# Defining the workflows for information management for the enhancement of digitization across the whole lifecycle

## The case of an airport project

Maria Ilia Ropaka | MSc Thesis

TU Delft

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a company of Royal HaskoningDHV

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# Defining the workflows for information management for the enhancement of digitization across the whole lifecycle

## The case of an airport project

**Master's Thesis**

for the degree of MSc in Construction Management and Engineering at the Delft University of Technology

Delft, October 14 , 2022
*to be defended publicly on October 21 , 2022 at TU Delft*


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# Preface

This graduation thesis with the title “Defining the workflows for information management for the enhancement of digitization across the whole lifecycle: The case of an airport project”, marks the final step of my journey towards the Master of Science degree in Construction Management and Engineering at Delft University of Technology. I faced many challenges during the past six months, yet with patience and determination, I managed to overcome any obstacle and maintain my focus on my end goal. First of all, I would like to thank my academic committee consisting of Prof.dr. Paul W. Chan, Dr. Tong Wang, and Dr. Johan Ninan for their valuable comments and feedback throughout the whole procedure. I really appreciate your guidance in linking my practice-oriented work with the theoretical setting, aiding me in making a complete and coherent story.

As this graduation thesis was conducted in collaboration with Netherlands Airport Consultants (NACO), I would also like to express my gratitude to my three company supervisors who helped me in different ways throughout this journey. Mr. Gerard van der Veer, whose precise comments and personal advice aided me in improving my work and staying on track. A special thanks to Mr. Radu Panaitescu as well for his valuable feedback and willingness to quickly address my questions and to Mr. Mike dos Santos Freitas for his precise comments and for devoting his time to help me understand all these complex concepts in such a short time period. At the same time, I would also like to thank each one of the participants in the semi-structured interviews who provided significant input into this research.

Finally, my heartfelt gratitude to my family and friends who were there by my side all these years, supporting me in every step of this journey. A big hug to my parents, who despite the distance, have continuously supported me and aided me in overcoming all the difficulties during this stressful period. A special thanks goes also to my boyfriend; you were always there and everything seemed easier because of you. Definitely, this achievement would not have been possible without all of you!

Delft, October 2022

Maria Ilia Ropaka

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# Executive Summary

The Architecture, Engineering, Construction and Operations (AECO) industry can be described as a fragmented industry, with relatively low productivity and efficiency. Digital solutions like Building Information Modelling (BIM) can increase an organization's productivity, by also contributing to the enhancement of the digital transformation process. However, the Built Environment has been slow to adopt digital transformation, due to insufficient information management. Existing literature concentrates on addressing this challenge, by focusing on a single aspect of information management rather than providing a comprehensive picture of all the procedures, parties engaged, information, formats and platforms used as well as their interdependencies. Therefore, the objective of this graduation research is to determine the workflows for information management to allow digitization across the whole lifecycle, by examining multiple aspects. More specifically, the procedures to be followed, the required information throughout the project stages as well as its distribution across the different parties involved, formats, and platforms used for information storage, and overall digital ambitions are examined.

A case study of an airport project is selected as the research methodology, consisting of a documentation review and semi-structured interviews. Such a case study is preferred as the research is conducted in collaboration with Netherlands Airport Consultants (NACO), an airport consultancy closely working with several international airports. The study of the documentation offers a comprehensive response to the procedures followed as well as the general type of information needed per project stage and the usual formats used. Furthermore, the various parties engaged throughout the entire process are highlighted. Complementary information on the aforementioned aspects is provided by the semi-structured interviews as well. In addition, the platforms used for information storage and the roles assigned to the various parties involved are specified in greater detail. Finally, the digital ambitions of the parties are also discussed.

