being from different specialized areas also differ in their experience within airport projects, ranging from a couple of years as BIM manager (from the appointed party) to approximately 25 years of experience (as a consultant and missing entities specialist). Interviewees have worked or been working in projects within the same facilities of Case B, considering the high level of BIM involvement developed for the studied case.

4.7 Semi-structured Interviews Structure

The interviews were conceived to follow a semi-structured format. This approach does not only guarantee acquiring the information desired but provides the interviewee a certain freedom degree to extend the answers provided. Additionally, the interviewer has the choice to steer the interview towards a certain topic or to get a deeper insight into a specific element or topic mentioned by the interviewee. The interviewees for this research project are involved into the same information requirements topic to a different degree and with a different perspective, providing a broader knowledge of the challenges faced in this area by the airport industry.

From the client's side, the contact was to ensure what was the perspective of the client and to define how their requirements are established into the Employer's Information Requirements provided to the contractor. As the counterpart, the contractor's side is addressed to have an insight into their perspective, how they understand the EIRs provided and how these are used in order to define the BIM Execution Plan required for the specific project to develop. As for the missing entities and Use Case specialists, the intention was to ensure a neutral approach to the information, not being biased by the intentions and expectations of the client nor the capabilities of the contractor.

The semi-structured interviews undertaken had a 45-minute period in which the background of the interviewees was discussed in order to analyse the *user* entity of the activity theory spectrum. The interviews include a brief description of the team structure and how communication between team members and with the client was done. This was intended to address the *community* and *division of labour* dimensions of the Activity Theory. Furthermore, the generalities of the EIR, BEP and implications into the contract are considered to include the *tool* dimension. Standards and classifications requested and/or used were considered in order to find the *rules* to which the information and users had to abide. The *object* considered refers to the asset information, including naming conventions, while the *output* is the process followed to retrieve the information required to perform the desired civil infrastructure Operation and Maintenance activities, being these the *outcomes* of the model.

4.8 Chapter Conclusions

There is no apparent way to establish a general list of information requirements that can be applied to different airport facilities. This limitation can be understood from (at least) two different fronts as was discovered in the exploratory and semi-structured interviews. On one side of the spectrum, the clients identify their project and the related facilities as unique; thus, specific data needs are developed for each of the assets that comprise the facilities. On the contrary, consultants (both of BIM and Information Delivery Manuals & processes) consider that the assets are not specific in any given way: buildings are only buildings that might differ from others in shape, but in essence are the same; hence, the same data requirements can be established for any airport facility.

The experience of the actors involved in the documentation to be governing the design and construction of the project is also of the utmost importance. As can be derived from the cases description, and supported by some interviewees, the familiarity of the client not only with the terms and definitions, but also the methodology and related processes has a great impact in the future implementation of BIM in the project phases. This is reflected automatically in the extent to which BIM is desired to be implemented, which can be used for coordination purposes only or it can be conceived as a system that can support and help the client to fulfil the organisation's objectives. When the contractor has already some experience working with this methodology, the documentation can be further improved but to a relative extent in comparison to a situation in which at least client and contractor are used to work with BIM for airport projects and facilities.

Other than experience, during the semi-structured interviews was identified an element that highlights the gap existing between the AEC and the Operations and Maintenance industry. Interests play an important role in the documentation developed, as mentioned above; however, when performing, individual interests are most likely to define the availability of data and information in subsequent lifecycle stages, regardless of which one it is. Although this tendency was mostly described referring to the contractor interests being incompatible with the operator's, it is worth to mention that this situation can be identified in other actors and stages of the projects, especially if the designer, the contractor and the project manager are different entities.

The aforementioned is not necessarily individual's fault but, considering the constant evolution and incessant need for speedy project deliveries, actors are focused on providing only what they are required to. This can be extrapolated to the situation in which an asset's project is already finished and the owner does not share information of how it was done to the community. The premise, simply put, is that even though these actors are in no obligation of providing that information, it can help the development of other parties involved in the project and in the industry.

Actors are usually not comfortable providing information that was not contractually required to them either because it takes more time and resources to be produced, which could impact directly their performance in areas where they will be evaluated, or because the processes followed were successful, providing them an advantage in the market which they are not willing to lose. Given this, the semi-structured interviews performed are to be analysed with the Activity Theory lens to understand, from the practitioners perspective, what are the elements and processes that condition the successful transfer of the information required for the Operations and Maintenance stage of civil infrastructure elements in airports facilities.

Chapter 5 – Theoretical Lens Data Analysis

Chapter Introduction

The previously executed document analysis of the case study develops a comparison of the available items from the projects studied. The main similarities and differences are addressed as how the societal factors (i.e. appointing and appointed parties) influence the production of the documentation to request and to be used throughout the project. This chapter aims to go a step further, identifying those elements comprised in the Activity Theory lens through the information provided in the aforementioned documentation comparison. For this, the first section of the chapter comprehends a thorough analysis of these elements through the Activity Theory in order to establish how they are composed. In the second section of the chapter, the tensions or contradictions between the different Activity Theory components are described, aiming to determine the most significant ones to the requisition, development, implementation, use and transfer of information for Operations and Maintenance activities in civil infrastructure elements of airport facilities, using BIM models.

5.1 Activity Theory Data Analysis

Activity Theory was considered as the theoretical lens to analyse the data from the semi-structured interviews in order to determine the factors involved in the development and use of BIM information for O&M purposes in civil infrastructure asset elements. Despite the fact that most of the elements are in constant interaction, the relationships between them is relevant to determine what are the causes that prevent Asset Management teams from utilising the information received either from the appointing parties (client) or from other appointed parties (contractors). The identification of these so called "contradictions" aims to further support their solution for a streamlined information flow that encompasses the whole lifecycle of an asset, which goes back to the contractual documentation. In order to achieve this, an analysis of a third level activity is undertaken. The first level, corresponds to when an asset need is established to fulfil an organisation's objectives, followed by the second level, in which through a regular inspection, it is determined what task is to be performed to the asset. As a third level, once it is determined that a maintenance activity is needed, the elements surrounding that activity are the ones to be analysed; considering as the object of the activity, the asset information; the subject that performs the activity; the community in which the subject develops; the tools that are used to perform the activity; and the rules that govern how the activity is to be performed. These elements are described in the following sub-sections and the way they were determined, is described in the sub-sequent section, aided with the diagrams corresponding to the interaction of the aforementioned elements in relation to each other as well as how they all influence the development of the asset information with which the maintenance activity is to be performed. In addition, the elements described are supported by quotes from the conducted semi-structured interviews, providing the perspective of the practitioners regarding this challenge as a differentiation from the previous literature review, described in the third chapter of this report.

5.1.1 Object

As established priorly, being able to communicate in the same terminology with other industry parties and collaborators is crucial for the understanding among actors, fostering collaboration, interoperability and, above all, integration. These conventions have been already established for elements such as files or layers within a project, as can be seen in PAS1192-2:2013, which in turn refers to the BS1192:2007 for aspects not covered. However, within the attributes covered are included the *location, originator, volume, level, file type (*i.e. information exchange, clash rendition*), discipline, unique number identifier (*concatenation of *file type* and *discipline).* The naming convention can be used to identify and retrieve specific information in an easy and fast way, instead of looking file after file for the required information.

If the same logic is applied to the elements within the models used for the projects (and further Asset Maintenance/Management activities), it would mean that there is an effective way to refer to the same items within the models throughout the life cycle of the assets. The implementation of naming conventions for objects would provide an easier parameter to identify these elements within the model other than the Globally Unique Identifier (GUID) which, in turn, would mean that the personnel from any party at any given stage of the lifecycle of an asset can identify, in simple terms, an object or element required whether for design, coordination, operation or maintenance purposes. Moreover, this method would provide one of the necessary attributes to actually integrate the information required for O&M purposes since the design stages of the project.

The barriers that prevent the creation and adoption of a naming convention for objects of civil engineering works can be identified in the different categories included within the Activity Theory model: *Subject, Community, Division of Labour, Tools, Rules* and *Object,* being the latter the already mentioned *naming conventions* to be used. The model entails identifying the tensions among these categories in order to be able to propose a solution to overcome them and provide a better *outcome* (O&M activities) out of the *object* that is recognised. Despite all of these elements influencing the development of the naming conventions, the other elements intervene in different stages during the asset lifecycle, as discussed below.

5.1.2 Subject

In a broad sense, the *Subject* is the person or the group of persons who are involved in the performance of the activity. In this case, the *Subject* considers the group of actors that are involved in the activity, in this case, the Asset Management. However, this group might be considered as only the maintenance staff and/or the operators of the civil works assets to be maintained. In reality, the conception of this group has to be extended to all the people that is actually involved in the development of the information required for the performance of the maintenance activities in the airport assets. This includes maintenance staff; asset management staff; contractor and designer modelers; contractor and designer BIM coordinators; contractor and designer BIM managers; any other relevant personnel involved in the creation, development, storage, retrieval of the information, any personnel involved in the decision making processes and the client.

This cluster of personnel has a direct or indirect influence in the ultimate information that is available for O&M purposes within the airport facilities as well as in the process of how it is transferred from one party to another. From them, a general classification can be made as follows: *client, appointing party, lead appointed party,* *appointed parties*, *task teams,* as have been established in the ISO19650-1:2018 and recognised by many actors in the industry. These constituents of the *Subject* dimension of the analysis can and will interchange roles as the project progresses and the asset lifecycle evolves. This constitutes one of the principal tensions or contradictions of the analysis given that every party mostly or only considers information that is relevant for their own purposes and not for the interests of the others:

> **Interviewee #5**: "We saw sometimes that the construction company is not interested in that (*description of an element)* and they are not delivering that data because they have no interest in providing that".

This can be considered as the fourth type of tension in the activity system as proposed by Engeström, a tension between different activities, provided that the development of the objects within the model is influenced by designers, who pass on the information to contractors, who will pass on the information back to the client. This situation is really common in projects that are procured under a Design-Bid-Build or a Design-Build Project Delivery Method.

5.1.3 Community

The *Community* in which these O&M activities are developed comprises the Airport Industry. The stakeholders of this *Community* concept involve designers, civil engineers, electrical engineers, mechanical engineers, asset managers, operators, owners, authorities and even passengers, as the final users of the facilities and services offered by the airport industry. It has been noted that there has to be a common agreement regarding the best practices and implementation of BIM methodologies throughout the asset lifecycle:

> **Interviewee #6**: "We noticed that it would be a better benefit if we would have better integrated models".

However, the mentioned agreements do not only refer to the general implementation of BIM. They have to go deeper into the components that comprise it, as the LOD and parameters. On the other side, difficulties arise when dealing with LOD for different purposes as can be design, construction, and asset management:

> **Interviewee #6**: "If you look to the BIMforum.org, you have these LOD100 to 300 is for the design phase. And this LOD300 we use it also to the 500 level for asset management. And that should include spaces, but also objects, but not so much in detail as for example the manufacturer does".

> **Interviewee #6**: "We are still struggling with the assets, because some assets are not decomposed good. We are still struggling with defining that geometry level alignment".

In this case, a contradiction apparently arises because of the peer agreement by the community to use certain LOD for design and asset management but it does not correspond to the level of granularity of the assets present in the models, which in turns presents a conflict with the geometry level of development. In addition, this goes on to the preparation of the personnel involved in the projects. Referring to modellers, most of the times people do not know how to choose what IFC entity to choose when dealing with airport-specific elements. The lack of preparation or knowledge regarding this could impact further into the management of the assets. The reason behind this is that elements can be given any entity during the modelling phase; however, when specific filters are applied to the model, the query may not provide the required information. These small differences of understanding the modelled elements might not represent a problem to the clients, but the contractors and asset managers that are involved in different airport projects will struggle with this. Every airport has a different plan of action to achieve their goals and through the use of certain tools; therefore, approaches to these components is different, but it is worth to consider that owners of these facilities may not only possess one airport which will eventually affect their organisation's operations.

5.1.4 Division of Labour

The Division of Labour refers to the specialisation of subjects by separating their tasks in order to achieve a higher efficiency. Even though this is not possible in a highly dynamic and complex project and environment as an airport entails, it does happen regarding the intervention of the actors involved. Collaboration among the parties is required to ensure all of them are working on the same bases:

> **Interviewee #7**: "I think we still have this silo working, so in their own discipline this works very well, but I think there is no big exchange between disciplines[…] The guy who is operating the business in the end is not involved in the beginning".

The aforementioned situation can lead to a poor communication between parties and a low involvement of them in the project. This is influenced as well by how early are the actors involved, which is not a common practice in relation to the construction industry:

> **Interviewee #7**: "Mostly, the Operator comes in very late. He says 'Ok, I need a lot of information', but he actually does not need this information, but somebody told him to have this information, 'because it is a BIM project, you will have a lot of information'".

Therefore, the expectations about the available data the operators will receive, are not aligned between them and other parties. This turns into other challenges, as how they will use the information in the Asset Management Systems employed or if they will need to retrieve the information from the facilities instead of the models. Furthermore, there is a perception of reluctance from the asset managers to modify their systems:

> **Interviewee #8**: "Contact with Asset Management is really difficult because they have a different way of thinking and a different way of wanting to have data, which makes it pretty hard to adapt the models exactly to what they want".

> **Interviewee #8**: "The Asset Management team did not want to change their systems and that is how they filled-in their systems beforehand. There would be a lot more possible if they would just be a bit more cooperative in the beginning".

This shows that there could be unacknowledged subjects from the asset manager side, given that there is not only one division in charge of the analysis and management of data and of the assets:

> **Interviewee #9**: "You need more than just AM. Within AM we have different teams. There is a team of data people, within there are also different groups, also a System Maintenance team does all the work, Facility Maintenance that we use or our Document Management System. another team that does a lot of the Data Analysis, so the Data Scientists, the Data Group, but also part of the AM is the Objects Specialists for each discipline".

The lack of knowledge of how the AM team is structured and their individual information needs turns into an omission of these requirements in the documentation to be handed in to the contractor. Therefore, this siloed workflow does not fulfil the needs to maintain the assets during the O&M stage; ergo, a close collaboration is needed among all the parties involved in order to actually provide the data required by them in order to perform the design, building, operations and maintenance activities on the airport assets.

5.1.5 Tools

The *tools* used to convey the information and to carry out the O&M activities related to the use of a BIM model go beyond the mere use of software. Asset Management Systems, Computerized Maintenance Management System, BIM authoring tools (i.e. Revit, ArchiCAD), model viewers/checkers (i.e. Navisworks, Solibri), all of these technologies have to be considered as tools in addition to documentation and communication means. Documents available and developed for the timely provision of information and frequent information exchanges between parties is essential because in them, the conditions of how they are to be performed, as well as their quality, are established. The documentation to consider goes as back as Request for Proposals, Technical Bids, Employer's Information Requirements, Contractual documentation, BIM Execution Plan, and the Common Data Environment to be used through the duration of the project. In them, the requisition and description of the assets' information, including the naming conventions to be used during the project, has to be established given that the actors will refer to the aforementioned documentation when modelling and retrieving information from the models, no matter if the intended use is for construction, model review or information extracts for asset maintenance.

> **Interviewee #7**: "[Communication] is crucial. I think the big like of Building Information Modelling is still the missing communication or, let's say, misinterpretation of information. […] Communication is not good in the construction business".

> **Interviewee #10**: "Communication is […] the most important factor. You really need to start explaining to every single part of the organisation that they will be affected by such a change [of working methodology]. You really need to explain them the benefits, show the steps to reach the change and why it is really needed".

As mentioned by both interviewees, communication is a very important tool during the lifecycle of the assets and in general for the construction industry. In addition, the frequency of the communication, regarding the information exchanges and collaboration methods, is also established in the aforementioned documentation tools. Because of this, collaboration procedures described in the BEP provide details about the meetings to be held, roles to be present and the people to reach out for when dealing with a certain issue in the project. However, it is important to define that communication is not only related to the written documentation:

> **Interviewee #9**: "It depends on what you want to communicate. It is a mix of everything. We work agile, so we have demos, meetings, […] we send newsletters. We inform them [stakeholders] about the standards that we are using and the updates that are happening".

Therefore, from the comment made by Interviewee #9, it is inferred that it is not only important to communicate, but also to identify the personnel to which information is to be communicated in order to define the periodicity of it and the means to be used. Maintenance personnel will have different interests in different data and information than managers which, in turn, will be different to what members of administrative board of the organisation will expect.

5.1.6 Rules

Rules to be considered for the development and establishment of the information to be transferred, including its granularity and naming conventions to be used in the project, encompass numerous levels. Due to the nature of infrastructure projects such as airports, the rules to consider and abide can go from local, regional, national, and international legislations to sustainability agreements. Standards, norms, and classifications are to be considered as well both in an industry and in an organisation level because they do not only influence the documentation developed for and to be used through the lifecycle of the assets, but also they have an impact in the delivery of the models of the project, which have to consider regulatory, organisational, asset and project levels, as depicted in Figure 07, presented during the buildingSMART International Virtual Summit (2020):

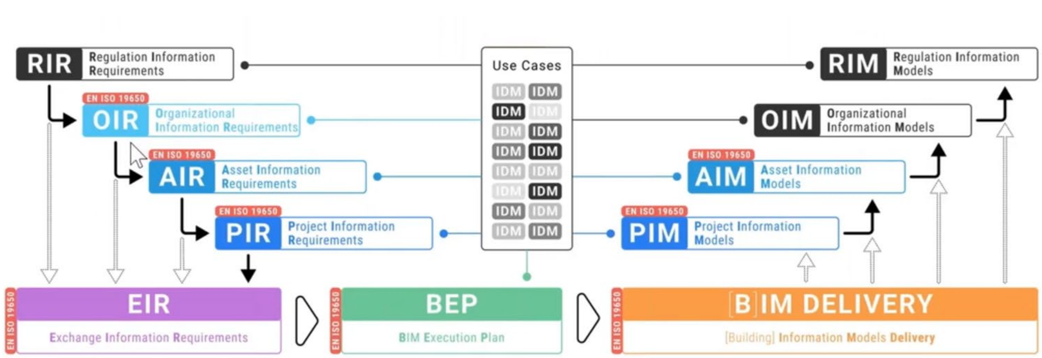

Figure 07 – Supporting Project Delivery, retrieved from Daniaud et al. (2020)

However, it is advisable to work with the latest versions available because they are not defined only because they are identified, for example, as standards:

> **Interviewee #9**: “When we speak about standards, it is not that the standards are totally perfect and they keep on evolving, and they keep fixing things, creating new versions of them”.

Hence, the inherent complexity of the projects increases by the dynamism of being up-to-date with the different standards and regulations that come into play not only for the construction industry but also for aviation regulations. While staying up-to-date might be necessary in an industry level, it is as important to establish the standards and regulations that will govern the project in that level. When considering multi-annual projects, regulations might get updates while still being in a construction or even operational phase which can be controversial when needed to comply with certain standards. For this reason, working with document-established standards and classifications is of the utmost importance, ensuring all the involved parties of the project or that will interact with the asset for Operations and Maintenance purposes, once it is finished, will work and refer to the same elements and items of data and information in the same way, avoiding misinterpretations and naming errors for assets, buildings, spaces, files, models, systems, equipment and elements.

5.2 Contradictions

The Activity Theory diagram unveils the different interactions that exist among the elements that encompass the activity system of retrieving the asset information to perform the maintenance operations. Referring to the aforementioned Activity Theory elements, the following contradictions can be found within the activity system:

- Asset Management Team – Community (*Subject – Community*):
  Once the management task to perform has been defined, the rest of the Asset Team Management is set to retrieve the information from the different models and/or databases in which it is contained. However, the community in which the team members are involved and how they interact between them is as important as the data itself. This type of contradiction within the elements of the activity system can be affected by the experience of the individual subjects involved in the information retrieval and their interaction with other teams and/or actors that may neglect certain operations or information elements given their experience either in the processes or in the industry itself. By omitting data because of the lack of experience of the asset management team members either with the methodology, the technology or the data elements themselves, the intended process of development and retrieval of the necessary attributes becomes compromised, leading to malpractices which derive into not providing the necessary attributes required to perform maintenance activities by the rest of the staff. This reflects into performing surveys to retrieve the required data from every system, asset or equipment to be analysed and maintained, influencing the costs and resources of the operational stage of the different facilities.

- Asset Management Team – Roles (*Subject- Division of Labour*):
The relationship between the team members and the different roles involved can create different tensions in the activity system. These can be divided into two main categories: discipline-related and asset-related. The first one can be identified with the differences between the disciplines directly and indirectly involved in the maintenance activities. The individual subject, especially an unexperienced one, may not be aware of the discipline-related data that should be available for the maintenance activities. An example of this can be when different pipes or electrical conduits run underneath or inside a civil element that is to undergo a major maintenance activity or repair. As for the asset-related tensions, the contradiction itself can be defined with the decomposition level of the assets or systems involved in the maintenance activities. An example of this can relate to the maintenance of a single medium-tension line that serves an asset, an equipment that needs to be repaired or the system that includes both the equipment and the subsequent lines. There might be certain elements within a system that require specific maintenance or procedures in order to allow the system to undergo a maintenance activity, which unexperienced personnel might not be aware of, hence, not providing the whole information required to perform it. Additionally, specific roles and maintenance tasks require different data. An example can be derived from a hydraulic system where the diameter of the pipes could be enough data to prepare the required maintenance tasks. On the other hand, an electrical system might not only require to get to know the wire gauge but also the tension levels of the wire and the equipment served.

- Asset Management Team – Standards and Classifications (*Subject – Rules*):
As mentioned in some of the interviews, it is important that the personnel involved in the project is aware of the standards, classifications, methodologies and/or regulations to be followed during their intervention.

> **Interviewee #3**: "If you want to do BIM (Level 2) correctly, select your people well. They have at least to be familiar with PAS and ISO ".

New personnel or staff that is not used to work with specific standards and/or regulations can affect both the quality of the object delivered (the asset information, in this case) and the processes required for this. While the latter may not directly affect the information itself, compromising the procedures and usage of the tools involved in the asset maintenance can derive into situations where re-work or re-development of the data is required. This leads to unexpected costs, human resources, and time, which in turn, later in the lifecycle of the asset, will affect the efficiency of the Asset Management team when providing maintenance to different assets and/or their components.

- Asset Management Team – Project Documentation (*Subject – Instruments*):
The relationship between the team members and the project documentation can be considered as important as it is with the rules, described previously. The inclusion of team members that are not aware of the complete documentation of the project and/or asset could compromise the development and the retrieval of the information to perform maintenance tasks on them. Mainly, containing the

information within a Common Data Environment of which the personnel is not completely aware of or that they do not completely understand, can prevent the team to perform efficiently the tasks required. Unprepared personnel will not possess the knowledge required to address specific task information needs, recurring to erroneous files leading to mistakes and even not the most up-to-date information available.

- Community – Project Documentation (*Community – Instruments*):
  Actors involvement in the project documentation has a major impact into how the information will be developed and delivered from one to another. Input from all the relevant parties is required to define the stage and final deliverables. However, their expertise goes beyond and is crucial for the definition of specific characteristics of the information. In this sense, different disciplines may require different LODs through the asset lifecycle; asset and system decomposition may differ from discipline and stage as well; formats in which the information is to be delivered may differ from phase to phase; information granularity may differ either between disciplines or between phases. Problems arise when the interested parties are not included or when they are included later in the process than they should; thus, missing insight could affect the development of the information to be handed-in in future stages of the project. Because of this, their input is of the utmost importance when preparing the required project documentation, as the BIM Execution Plan, and the processes followed to require the related information and its delivery.

- Community – Standards and Classifications (*Community – Rules*):
  As the relationship between the actors involved in the project and the documentation used in it is crucial for the development of the information to be produced through the lifecycle of the assets, the agreement on the standards and classifications can be considered of equal or bigger importance. The peer agreement on a national or international classification method and standard to work with is the basis on which the whole team will work through the lifecycle of the project. The decision to use a certain classification system has to follow not only design and construction purposes as most of the times it is elected. The classification system has to serve as the common understanding between the different disciplines and parties involved in the project so every team member can identify what others are referring to, increasing the efficiency of the tasks. Given the lack of a civil infrastructure classification system, organisations across the world use the definitions they consider the most useful for their own interests, leading to discrepancies between airports and limiting the application of knowledge acquired in previous projects and forcing individuals to learn different systems to work with. While this might not present a problem to the operators and the clients, it certainly limits the efficiency of the designers and contractors involved earlier in the assets' lifecycle or even later, in event of a possible refurbishment or expansion. The inclusion of different classifications can ease the transition and referral to the elements between different stages, disciplines and roles.