Therefore, the case study findings lead to the creation of a process map, demonstrating more efficient workflows to be followed, by linking the distributed information between the different parties involved throughout the several project stages, while also considering each party’s digital ambitions. The process map is demarcated by two axes. The project stages are illustrated in the horizontal axis, according to the RIBA Plan of Work (2020), since it is considered one of the most recently published plans of work. The vertical axis lists all of the various parties engaged during the whole lifecycle. The main processes identified during each project stage concern the production of information deliverables by the respective party, using a suitable format. As both geometrical and non-geometrical information is generated during the different project stages, different formats are used, i.e. information models and documentation. Subsequently and at the end of each stage, the respective information is shared with other parties during specific information exchange moments. A collaborative environment is also used by the different parties, both during

production and information sharing. Depending on the project stage, each information deliverable might be in a different state, which is clearly illustrated in this environment. More particularly, the process map depicts a current situation in which all of the activities in the process map might be completed without the use of further technological advancements. However, as this process is not static but rather more dynamic, certain future suggestions are included while designing the process map. These consider a further improvement of the whole procedure by implementing the organizations' future digital ambitions. These digital ambitions mostly concern the usage and eventual reuse of information at the beginning of new projects, as well as the enhancement of collaboration between the different parties involved in the process.

The proposed process map can thus be used as guidance for any organization within the construction industry that embarks on this digital transition or simply wishes to improve its working practices, as it considers the processes that occur within the lifecycle of any project, regardless of the field. Additionally, the information is relevant to any object, making it suitable for a variety of purposes. Moreover, the process map can also represent a crucial step in linking the start and the end of a process.

Concluding, as digital transformation becomes even more widespread, a growing number of organizations strive for effective information management. To acquire a more reliable view of the subject, it is necessary to look at several aspects at once, hence the development of the proposed process map. To increase the validity of the outcome, more research and elaboration of the process map's elements is advised. Recommendations for the construction industry, with regard to the incorporation of digital ambitions, are also provided together with suggestions for a further enhancement of the company’s information management.

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# List of Abbreviations

| | |
|---|---|
| AAS | Amsterdam Airport Schiphol |
| AECO | Architecture, Engineering, Construction and Operations |
| AIM | Asset Information Model |
| AIR | Asset Information Requirements |
| BEP | BIM Execution Plan |
| BIM | Building Information Modelling |
| CAD | Computer Aided Design |
| CDE | Common Data Environment |
| DDS | Data Dictionary Schiphol |
| EIR | Exchange Information Requirements |
| IM | Information Management |
| ISO | International Organization for Standardization |
| NACO | Netherlands Airport Consultants |
| OIR | Organizational Information Requirements |
| PIM | Project Information Model |
| PIR | Project Information Requirements |

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# 1. Introduction

The Architecture, Engineering, Construction and Operations (AECO) industry is usually perceived as a fragmented industry, with relatively low productivity and efficiency (Fulford & Standing, 2014). The industry is highly conservative, spread among a wide range of actors and disciplines, with this peculiarity resulting in rather slow adoption of innovations and technologies in the sector. It should be mentioned that according to Chan et al. (2020), and in comparison to other industries, the Built Environment industry has been slow to embrace digital change, yet there have been significant advancements in recent decades. More specifically, and as illustrated in Figure 1, the construction sector shows a stable or decreasing annual productivity growth (Sturm et al., 2022). Furthermore, it is also worth noting that the construction sector's productivity has expanded at a 1% annual rate during the last two decades, compared to 2.8% for the global economy as a whole (Barbosa et al., 2017).