- Community – Asset Information (*Community – Object*):
  Community actors have different interests and, therefore, different perspectives regarding the information that should be included in the models and the elements within them. Even more, some have opted for having a different approach to the information itself: while some clients or appointing parties may opt for 3D-graphic models, others have decided to go for data models, where the most important element is the information contained and the relationships that can be established with other elements or actors involved in the same project or asset. Considering this, the focus has turned from task-driven to data-driven:

  > **Interviewee #10**: "You could also feel a lot the war between […] multiple worlds where people could not really understand the link of the different department that basically everyone should become more data-driven rather than application-driven".

  Tension arises when two different actors within the airport community have different approaches to the information to be included in the models. On one side, designers and contractors might be more application-driven, considering that their approach is more focused on developing information for the actual construction purposes only, not developing the information for maintenance purposes either because it is not established in the contractual documentation or due to a lack of interest in it:

  > **Interviewee #6**: "We saw sometimes that the construction company is not interested in that (non-graphical properties) and they are not delivering that data because they have no interest in providing that. And sometimes it was also not clear what to fill in".

  Even though attempts to unify approaches have been made, there still exists a dissonance between the object-oriented modelling to the data-driven methodology. The problem between them lies in the fact that the first one is more prone to delay information retrieval and use processes given the high amount of graphical data that is required to process both by the computer and by the user. On the other hand, data-driven processes do not need to work and process the geometry information and allows the user to actually perform a higher number of activities related to data elements than those specifically related to objects.

- Roles – Asset Information (*Division of Labour – Object*):
  While the community actors (architects, designers, engineers, contractors, operators, clients) do have an interpretation of data and information, and what should be included within models, it is not less important to consider the individual information needs for the different roles involved in the asset lifecycle:

  > **Interviewee #10**: "Different specialists need information to ensure what needs to be maintained, when it needs to be maintained, when you need to change it. These requirements are needed for multiple processes. […] Multiple stakeholders need a specific type of information per asset type".

Even though a general definition of what information should be included in the models is necessary for the documentation of the project and further lifecycle stages of the asset, the information required for different roles' tasks differs not only in its granularity but also its composition: either managerial or technical. Therefore, to serve the interests of the personnel, models should not only be defined in the corresponding documentation to be object or data oriented, but also the deliverables have to be defined in terms of granularity, development, classifications, and information required:

> **Interviewee #9**: "The data model that we have created and that we are improving is based on Linked Data […] This technology gives you the possibility to create your data model, but also link it to other data models, other classifications, other standards. We have the connection with the Dutch standard, NL-SfB […] and we have a mapping to the international standard, the IFC standard".

> **Interviewee #10**: "The Data Model has the different objects, different Asset types needed for Maintenance. Every different object can have different characteristics, properties, documents, actors related, relationships with other objects, with particular functions of the organisation, with different locations and room usages".

Considering this, the deliverables, and not only the models, have to be properly defined and detailed in the project's documentation in order to address not only a specific phase information needs, but to cover the whole asset lifecycle as it is depicted in the PAS1192-2 information lifecycle.

5.3 Discussion

Developing a solution that can address the interests of all the actors involved in an asset lifecycle, as well as the individual needs and interests of their team members might not be realistic, but it certainly can be tackled. The proposal is to follow a backwards analysis of what needs to be achieved or what is expected to be done and then, from those general objectives, break down what it is required to achieve them per actor and then per discipline. Considering the Activity Theory diagram, how a maintenance activity is performed can be defined in the following way:

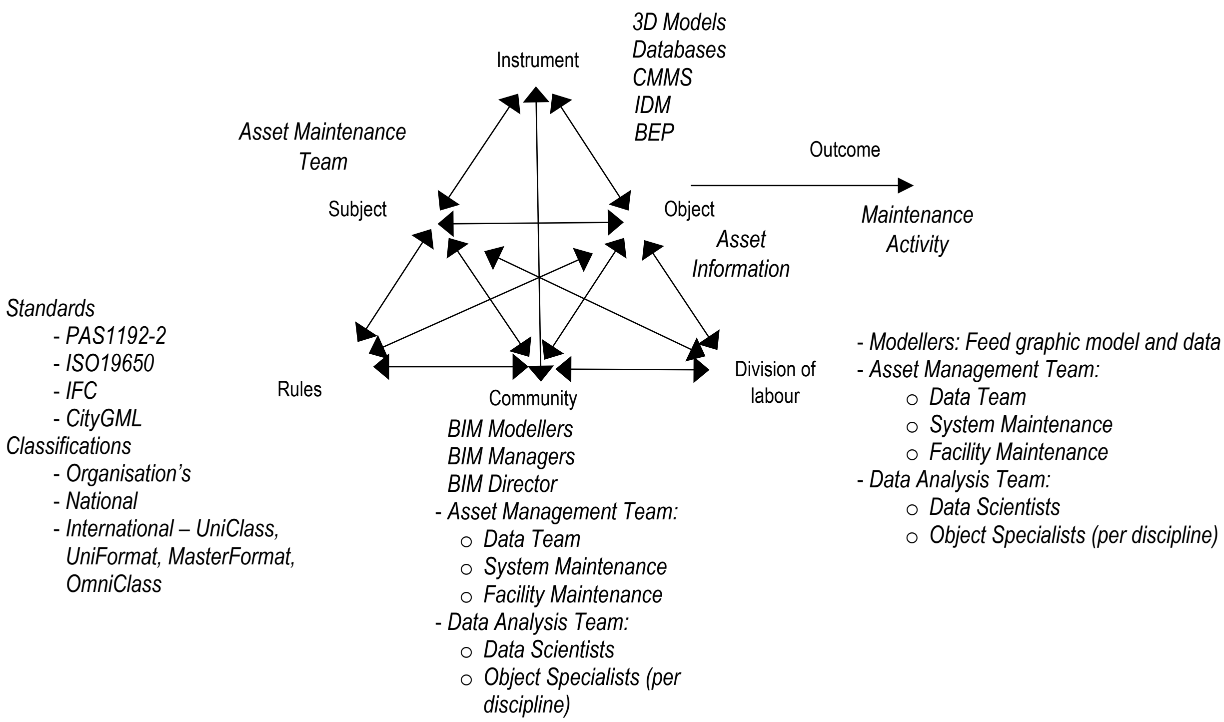

Figure 08 – Action: Maintenance Activity Performance

As shown, the different dimensions comprised in the activity can be described and decomposed thoroughly. The *Object* of the activity is considered to be the *Asset information* as a general concept. The Asset Information to consider and to retrieve in order to perform any desired maintenance activity on the assets of an airport facilities will vary from one system to another and will differ if it relates to a building environment element or to a civil infrastructure one. However, there are individual characteristics from different categories that help not only in the identification of the information but also in their utilisation. In this sense, *data* becomes *information* once the context in which it belongs and the purpose it will serve are established. The following listed attributes are examples of data, that can be used for further asset maintenance purposes:

- Type
- Name
- Classification Code
- Manufacturer
- Guarantee period
- Type number
- ID: UID / GUID
- HTML link

These attributes can provide the required information for an asset maintenance team, as well as for an Asset Manager, to perform the activities (*Outcome*) that were identified in the literature review, such as *Assessment and Monitoring, Documentation, Emergency Management, Energy and Space Management, Maintenance of Service Information and Warranties,* and *Retrofit Planning* of the premises. Additionally, the same attributes can be used to perform tasks as *Asset Surveys, Filling in documents, Key Performance Indicators calculations,* and *Graphic Reports*, aided with pictures of the assets to be intervened and the systems involved. Additionally, these properties and attributes of modelled objects contain basic but enough data for the identification of elements within the model and to determine whether a maintenance activity is required or not and when it should be performed, which can be used in collaboration with a Computerized Maintenance Management System.

Despite this information being available or provided for the O&M lifecycle phase, it is still complicated to determine its usefulness as the level of granularity of the information is closely related to how information is created but, most importantly, handled. A common practice in the construction industry, has been the development of object-oriented models, in which the elements present in them contain or are able to store the attributes aforementioned. However, for the asset Operation and Maintenance phase, Asset Managers (*Subjects)* may consider assets in a different scale than designers and contractors do. While the Asset Management Team can identify an entire lighting system as a sole asset, in many BIM authoring tools every single object is an entity by itself.

Because of the variances in the approach to the elements and their data, the granularity of the information (or the differentiation between groupings and individual objects) of the previously mentioned properties and attributes become more difficult to use and to handle by the different teams involved (either modellers or maintenance staff, differentiation made by the *Division of labour*). So, in order to have only the necessary information of the assets that are present in the models, extracts can be obtained, limiting the asset-related information to only what is needed for their maintenance. These can be provided in different formats and are not the only options for the information exchange to be executed. For example, information can be either shared in an IFC file or even an MVD (being the latter intended for a specific purpose) or any other file type that can provide the required information, such as JSON or XML files.

However, in order for these definitions to be established, the actors involved in the project, part of the AECO industry (*Community*) and more specifically of the branch dedicated to airport facilities. The *Community* cannot be limited to the personnel performing the maintenance activity because they are not the only ones retrieving the information, verifying it on the field, performing the maintenance required, updating the information database, updating the models and communicating the results of the activity, either desired and foreseen or not. Thus, the community comprises the modellers, the BIM managers, the BIM director, the data team, the system(s) maintenance team(s), the facility maintenance team, data scientists, and object specialists of each of the disciplines that are involved or may be affected by the maintenance activities performed.

These personnel must adhere to certain standards and classifications (*Rules*) which determine how an efficient process can be achieved and make the information easier to handle for all the personnel involved. It is worth to notice that not all of Asset Managers, BIM modellers, and contractors are involved only in airport facilities' projects. It is with and within the different *Instruments* used in the project that these definitions and requirements are described and executed. This is the reason why BIM is considered in this research as a socio-technical methodology, due to the strong correlation between the technology solutions used and the human interventions for them to be applied to get the desired results. The implementation of a socio-technical methodology, as BIM is, infers that numerous elements come into play to actually make it useful. The use of instruments is more extensive than in previous stages to include more than the 3D models or databases from which the information is retrieved. The tools considered are not only the BIM authoring tools and corresponding models, but the documentation used to produce them as required in order to fulfil the appointing party's needs.

In this case, the documentation involved includes the BEP, Information Delivery Manuals, and Employer's Information Requirements. It is important to keep in mind that these non-contractual documents are closely related to the contractual documentation between the appointing party and the appointed party. Contractual and non-contractual documentation has to be considered as the means by which the foundations of the models and the processes are established. The documentation plays an important role because in it, the standards, and classifications to be used are described. The latter can consider different purposes and levels as can be an organisation's classification, a national classification, or an international classification method.

Additionally, the *division of labour* is vaster than in previous activities (as shown in Figure 09 below) given that this action includes the modellers, who integrate the geometry and data into the models; the data team, who can retrieve and check the quality of the data contained in the models; the facility maintenance team, identifying the maintenance activities to be performed; the system maintenance team, verifying the system's components during the inspections and determining which require maintenance activities performed, cross-referencing the data retrieve from the model with the on-site situation.

Because of the aforementioned relationships between the different dimensions of the analysed maintenance activity, it is necessary to step back in the timeline. Before the maintenance activity can be executed, it is necessary to determine, through a regular inspection of the assets, what action is required to take toward an asset, whether to perform *preventive maintenance,* to *repair* the asset or to *replace* it. Figure 09 establishes the involved dimensions for this action to happen:

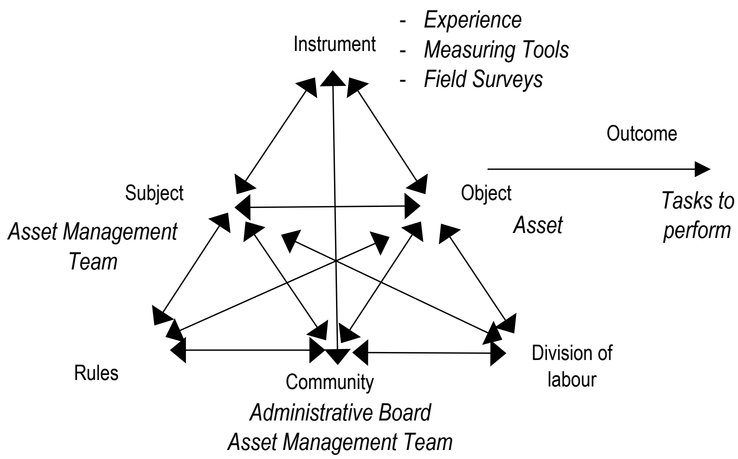

Figure 09 – Action: Regular Inspection

As shown in Figure 09, the *Object* of the activity in this case is the Asset itself, for which the definition of the required maintenance activity is the *Outcome* of the activity. In addition, the *Subject* is still considered the Asset Management Team, specifically the maintenance staff, given that their members perform the inspection on the assets to determine what action is required on them. The *Instruments'* dimension changes from the BIM models, databases, documentation, and CMMS to the measuring tools used for the inspections, the filled-in surveys to keep track of the status of the assets, and the experience of the personnel involved in the inspection. Maintenance tasks to be performed in the civil infrastructure elements within an airport, derived from these inspections, can be added to the ones described previously based on the literature review performed in Chapter 3. These can include but not limit to:

- Regular inspections
- Minor repairs (in roads, runways, and taxiways)
    - Joint re-sealing
    - Crack stopping
    - Removal of rubber deposits
- Periodic renewal of top pavement layer (for roads, runways, and taxiways)
- Pavement lifting
- Soil stabilisation

However, the needs to maintain the assets in an operational status and functioning adequately are established before these regular inspection activities take place. This takes the analysis to a previous step in the definition of what is required to perform and to comply with, which can be identified in the Figure 10 shown below:

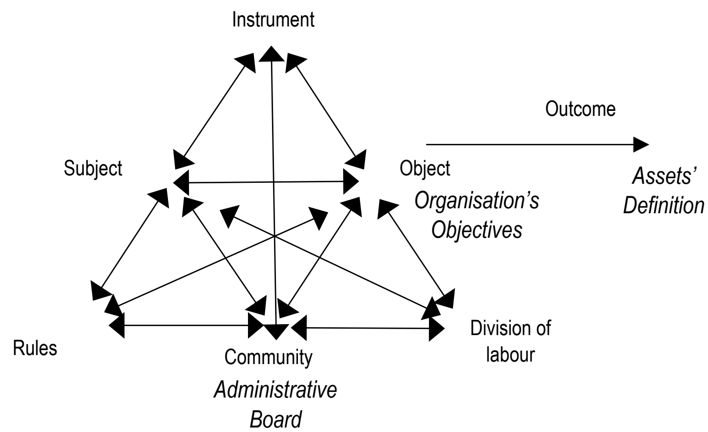

Figure 10 – Action: Establishing the Assets' Definitions

At this level, in a generic setting, the Administrative Board decides what actions to take in order to fulfil the organisation's objectives. In this case, they refer to the definition of the assets' needs in order to perform what is required to successfully meet those objectives. Specifically to this case, assets can refer not only to the passenger terminal building, but also to the control tower, parking spaces, land, runways, and taxiways. In this level of action, the object to which the activities are directed are the facilities *as part* of the organisation's objectives. In turn, the outcome of the activity will be the definition of the assets required to fulfil those objectives, making it the reason for the other elements to be considered as above mentioned. It is this level the one that determines further down the road what has to be done in order to comply with the appointing party's requirements, but it should be also the level that must consider the inclusion of an Asset Management team or consultant in order to establish, in conjunction with the appointing party's representatives, the correct assets to be defined and how these operational and maintenance needs are going to be placed in the documentation to be used for the subsequent levels. This will derive in the description of the Employer's Information Requirements, which will direct how the BEP will be defined before the contract award and how it will be specified after this has taken place.

Infrastructure, in combination with other transportation means, is also to be considered as can be taxi bays, metro, bus, and/or train stations but it is to be noted that these relationships also involve a higher level of organisation, integration and coordination in which other parties are involved; thus, this last level is not to be analysed for this research project.

5.4 Chapter Conclusions

In order to develop a BIM model that is adequate to perform any desired activities with it, those activities have to be determined first. A main differentiator that can be identified is whether the BIM is intended to be used for the Project phase only (Project Information Model) or for the O&M phase (Asset Information Model).

This derives into different applications of the information available, which can range from 2D documentation production, 3D design, disciplines coordination, clash control, visualizations, presentations, 4D simulations and VR simulations for future users and stakeholders of the premises. These intended or desired uses must be mentioned in the administrative documentation related to the model to ensure they are developed and that the model is fit-for-purpose once it is handed over back to the appointing party. As a general rule, the more specific the intended uses of the BIM model, the more specific the description of its characteristics should be. However, most of the appointing parties are not familiar with the potential of the use of a BIM model for their projects and do not have the necessary knowledge related to them, to properly describe what they require and what they are expecting the appointed parties to develop.

When the appointing party is not familiar with the product nor the methodology used to develop it, the request to the appointed party could turn into an advantage or a disadvantage. The first one can be related to the ability of the appointed party to steer the development of the model towards what that party already knows, avoiding undesired learning curves when delving into a different area that is not one of their strengths or expertise. This will turn into an efficient development of the model if the information exchanges are carried out as planned by both parties, impacting both the human and the financial resources that the appointed party will determine to the project. On the contrary, this can be an enormous disadvantage for the development of the model, resulting in misunderstandings of the capabilities of the appointed party and the expectations of the appointing party, which, in turn, can become causal of numerous claims throughout the project development. Ultimately, this could derive in providing not only something that is not fit-for-purpose for the appointing party but something that could be considered not useful at all by the operator of the facilities and the asset manager.

The uses of the BIM model, defined in the documentation of the project, most likely will determine the extracts with which the operator and asset manager will work due to their relationship with geometry and graphical specifications of the elements modelled. For these characteristics to be assured, it is necessary to establish the quality of the models at each milestone throughout the project realisation. These become even more relevant when the information is to be shared not only between different appointed parties (namely contractors) during the project stage, but also with parties involved later in the asset lifecycle (i.e. the operator and asset manager). Thus, an agreement on which naming conventions to be used for elements or assets, levels, spaces, groupings, models, files, and systems for future tasks and common knowledge among the project parties and within the organisation is essential. A hierarchy has to be defined for these elements and systems to be present in the model; therefore, input from the different disciplines will be required.

As mentioned before, these specifications have to be written down in the documentation of the project. Lack of experience and familiarity with the BIM methodology can reflect into the level of detail of those specifications and requirements from the appointing party to the appointed party, through the Employer's Information Requirements. In turn, the appointed party can influence those not so detailed requirements within the pre-contract award BIM Execution Plan to ensure the methodology will be carried out correctly, or at least as intended for the desired purposes. Since the BEP is a living document, changes on it are expected not only after the contract is awarded to the appointed party, but also through the project lifecycle, after the defined milestones. It has to be updated to ensure the content is aligned to the purpose of the current stage and to ensure the deliverables will be what the appointing party is expecting from the appointed party. These expectations must consider the design, construction and operation phases. Even though this is a general approach, differences between the projects can be found considering that appointing parties could intend to use differently the BIM model, the interests in following the BIM methodology can differ from organisation to organisation, the appointing party's knowledge can vary (depending on how often they take-out projects with it involved and when they carried out the last of them), awareness and understanding that, to facilitate information transfer between parties and phases, interoperability of software and integration of activities is eased by the use of agreed naming conventions for elements and their properties, available in the model.

Considering not only the high amount of information that is developed in a project, but also the requirements that have to be fulfilled, communication becomes a cornerstone. However, communication does not only refer to meetings, virtual meetings and emails. Any type of information and/or knowledge transfer has to be considered and their means, become the *tools* by which the information is conveyed: documentation (RFP, EIR, , RFI, BEP, IDM), submittals, transmittals, 2D documentation, 3D models, data extracts, MVD, meetings, workshops, newsletters. Through this continuous collaboration with the corresponding parties, *division of labour* as an ideology, is eliminated. The central thought becomes to provide the best product/service per discipline and appointed party, without the siloed thinking that limits interaction between parties until the finished product (asset information) is to be shared.

So, how to provide a solution that considers the information to be shared, involving the corresponding parties in a timely manner to efficiently perform maintenance activities in civil infrastructure elements within an airport's facilities? The following chapter describes a proposal of a process map, developed by integrating the perspectives of the different interviewees of this research study, in an attempt to comply with the regulations that govern in the corresponding construction industry. The challenge to integrate all the perspectives resides in the complex environment that comprises an airport physically, and with the project's structure: different stakeholders, roles, asset types are involved, as described in the Activity Theory analysis; therefore, a general definition of the information requirements is not enough. Information composition is related to the granularity and the orientation required, considering the approach that the final user will take towards that information.

Chapter 6 – Process Map Design

Chapter Introduction

The following chapter describes the process followed to develop the proposed process map to address the challenges faced by practitioners from different perspectives, as identified in the contradictions analysed in the previous chapter. First, the approach to the solution is described briefly, followed by a description of the steps for the creation of the process map itself. The information lifecycle is considered as the baseline for the development of the process map and, as a complement, Figure 12 provides a basis for the differentiation of information needs depending not only on their use, but also the final users of the information. The subsequent sub-section refers to the identification of the different stages that are affected and the actions to take to ensure the information for O&M purposes of civil infrastructure elements in airports is provided as complete as possible in a timely manner. Then, the activities to be performed and actions to be taken in each of the described stages are presented, as well as the actions required to manage to get them included into the process map. From them, it is possible to summarize the responsibilities and the actors involved in the development and addition of those information requirements. Derived from the presented process map, the next chapter describes thoroughly the conclusions and recommendations for the application of the former.

6.1 Process Map Approach

In order to conciliate the findings of the different sections (theoretical background, data collection, and the theoretical lens data analysis) of this research project, into an element that can be used for further reference and application in the industry, a process map is proposed. The achievement of the integration of the information needs for Operations and Maintenance activities will be easier if an already existing framework is considered as a reference. Thereby, the *Information Lifecycle* diagram of the PAS1192-2:2013 has been selected. The reasons are the familiarity of practitioners, its completeness in relation to the whole lifecycle of an asset and that it served as a basis for ISO19650, so the resulting process map can be implemented, scaled and extended according to the available standards. Additionally, the utility of a process map resides in the ease of its applicability as well as the identification of the elements involved, the steps to follow, the input required, and the output expected from the process for which it is designed.

6.2 Process Description

As the starting point for the development of the process map, the semi-structured interviews responses and their correspondent Activity Theory analysis are considered. From them, it is derived that some of the main challenges for the integration of the Operations and Maintenance phase into the design stages of the AEC industry are the lack of information of the objects modelled or that the available information is not useful enough to actually be utilised during the O&M stage of the assets. To understand this, the following diagram has been developed to identify the process and documentation through which the information has to pass to ensure the correct and necessary information is available to use it for O&M purposes for civil infrastructure elements in an airport facility. Figure 11 depicts the general process that information follows, starting from the appointing party's (client) organisation needs, until it is delivered back from the appointed party (contractor) after the design and construction processes to enter the O&M asset lifecycle stage:

Figure 11 – Information lifecycle as a streamline

However, there still persists the need to connect the last link of the lifecycle with the first one, as it is depicted in the PAS1192-2. Having this in mind, the process to follow to ensure that the information is indeed delivered as requested is not exclusively related to the aforementioned *Information Production & Delivery* step of the information lifecycle. It goes back to steps where even the contract is not awarded yet, as was established in the *Discussion* section of the previous chapter. The starting point to consider are the organisation's goals which, in turn, will determine the organisation's needs (see Figure 10 and Figure 09). It is therefore of the utmost importance to identify that the organisation's goals and needs will influence the information needs of the team involved in the project delivery. To accomplish those goals, different levels of information and interests of the varied team members involved have to be considered, as described by the diagram of Re Cecconi et al. (2017, p. 2):

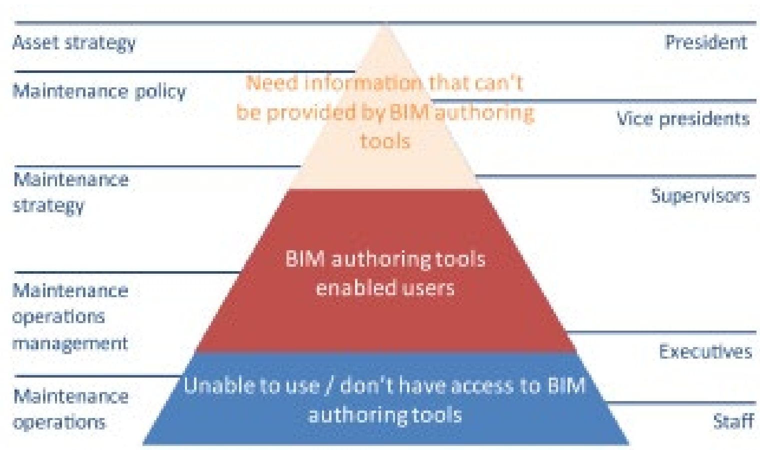

Figure 12 – Information uses and users versus building information modeling in asset management, retrieved from Re Cecconi et al. (2017)

Referring to the diagram above, for maintenance operations and their management, the practitioners involved, namely staff and their managers, do not necessarily have access to BIM authoring tools (as the happens with the staff), so their managers have to make sure their teams do get the necessary information to perform their activities. Thus, this process is intended to address the information needs of those members of staff and management teams, which are more specific than other managerial levels would require.