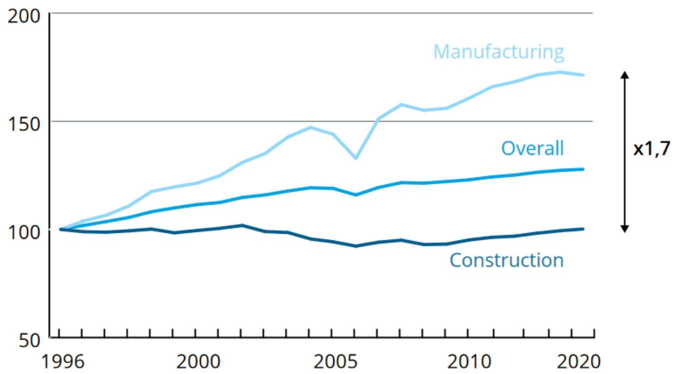


*Figure 1 - Productivity growth of Construction sector (Sturm et al., 2022)*

Focusing on the AECO industry, digital tools like Building Information Modelling (BIM) aid in enhancing the productivity of an organization. According to BNL (2017) and the Ministry of Local Government and Modernisation (2011), BIM adoption is depicted as an important aspect of the digital transformation process. Moreover, it also contributes to effective communication and collaboration with other key actors, such as property owners, operators, and contractors throughout the whole lifecycle of a project. In a recent declaration of "Europe's Digital Decade", digital transformation is named as one of the European Union's priority areas (European Commission, 2021).

Recently, there has been growing interest in ensuring that information can be retrieved and eventually reused. In the AECO industry, several actors are engaged throughout different stages of a project, thus a vast amount of information is transferred between them. Therefore, efficient information management ensures that the right actors can access the correct information when needed, avoiding in that way miscommunication that could lead to project delays. According to Mokhtar et al. (2020), an organization's and information professionals' ability to manage information successfully can be aided by digital technology. As described by Li et al. (2021), the AECO sector is becoming increasingly information-intensive as information technology develops at a rapid pace.

However, the overall digitization in the construction sector is considered still relatively low in comparison to other sectors (Manyika et al., 2015), an issue that can be linked to poor information management (EU BIM Task Group, 2017). As illustrated below in Figure 2, information flow plays an important role throughout every stage of the process, thus a potential malfunction in the information management and sharing could hamper the smooth flow of the construction supply chain. Mistakes made in the exchange of information or insufficient communication between the actors could eventually lead to delays in the project's completion.