6.3 Steps Identification

For the process to be completely defined, it is necessary to determine the different stages that are to be achieved and, in this case, the documentation involved into the development of the required information and transfer to the appointed party once the design and build phases have been completed. Figure 11 depicts the following stages and documentation that are considered to have a major influence in these processes:

- Asset Assessment: This stage is developed to determine what are the asset needs of the organisation in order to satisfy their goals. The outcome of this stage can be determined by the assessment of an existing asset which may enter a process of maintenance, refurbishment, end of life or building. In case it is determined that there is a need to create or improve an asset of the facilities, the following stage entered is the definition of the Employer's Information Requirements.

- Employer's Information Requirements: The definition of the EIRs is the basis on which the project is going to be developed and on which the selection of the contractor(s) that will carry it out will be defined. The EIRs are structured considering the information management, the commercial management and the competence management, as described in PAS1192-2:2013. These three sections have important influence in the BIM models to be developed for which certain considerations have to be added. These are described in the following sub-section.

- Procurement: The services procurement stage is to be considered as important as the other stages along the information lifecycle. Even though this is more an operation than an actual stage, it marks the differentiation between the EIRs and the BIM Execution Plan (BEP). In other words, this step is determining what the appointing party is communicating it wants and expects to receive by the end of the project and what the appointed party understood and is capable to develop to fulfil those needs of the former.

- Pre-contract award BEP: This document is the first of a series of BEPs to be developed throughout the project. This first one BEP considers the goals and milestones of the project, the project information model deliverable strategy and the project implementation one. The latter is to be considered as a crucial item given that it provides the appointed party the opportunity to express their concerns regarding the different gateways through which the information passes through within the Common Data Environment (CDE) throughout the project lifecycle, specifically for those related to the Work in progress (WIP) statuses when they turn into Shared ones. This will help define both characteristics and attributes of the elements modelled as well as increase the responsibilities for the contractor.

- Contract award: As the Procurement stage, this milestone during the project lifecycle is of great relevance. Even though the BEP can still and should be updated, the pre-contract award one is going to set the boundaries and limits to which the BIM implementation can be taken. Post-contract award BEPs should be considered only as an improvement of the previous version in order to adequate the requisitions to the current phase of the project.

- Post-contract award BEP: The document is defined by the inclusion of the previous stated elements of the EIRs, the previous BEP developed and improvement and further specification of sections that include the management of the project, the planning and documentation, the method and procedures, and the IT solutions for the project. These four sections are to be improved in order to include the desired information for O&M purposes in order to make it available by the finalisation of the project and its handover for this phase commencement.

- Mobilization: This stage is characterised by the appointed party performing all the necessary actions in order to ensure that the CDE, the software and versions selected, and the personnel are able to perform their intended actions up to the quality stated in the BEP and in a (desirable) flawless process. Any inconveniences and possible troubles with these technological and preparation elements should be addressed preferably before commencing the data production, avoiding unnecessary re-work or transfer problems.

- Information Production and Delivery: While requirements are established before the commencement of the actual project, it is necessary to watch their compliance throughout the duration of the project. This is to ensure that what was already established in the corresponding documentation, which aims to fulfil the information needs not only for design and construction processes, but also the O&M information needs since the design stage, is done correctly. This includes processes of QA/QC along the project lifecycle. These go back to the gateways mentioned in the pre-contract award BEP.

- AIM for Asset Operation and Maintenance: Any particular information that is to be requested for these purposes that goes beyond conventional scope has to be mentioned and agreed priorly in the project documentation to ensure the necessary information is transferred correctly during the handover process from the appointed party back to the appointing party.

6.4 Road Map

The aforementioned stages and documents include different sections and actions to be addressed to ensure the process is fit-for-purpose to the appointing party's goals. The following documentation and steps are considered as the most important to undertake actions to successfully intervene the already established process in order to ensure the final users will get the information they require:

- Employer's Information Requirements (*Appointing party)*
- Pre-contract award BEP (*Appointed party)*
    - Project Implementation Plan (*BIM Manager*)
- Post-contract award BEP (*Appointed Party)*
    - Task Information Delivery Plan
    - Master Information Delivery Plan
    - Standard Method and Procedure
    - IT solutions
- Mobilization
- Information Production and Delivery

6.5 Responsibility Matrix

Considering the actions of the previous *Activities Description* sub-section, the following matrix has been developed in order to allocate the actions to be performed:

ACTIVITIES	**Appointing Party**			**Appointed Party**			
	Administrative Board	Asset Manager	BIM Manager	Project Manager	BIM Director	BIM Manager	Asset Task Manager
EIRs							
Information Management Definition		**X**	**X**				
Commercial Management Definition	**X**						
Competence Assessment Definition		**X**					
Pre-contract award BEP							
G1: WIP-Shared						**X**	

G4: WIP-Shared					X		
G5: Shared - Accepted					X		
Post-contract award BEP							
TIDP						X	
MIDP					X		
SMP						X	X
IT Solutions						X	X
Mobilization							
Training & Education				X	X		
Information Production & Delivery							
Design level of model definition						X	
Build & Commissioning level of model definition						X	X
Handover & Closeout level of model definition					X		
Operation & In-Use level of model definition		X	X				

Table 05 – O&M Information Addition Responsibility Matrix

NOTE: The actions to be undertaken that have more than one responsible actor refer to those that require collaboration because of the different approaches to be considered.

6.6 Process Map Design

Considering the Responsibility Matrix presented in Table 05 of the previous sub-section, and the documentation and steps to be intervened, the process map for integrating the O&M information needs from the design stage, can be defined as follows in this sub-section.

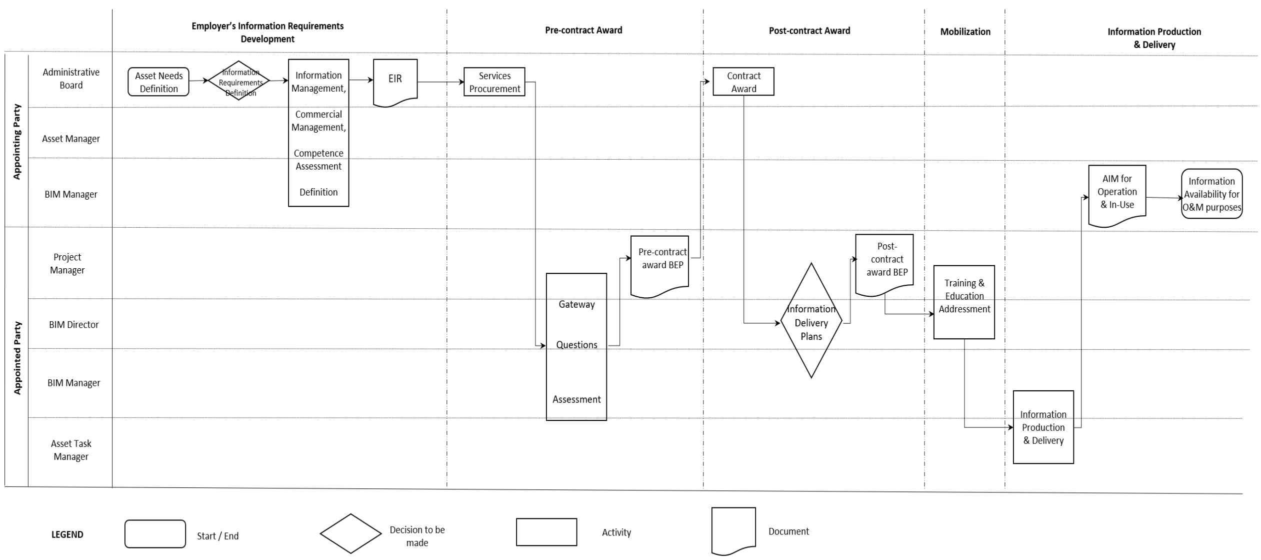

Figure 13 – Information Availability for O&M Purposes Process Map

The general process to develop the information that is required for handover and to fulfil O&M needs can be identified in Figure 13 shown above. However, as described in the *Discussion* section of the previous chapter, a late intervention of the Asset Management personnel in the process has a strong influence in the final result given that their information needs tend not to be covered by the handed over information package. To address this, and based on the analysis performed, the intervention in the process has to be addressed from the beginning of the information lifecycle. For this, the first stage considered is the Asset Assessment given that from this step, a determination towards a certain asset will be taken. Either if the decision made is to build a new asset or to provide maintenance to the existing one, the needs to be fulfilled by the asset are going to be established in the EIR.

The EIR is clearly defined in the PAS1192-2; however, the following interventions are considered to be able to establish the bases on which O&M information will be produced. First, regarding the information management, the levels of detail of the information required have to be established. For this, a clearly defined list of requirements for information submission at defined project stages that are aligned with the *Levels of model definition* is desired but an assessment from an Asset Manager of the appointing party is suggested in order to define the information needs for those stages, which in turn should be based on the data team, the system maintenance team and the facility maintenance team of the appointing party.

Additionally, the Asset Manager should define the training that the personnel requires in case of usage of any specific software or tools during the information production or for the information extraction interoperability. The interoperability between BIM authoring tools and the instruments used in site both for input and update of databases with information or attributes of the assets, or the input and update of models used for operations and maintenance purposes. In case any specific training is required, the appointing party's team can offer it in order to reduce times and, in conjunction, obtain the desired information output in an efficient way. Regarding the planning of the work and data segregation, any specific consideration for the naming conventions has to be mentioned so the future appointed party can prepare both the models and the documentation accordingly. As a complement, the Asset Manager must assess if there is any specific information to be included in the models that will be received from the appointed party and if any specific standard is to be followed, as ISO19650.

The particular constraints for models must address those elements and situations that can reduce drastically the performance of the teams viewing, editing, updating and retrieving the information from the models. In this case, practitioners have identified that files from BIM authoring tools should not exceed more than 1GB of size and that asset build-ups should not be larger than 2MB. Any constraints related to the Asset Management software to be used have to be included here as well, whether it is Maximo, a Data Configuration Management System or a Computerized Maintenance Management System. The Asset Manager should define these with the staff involved. It is also necessary to consider if any particular software file format is to be excluded from the ones available, for which interoperability, data to be transmitted, how and what information is read, and what is fed to handheld devices or printed formats for surveys and regular inspections. These actions can be summarized in the following figure:

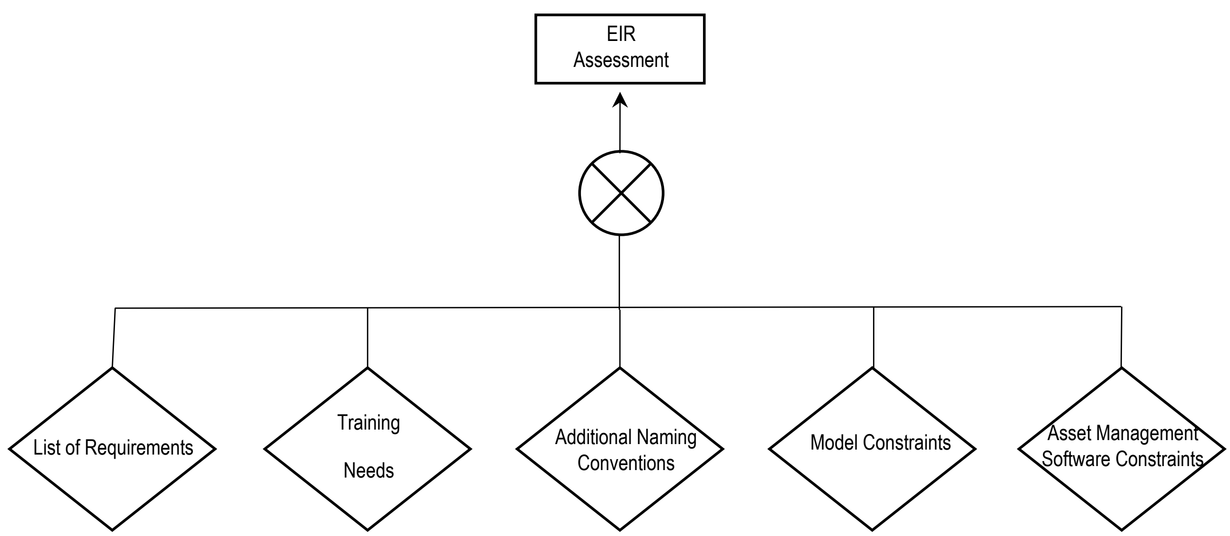

Figure 14 – EIR's Information Management Assessment

For the commercial management section, it must be considered for the responsibility matrix that there has to be a coordination between the BIM manager and the Specifications leader in order to include the correct information about the model assets, equipment, and/or systems as desired and/or decomposed as needed.

As for the competence assessment, the appointing party and asset manager should determine what qualifications or experience is required to gather the necessary information for O&M, include it in a timely manner into the model and extract it adequately to share with the intended actors or team members. These interventions can be identified in the following figure:

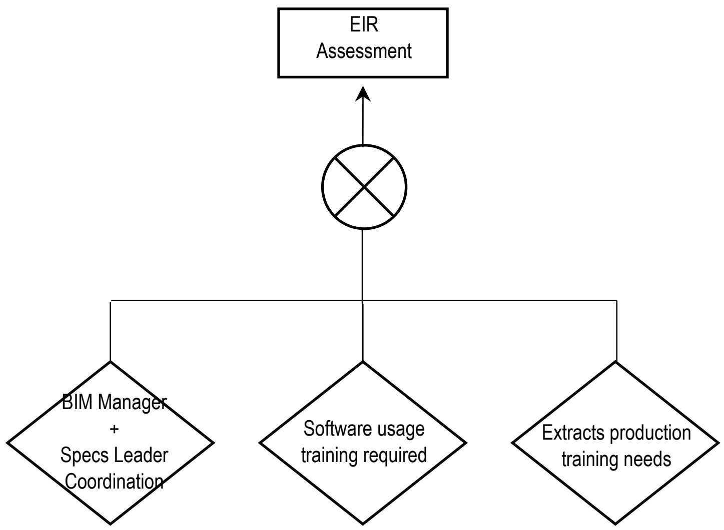

Figure 15 – EIR's Commercial Management & Competence Assessment

Once the EIR documentation is prepared, the Pre-contract award BEP is the next documentation to be edited. In this case, the actions taken must be to address the Project Implementation Plan. These are related to the supplier's building information management assessment and specifically in relation to the Common Data Environment Gateways that the information has to pass in order to be distributed from the main appointed party to the appointing party and from other (sub-)appointed parties to the main appointed party and back to the appointing party once it has to be handed over. The actions must take place in three different gates. In the first, the technical content to be assessed has to include the properties and attributes to be included in the models. As for the standard method procedure, it is required to determine the information characteristics in order to establish how the information is to be named, expressed, referenced and shared. Both imply an added responsibility to the main contractor and designer, who have to request this details to the appointing party. For the second gate to be addressed (the fourth), the information to be checked, reviewed and approved for design compliance must include the information for O&M, which will add another responsibility to the main contractor, who has to ensure this information is present even though it will not be used by the main contractor. As for the final gateway to consider (the fifth), the information to be verified and validated for the AIM has to be based on what was included, checked, reviewed and approved by the main contractor (or appointed party) in the previous gateway. These actions are intended to address the contradiction identified between the division of labour and the object of the study (team members and asset information) and between the object of the study and the instruments (asset information, and documentation and models).

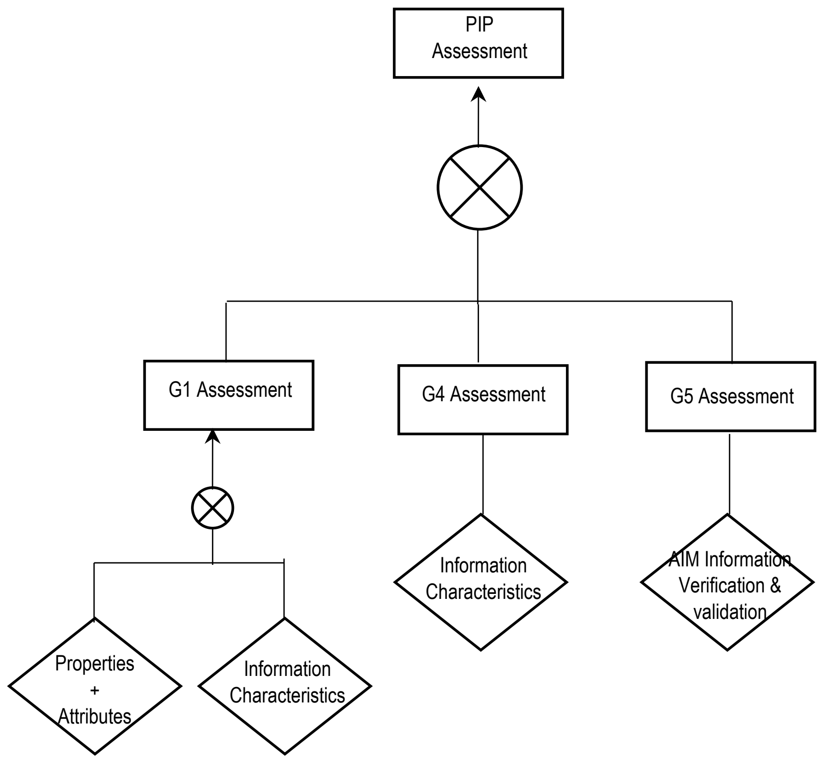

Figure 16 – Pre-contract award BEP's CDE Gateways Assessment

The post-contract award BEP will also be modified. The actions to be taken include the extension of the task information delivery plan (TIDP), the master information delivery plan (MIDP), the standard method and procedure and the management information (related to the roles and responsibilities). The TIDP is addressed by including another task devoted specifically to the inclusion of the O&M database information preparation. This is to be based on the requested properties and attributes correspondent to the aforementioned Project Implementation Plan. It is necessary to determine a responsible for this information. Additionally, the milestones defined will determine which level of model definition will mark the extraction or separation of the data for O&M and construction purposes, given that for the former, an extensive graphical definition is not required. A different team member has to be appointed to carry out the gathering of the aforementioned information in order to keep the model(s) updated accordingly to the model definition that is to be delivered on each milestone.

The Master Information Delivery Plan, in turn, has to consider the inclusion of a topic for the induction meeting agenda: the training needed for modellers, BIM managers and specifications teams toward Asset Management information that has to be described. This includes the elements and systems to be included, the software to be used, the specifications of the elements and the corresponding attributes, as well as the information extracts for information sharing with other actors and the appointing party. In addition, the deliverables have to be verified in order to include equipment schedules, room data sheets and other required specifications or data for the O&M stage.

The section corresponding to the standard method and procedure is the one which may not have the most changes, but the inclusion of the information described can provide the developed models a huge difference in comparison to those only intended to construction purposes. The volume strategy should not only follow considerations regarding the structural elements, but also those that correspond to assets' or even systems decomposition, depending on how important their elements are for the correct operation of the assets once they are in use. Additionally, it is suggested that the naming conventions should include levels, systems, buildings and assets in order to facilitate the development and identification of specific documentation during the *Information Production* stage.

Afterwards, the attributes data is to be extended to include those fields that the Asset Management team is more interested in. These include (but may not limit to):

- Installation dates
- Supplier info
- Manufacturer
- Warranties
- Height / Size
- Function
- Performance
- Specifications
- Elements related
- Systems related
- Assets related
- Surrounding elements
- Surrounding systems
- Surrounding assets
- Functions related
- Classifications for O&M (These are considered within the PAS1192-2, but others can be implemented as long as they are present in the modelled elements' attributes):
    - Installation information
    - In-use design information
    - Maintenance cost information

Lastly, within this step, the IT solutions have to be verified to include the exchange formats that are required for O&M, such as IFC, SPF, XML, JSON, CityGML, SQUL, ODB, NSF, WMDE. As a complement, the process and data management systems have to be extended to include those corresponding to Computerised Maintenance Management Systems, and Data Configuration Management Systems in addition to the Construction Management Software to be used.

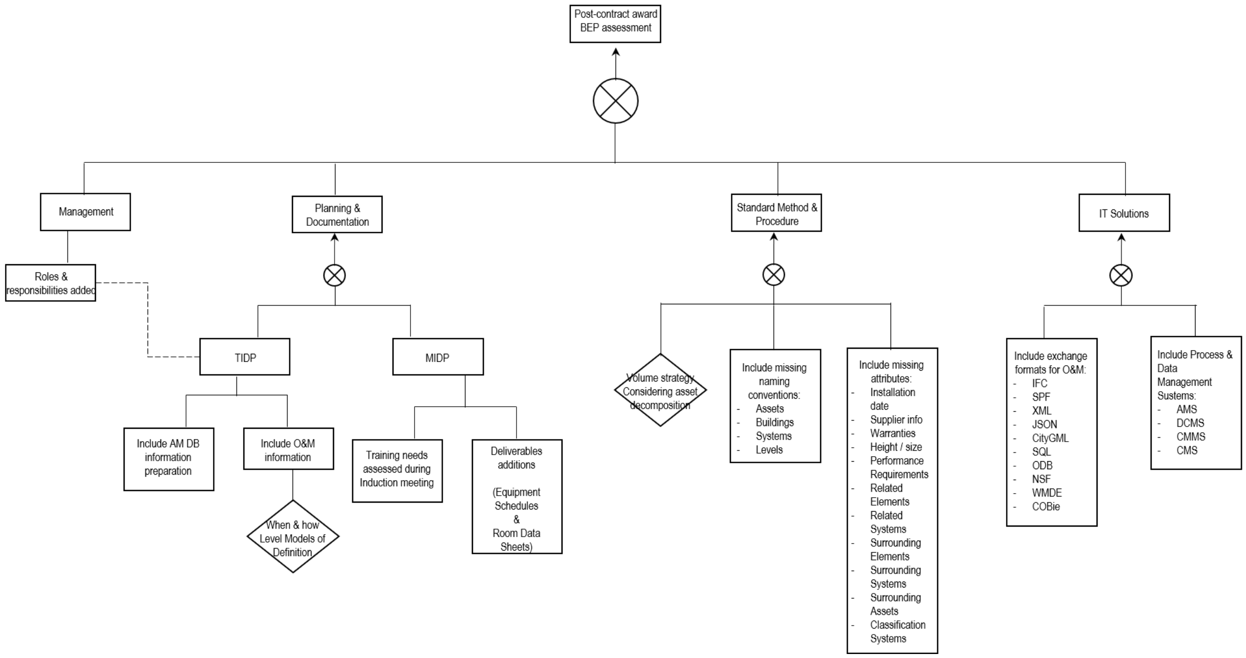

Figure 17 – Post-contract award BEP Assessment

The mobilization stage remains the same; however, the appointed party must make sure that their team has all the appropriate skills and competencies not only to operate the software, use the standards agreed, and apply the corresponding classifications. It is necessary to also ensure that the team is capable of producing the information extracts with the desired format and data contained in them.

The Information Production and Delivery stage will be influenced by the previously described actions within the process. The Common Data Environment exchanges of information are to be improved with the assessment of the Project Implementation Plan of the pre-contract award BEP and the actions taken for the different gateways to include the information required for O&M and its verification and approval before it is transmitted back to the appointing party. During this stage is when the decisions made in the documentation for the information production will be reflected in the model, making it the most important of the whole process. It is also a decisive point regarding the differentiation of the Project Information Model, used for design and construction stages, and the Asset Information Model, which is intended for Operation and In-use.

Even though the PAS1192-2 considers a differentiation of the PIM and the AIM once the PIM is handed over back to the appointing party, the information required by the Asset Management staff to perform their intended activities can be retrieved once the Design stage has been finalised. From then on, the attributes that were included or that were extended for the modelled elements only have to be verified. As mentioned before, the milestones that are defined in the TIDP should not only be aligned to the design and construction programmes, but also to the different Levels of Model Definition. It is with the latter with which the extraction of the information for O&M purposes must be done and it can be available between the *Design* stage, and the *Build and Commission* stage. From that point, the model improvements should only be in graphical terms for coordination purposes (as intended for the Construction phase) and the non-graphical information included can be constantly verified and updated in case it is needed in terms of positioning or elements related. If there is a case in which the modelled element changes, the modifications are to be coordinated with the specifications team and the design team, which in turn must coordinate that with the other disciplines involved, including the modelling team(s). Considering the aforementioned and described actions, the interventions in the process result in the following figure:

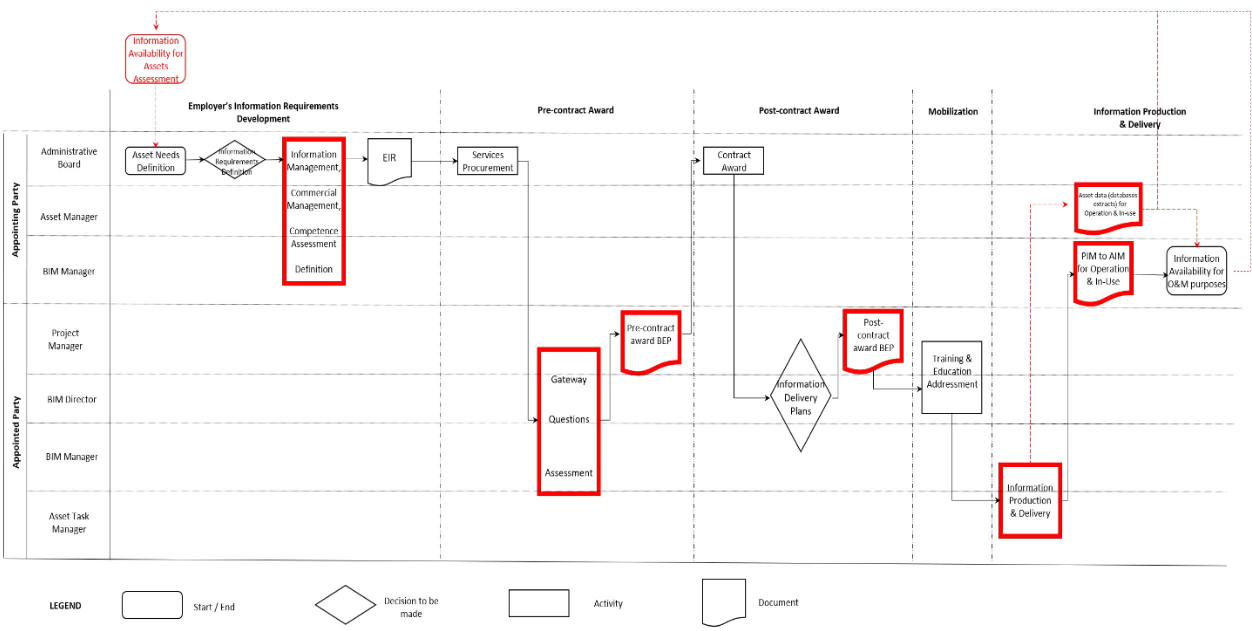

Figure 18 – Proposed Information Availability for O&M Purposes Process Map

6.7 Chapter Conclusions

The suggested process map is derived from a series of identified missing attributes, properties and actions throughout the current lifecycle practices. The main idea behind it is not only to provide the information required for O&M purposes in civil infrastructure elements within airport facilities, but to foster the integration and the development of the missing information related to these activities. The missing attributes and properties have been included within the process of design via their implementation in the assessment and definition of the documentation that defines the modelling processes. Thus, the inclusion of the required data has been addressed and can be followed through the whole information lifecycle. Because of previously mentioned relationships and interactions between elements and their surroundings, it was considered not only to include data related to the element addressed, but to include data of those other elements and systems to which it is related or by which it is surrounded. This consideration comes from the consideration that when a civil infrastructure element undergoes any maintenance activity, the immediate context is most likely to be intervened as well, thus the inclusion of these other systems and their data.

Chapter 7 – Conclusions & Recommendations

7.1 Main Conclusions

Building information models are tools that have been used for design and construction purposes since the technology dedicated to their authorship was developed. Because of this and that the personnel that is in constant interaction with the models during the first stages of an asset lifecycle is mainly 3-dimensionally oriented (designers, architects, engineers, contractors), these tools have not been fully exploited after the handover and closeout of projects. In fact, this 3D orientation has prevented the O&M industry to adopt the BIM models into their practices because they do not see them as useful as their methods and not very compatible with the systems they use for their activities.

The aforementioned is related to the fact that personnel and staff that is in charge of asset maintenance and their operations is not familiar with the BIM authoring tools, limiting even more the acceptance of the models. Because of these reasons, building information models were not a common practice for O&M. However, they do have a lot of potential and they have been used to support different activities during the Operation stage of assets. These answer the fourth sub-research question and can include *Assessment and Monitoring, Documentation, Emergency Management, Energy and Space Management, Maintenance of Service Information and Warranties,* and *Retrofit Planning* of the premises. Additionally, the same attributes can be used to perform tasks as *Asset Surveys, Filling in documents, Key Performance Indicators calculations,* and *Graphic Reports*, aided with pictures of the assets to be intervened and the systems involved. Additionally, within airport premises, these can also be extended to include not only *regular inspections*, but also *minor repairs* in roads, runways, and taxiways (such as *joint re-sealing, crack stopping*, and *removal of rubber deposits*), *periodic renewal of top pavement layers* (for roads, runways, and taxiways), *pavement lifting* and *soil stabilisation*.

All these activities have a context in which they are developed, which was identified in the Chapter 5, answering the third sub-research question. This is comprised of six different dimensions that produce an outcome, namely: Community, Subject, Rules, Tools, Division of Labour and the Object of the activity itself. These encompass different elements that influence the development of the maintenance activities carried out in an airport facility. This means that not only the directly involved personnel are the ones responsible for the activities. Because of the complex dynamic nature of an infrastructure project such as an airport, the activities include the system maintenance team, the facility maintenance team, the data analysis team, the BIM modellers, BIM managers, BIM director, standards followed (as PAS or ISO), classifications used (which can range from an organisational to an international level), tools used to perform the activities (such as 3D models, databases, configuration management systems, computerised maintenance management systems, but also documentation as the BIM Execution Plan, the Information Delivery Manual and the Employer's Information Requirements), and the subject that actually performs the activities. However, these dimensions are determined by previous activities as the theoretical lens analysis showed. Because of this, other elements have to be considered as well, like the experience of the subjects, measuring tools used, and field surveys (as tools) and actors such as the Administrative Board that will determine further usage of the information produced and describing it within the EIR.

The aforementioned dimensions and elements are in constant interaction in processes that range from the concept stage all the way to the in-use stage of the assets (second sub-research question). The processes followed to provide the information required from the model for the operations and maintenance activities to be performed in an airport project, the general structure followed is the same in most of the cases. This considers the development of the Employer's Information Requirements that have to be addressed by the BIM Execution Plan and to keep this as a live document that can and has to be updated after every stage of the project's lifecycle to keep an eye on the objectives to be achieved by the client. From there, the contractor can establish the methods needed to get the information from different parties as required. Most likely, this coincides with an update of the client about the interests for which the model is developed. Therefore, in the cases in which there is not a thoroughly developed strategy for the model, this will end up being a three-dimensional model developed for construction purposes with a huge load of information that could or could not be required for operations and maintenance.

In the cases where a long-term strategy has been developed, the client most likely will have determined for which purposes he wants the model for. This is followed with a close communication with the final users of the model, retrieving their needs and establishing those in the Employer's Information Requirements. Once these have been established, the required documentation (i.e. EIR and any additional appendices) is handed in to the contractor which will produce a model that satisfy these information needs. However, in this cases the details of the information to be included in the model are defined with precision and extensively. This implies different Levels of Development for different systems involved in the project, to follow a specific national or international classification system of the elements included in the model (e.g. UniFormat II, MasterFormat, NL-SfB), to comply with a specific national or international standard (e.g. PAS1192, ISO19650), to export the models in a specific file format or a certain version of a file format in addition to native files (e.g. IFC4 in addition to Revit, Navisworks native file formats). Additionally, attributes that can be included into the models and that would represent a great advantage for asset managers when receiving information from the appointing party (client) include:

- Unique ID
- Sizing
- Specifications
- Performance requirements
- Supplier information
- Warranties
- Installation dates
- *Elements related*
- *Systems related*
- *Surrounding elements*
- *Surrounding systems*
- *Surrounding assets*
- *Classification systems (O&M can include maintenance cost)*

Even though a BIM model can be further developed into an AIM (model) and be used to retrieve the information required for the different CMMS, CAFM and/or EAM systems and for different operations and maintenance activities, if the activities are identified and the process is backtracked towards the information requirements, the process could become seamless and the information handover process more efficient towards a more integrated lifecycle approach of the airport facilities. This requires the intervention and inclusion of the Asset Manager or personnel from the Asset Management team in order to define the attributes that will most likely be used during the O&M phase. To ensure that these will be provided, it is suggested to appoint a task manager that will be in charge of the development of these attributes, the inclusion of the information that they should contain and the proper extraction of them for future transfer either back to the appointing party, or to the operator or asset manager in charge of the facilities.

When this information is established and requested to the contractor, it is easier to comply with it and the model output will be in accordance with the client's needs after validation of the information contained. However, information is usually requested to fulfil only the first lifecycle needs which would correspond to construction purposes. This is the main reason why for the latter, models have to be developed again. The siloed situation and lack of communication between the different stages of the building's lifecycle derives in the loss of information and know-how gained during the first phases of the project. That is why initiating any project or asset lifecycle stage is better and easier when correct and sufficient information is available. Establishing the Operations and Maintenance needs from the designing stage can improve the quality of the model handed-in to the client and be useful not only for these purposes but even when an expansion would be required, which can be expected in airport projects given that they are planned in different phases to allocate and fulfil the aerial transportation demands.

Considering the literature review and the data collection of this research project, an answer to the first research sub-question can be provided as well. It entails the information detail to fulfil the client's needs to perform operation and maintenance activities in an airport project. It is not possible to establish a single parameter of detail for the whole model or for the complete group of assets present in the premises. This is not because of the different systems; it is possible to develop a whole architectural, structural and utilities model in a single level of development as those established by BIM Forum. The main difference resides in the fact that the level of development of the elements present in the model is not the same for construction purposes (where a high degree of geometry detail is required) than the one that is required for Operations and Maintenance of the facilities. To determine this information, elements to be considered include the level of development of the models, the classification system to be used for the elements included in the model, the BIM Execution Plan, and the Employer's Information Requirements. More importantly, the necessary elements to be defined and detailed in the model for this purposes will be determined by the intended use of the model; therefore, the activities for which it will be used. A model that is developed for construction purposes includes an amount of information that is overwhelming for operations and maintenance purposes. Therefore, the whole set of documentation and standards and regulations to follow, as well as the level of model definition, level of development and level of information needed, will determine the precise level of detail for every project and each element present in them.

Considering this, the main research question of "*how can the handed-in BIM information model fulfil the information needs for operation and maintenance practices' purposes in an airport project?"* can be addressed. It is indeed not as easy as just including the people that is in charge of the O&M of the assets in the process. They have to have an active role not only during the assessment of the assets, but also during the preparation of the EIR, determining the attributes that they consider are most likely to be used during later lifecycle stages of the assets. Providing all the existing attributes will only overload the models with information that will not be used completely once the models are handed over, that is why the assessment is needed. In case the attributes required are not included, a second assessment is to be performed, in this case by the appointed party, to describe what is to be developed during the design and construction project as established in the BEP. This is further specified in the post-contract award so the required information can be developed during the *Production and Delivery* step of the process and so, it can be available to fulfil the Asset Operation & Maintenance needs of both the correspondent team and the appointing party.

7.2 Project Level Recommendations

On a project basis it can become rather difficult to determine what is possible to do given that it depends on what phase the project is on. However, certain general recommendations can be drawn from this research project. It is advisable to determine which attributes can still be added to the elements modelled. If none is possible, a solution can be to develop an XML database to be filled in with data extracted from the model's BIM authoring tool or even from a model checker and then populate the missing fields. This can be done in close collaboration with the team members involved with Specifications. Additionally, it is recommended to make all the team aware of the processes of how the information is developed, verified, and shared with other parties. This can be provided in a single meeting or even an internally shared document. Therefore, the processes, methods, technologies and tools used in the project, as well as the standards and classifications, must be known to all the project team members. This will not only provide a solid basis that would prepare them to identify if any process related to the CDE shares with other parties, has been skipped; it can benefit the project by possibly getting new insights from other perspectives on how to improve the methods used or to exploit to the full potential the used tools.

7.3 Company Level Recommendations

It is advised for the company to provide training or at least develop awareness related to the usage of BIM, implementation of Digital Twins and usage of any particular technology that is to be used in a project for the whole personnel, not only for the team members directly involved with the usage of the technology. The company has already a vast experience in designing and engineering airport solutions and has been a pioneer in the implementation of BIM solutions into the airport industry; hence, providing maintenance of databases and IT systems as an active service and not only during downtime. This can foster the development and implementation of Digital Twins which, in turn, can provide them with a huge advantage over competitors, given that they already have experience and are familiar with the models, for future projects, developments and/or expansions within clients' facilities. Offering these services can as well provide an advantage during the tendering process of new projects. Additionally, considering a possible shift in the industry from a model-based approach to data-based approach can support the company getting a head-start when new technologies enter the market, considering what is more important for the O&M stage. As a complement, geometry can be generated solely from information, and location can be described from information as well; hence, availability of these attributes can provide specific enough information to create a model for further expansions or projects to be executed, including Maintenance interventions, instead of a highly detailed model with overwhelming unnecessary information for a conceptual stage.

7.4 Industry Level Recommendations

There is still the need to develop a classification specifically for civil infrastructure elements as well as a definition of the different levels of development that they can have, depending on the project lifecycle phase. With this addition, the transfer of projects' information would be seamless not only between actors involved but also between software used due to the eased identification that these elements would offer. In addition, the level of development of the elements would allow modellers and engineers to acquire the required information when on-site without relying on the development of a fully detailed model for its documentation. The different levels of development can provide the granularity necessary for information for O&M purposes to be shared earlier in the project for its verification regarding quality compliance, avoiding latter re-work or time, financial and human resources spent acquiring this information. Some attributes to be included in the modelled elements have already been described in this research project, so software vendors can work hand-to-hand with designers, engineers, operators, and asset managers to facilitate solutions that they have been implementing in their projects for long.

As additional measures, working on an open file format in line with international standards can ease administrative and technical burdens for all the stakeholders involved in construction projects. Software vendors should consider start developing and improving tools that work more data-driven than application driven as numerous architectural, structural and MEP systems solutions in the market. It might be a difficult transition, but technology developments could turn current solutions obsolete.

7.5 Academy Level Recommendations

Academic relevance derived from this research project can be identified in the different dimensions and elements described within the Activity Theory analysis and their relationships. The *tensions* or *contradictions* described can be further analysed to determine other possible solutions to the challenges faced within the AECO industry in relation to design, construction, and operation and maintenance of airport projects. Additionally, the shared object model of the activity theory can and should be further studied in relation to other perspectives, all intervening the studied object simultaneously. Further implications in data-driven collaboration can derive in different Use Cases that can be fulfilled with the same data, increasing possibilities of standardisation in the development of data, as well as in project delivery methods is to be analysed. It is worth to study the implications that changes in these processes will have in the project delivery methods as well, which can derive in the need of a different approach to how and what is procured for this type of projects.

7.6 Limitations and Further Research

This research project was conducted in collaboration with Netherlands Airport Consultants (NACO), which limited the cases pool to the information the company had available of the projects it has been involved. Additionally, documentation from other projects could not be released given legal limitations and project status. Because of this, I selected the cases by those that could provide different levels of BIM implementation but could still provide enough information to analyse the differences between them. The approach of addressing different roles from different organisations had the intention to cover as much fronts as possible but deeper understanding of every perspective is required to achieve a successful result regarding the information needs of other parties.

The perspective of the designer and contractor appointed parties, as well as the client's as the appointing party, can be well complemented by performing research from the Asset Manager's side, also as an appointing party but integrated earlier into the project's lifecycle; however, it has to be noted that the organisation structure can differ from one airport to another, with different roles and different teams assigned to different assets, meaning that the results from this research cannot be applied to the airport industry in general.

A fundamental limitation to consider is the disparity of scale and financial resources between local, regional, national and international airports. Moreover, despite the fact that international airports tend to have more resources both financial and technologically speaking, these will vary from country to country. This influences their development and plays an important role when deciding the organisation's goals and when these are to be achieved. Therefore, goals can be established in a different timeline, meaning that airports' technological development can be oriented to the same final purpose, but the vision is to achieve them in different points, as happened with both the studied cases of this research project. In future research, I would suggest to identify and gather information from airport facilities of roughly the same scale or approach.

Even though the information contained within the models is the main focus of this study, it should be reminded that this dimension includes other topics that need to be addressed. As was described in this research project, it is not only about the study objects, but also about the tools that mediate the interactions of the subjects with those objects while being regulated by numerous regulations on a local, national and international level, not only for design and construction subjects, but also with those related to operations and performance. Those tools, in this sense, documentation and more specifically, contractual documentation, have not been completely developed to address things related to BIM models and their components, such as:

- Model Responsibility / Accountability
- Liability
- Privacy
- Data Ownership
- Data Consistency
- Data Availability

These become more and more important considering the direction technology development is aiming at. Data is becoming the most important element for any industry and for AECO is not different. In addition to this, communication technologies are able to provide more support and have more room for applications than ever. Considering this, new innovations and their application within the AECO industry will require a proper documentation that governs the project, the information exchanges and correct integration of the parties, their tools and the contents produced for the projects. Therefore, new collaboration methods and regulations are to be studied to determine their impact in these types of projects. This is to be considered of utmost importance given that technology advances much faster than we, as humans, can identify possible uses. New applications that are not considered right now can be deployed by high-speed data transmission with 5G and future 6G networks, as well as with the development of quantum computing. With this, integration of all the parties involved in a project can become crucial to include and analyse all the variables that can intervene in the realisation of a project or a maintenance activity, leading to more accurate planning, more efficient works faster data transfers and perhaps even faster construction methods. All of this while linking all the data attributes and properties of all the elements required in a project, including an automatic upload of the information once an element is defined in the model, as well as its placement in site. These have to be addressed in a pro-active approach instead of a reactive one, providing the industry the advantage of steering technology applications instead of letting them steer the future of the AECO industry.

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Appendices

Appendix A – Content-Research Questions relationship

Section	Research Question
1. Introduction to the topic	
2. Research Methodology	
3. Theoretical Background	**1, 4**
3.1. Current situation	
3.2 Information Needs	
3.3 Definition and Implementation	
3.4 Activity Theory	
4. Data Collection	**1, 4**
4.1. Exploratory Interviews Findings	
4.2. Case A	
4.3. Case B	
4.4. Interview Candidates	
4.5. Interview Structure	
5. Data Analysis	**2, 3**
5.1. Case Study Comparison	
5.2. Preliminary Case Study Conclusion	
5.3. Activity Theory Data Analysis	
5.4. Contradictions	
5.5. Discussion	
6. Process Map Design	**2, 3, 4**
6.1. Process Map Approach	
6.2. Process Description	
6.3. Stages Identification	
6.4. Activities Description	
6.5. Responsibility Matrix	
6.6. Process Map Design	
7. Conclusions & Recommendations	**1, 2, 3, 4**
7.1. Main Conclusions	
7.2. Recommendations & Limitations	

Appendix B – Research Questions Material & Methods

Research Question	Research Object	Source / Reference	Method
1	Level of information	- Literature Review - Primary source	- SCOPUS Search and TU Delft Library Access - Semi-structured Interviews
2	Information exchange processes	- Primary source - National and International Standards (PAS1192-2:2013; ISO19650)	- Semi-structured Interviews - Provided by collaborating company
3	Asset maintenance activities	- Literature Review - Primary source	- SCOPUS Search and TU Delft Library Access - Semi-structured interviews
4	Information needs	- Literature Review - Primary source	- SCOPUS Search and TU Delft Library Access - Semi-structured Interviews

Appendix C – List of Interviewees

Exploratory Interviews		
Name	**Organisation**	**Role**
Mike dos Santos Freitas	NACO	BIM Coordinator
Pim Meyboom	NACO	Senior PM
Christopher André	NACO	Civil 3D / BIM Specialist
Frank Sijbolts	NACO	Special Airport Systems
Semi-structured Interviews		
Name	**Organisation**	**Role**
Hans Hendriks	deBIMspecialist	Owner & Consultant
Thomas Glättli	buildingSMART Switzerland	PMO Use Case Management
Lucas Chambille	Amsterdam Airport Schiphol	BIM Advisor
Arisca Droog	Amsterdam Airport Schiphol	Data Engineer
Maya Tryfona	Amsterdam Airport Schiphol	Data Engineer

Appendix D – Exploratory Interviews Structure

Exploratory Interviews

Outline

Date Actor
Project Interviewee

Personal introduction with the interviewee and brief introduction of the thesis project. Mention that this is only an exploratory interview to have a general overview of the situation.

A) Background
   a. Education
   b. Professional experience
   c. Role in the project
B) General project information
   a. Project status
   b. Project's O&M team organization
   c. Project's O&M team activities
C) Project specific BIM and information for O&M experience
   a. BIM use
   b. Information use (brief definition of *information* and distinction with *data*)
   c. Information differences between Architecture and MEP models
   d. Information detail required
   e. Personnel/role performing O&M activities
   f. Tools/software used in O&M activities
   g. Formats used in software for O&M activities
   h. Decision making moments in O&M of the project
D) Alignment of O&M practices with BIM standards
   a. Actors involved in handover & closeout
   b. Documentation, non-graphical data, and graphical model required for O&M activities
   c. O&M requirements established for design phase
E) Possible further interviews
   a. Follow-up interview* (if applicable)
   b. Potential interviewees
   c. Additional comments

Appendix E – Semi-structured Interviews Outline

Semi-structured Interviews
Outline

Personal introduction with the interviewee and brief introduction of the thesis project. Mention that this is only an exploratory interview to have a general overview of the situation.

Date: Team:
Project: Interviewee:

A) Background
   a. Education:
   b. Professional experience:
   c. Role in project:

B) General project information
   a. Project status:
   b. Project's BIM team structure/activities:
   c. Project's O&M team structure/activities:
   d. Information provision to the BIM team (means, periodicity, roles):
   e. Information provision to the O&M team (means, periodicity, roles):

C) Project specific BIM and information for O&M
   a. What was the BIM use in the project?
   b. What were the BIM responsibilities of the team in the project?
   c. What are the main O&M activities supported by information retrieved from BIM models?
   d. What are the main Civil O&M activities supported by information retrieved from BIM models?
   e. What other Civil O&M activities would the organisation like to be supported by information retrieved from BIM models? Why?
   f. Why are these not supported with information from BIM models yet?
   g. How is the communication within the BIM team (means/how, periodicity, roles, when, what)?
   h. Who Operates and Maintains the elements of the facilities that are related to civil works?
   i. How is the communication with that team (means/how, periodicity, roles, when, what)?
   j. What Information does that team ask to be included in the models and for what uses?
   k. What are the main Information differences between Terminal building models & Civil infrastructure ones?
   l. What are the main elements that are not included within the IFC schema when talking about Civil IFC entities?
   m. What was the level of detail of the Information required for Civil Works?
   n. In which documentation is this established?
   o. What of this information is currently considered to be included in the EIR? Why?

D) Documentation and handed-in information
   a. Very few clients will be able to require the specific information they need. What are the main reasons for this?
   b. What is the difference between airports?
   c. How do you (as an organisation) establish the information needs of each O&M to be performed?
   d. What do you consider are the main challenges when transferring information needs from the O&M team to the organisation and then to the contractor?
   e. What are the main differences between what is requested from the team to what is actually handed-back to them by the end of the project?
   f. What do you consider would be the best approach to request the information needed for O&M activities?
   g. What are the specifications regarding the documentation, non-graphical data, and graphical model information required for O&M activities?

E) Information Needs
   a. What type of information do you consider necessary to be established in the EIR when referring to O&M activities?
   b. What should be the format of the information to be used for O&M activities?
   c. What is your opinion about the main challenges for handing over Civil BIM information?
   d. What has been done to overcome them?
   e. What do you think would be a solution to avoid these problems during project's realisation?
   f. How would defining element entities within the IFC schema help O&M activities in the future?
   g. What details and specific information should be included in these IFC entities?
   h. What are the limitations of this?
   i. What are the main extracts O&M team asks for, from the models?
   j. How would the inclusion of these requirements and information to the model steer the development of it, towards a Digital Twin?

F) Possible further interviews
   a. Follow-up interview* (if applicable)
   b. Potential interviewees
   c. Additional comments

Appendix F – List of Figures

Appendix G – List of Tables