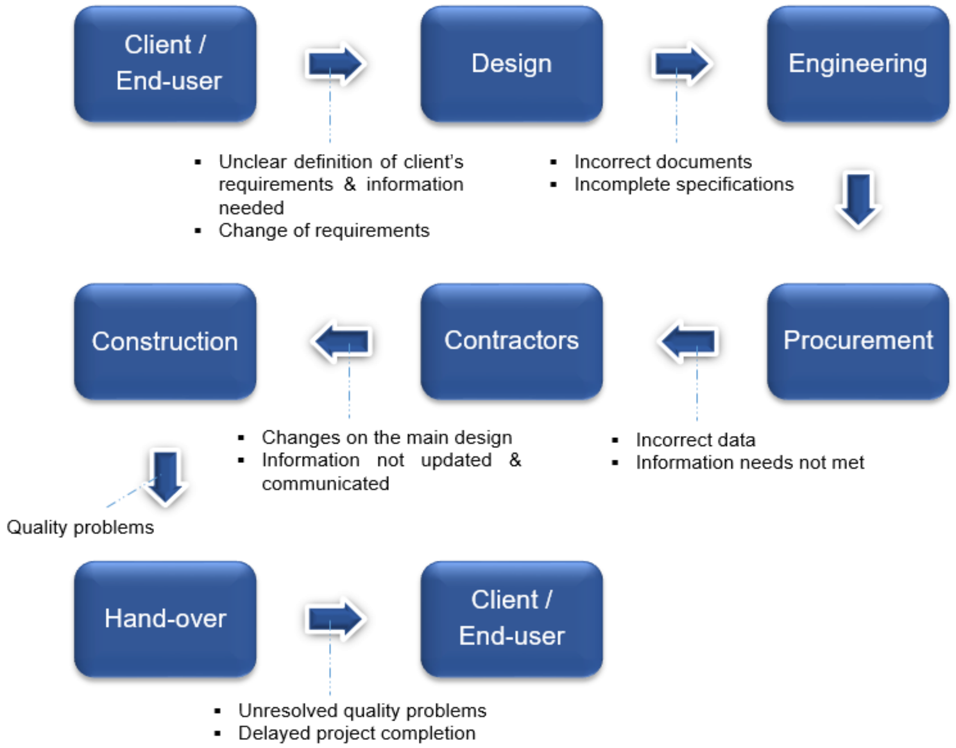


*Figure 2 - Construction supply chain problems (Vrijhoef & Koskela, 2000)*

BIM, being a digital tool that offers a 3D representation of a structure's physical and functional characteristics, can significantly contribute to efficient information management. It can be perceived as a useful tool for integrating data from various stages to increase information communication and reuse between the actors, being also a critical component of construction lifecycle management (Xu et al., 2014). By implementing BIM, the information deriving from different actors at different stages of the process can be integrated into a shared platform, using shared forms to facilitate communication and decision-making. Therefore, the effectiveness of an organization's information sharing process can have a substantial impact on its capacity to gather, analyze, and decision-making around its assets. Abanda et al. (2018) also pinpoint that a key factor that contributes to a successful project management is information management through the use of BIM. However, such a statement can only be ensured only if the information flow is clearly defined among the actors involved (Ho et al., 2013).

One of the principal elements of the International Organization for Standardization (ISO) 19650 series, which was recently published, is information requirements management, acting as a tool to support information management processes (Churcher et al., 2020). According to European Federation of Engineering Consultancy Associations (2020), information requirements are used to define the information that an asset or project supply chain members must deliver as part of their tasks and will be saved in the Project Information Model (PIM) or the Asset Information Model (AIM). Transferring information to the subsequent lifecycle phase might turn it into a valuable asset (World Business Council for Sustainable Development, 2021), yet the information dependencies within the actors involved through the different project stages ought to be formerly determined (Li et al., 2021). However, planning what information will be delivered, during which stage, and what resources and actors will be needed becomes a very difficult task without determining the actual information needed and the processes to be followed.

## 1.1 Problem Statement

As digital transformation tends to become a fundamental element of the AECO industry, an increasing number of organizations strive for efficient information management. When addressing information management, it is important to consider all the project stages with each stage requiring a different type of information. Moreover, several actors and different teams are involved through the stages, each one providing or requiring a different type of information as well.

Research has been focusing on developing tools to enhance this digital transformation, yet poor information management, hampering efforts on digitization, is still observed. Researches have been suggesting the development of frameworks revolving around the subject of lifecycle management, yet the majority of them concentrate on cost, environment, and sustainability and less attention is paid to actual information management. Therefore, there have been several studies aiming at the development of frameworks, which link the environmental and cost assessment of buildings together with the 3D models that are used throughout the whole lifecycle, yet without focusing on the actual information that is distributed.

Hu (2008), one of the researchers that address the topic of lifecycle information management, proposes an information lifecycle modelling framework that may be utilized by any stakeholder that has access to building lifecycle information. The framework outlines basic concepts of information management such as the necessity for defining a construction project’s process management together with its goals, which is then translated into information. Moreover, the need for developing an Information Technology infrastructure for construction projects is also outlined, providing storage for the information that is distributed throughout the lifecycle. However, this framework follows a rather general approach, presenting the basic concepts of information management without emphasizing on the sequence of events, parties involved, or precise information distributed among them.

Another study by Malagnino et al. (2017), proposes that the current BIM approach could be improved by including the concept of Product Lifecycle Management, which would enhance how a product's whole lifecycle and the information related to it are handled. Therefore, the study's final outcome is a conceptual model that defines the responsibilities of internal and external stakeholders within each project phase and offers them the ability to add information and manage the 3D models in accordance with a standardized process. However, this conceptual model focuses on defining the roles of the various parties involved in the process by presenting who should have access to information and during which project stage, without analyzing what kind of information is distributed between them.

Furthermore, Li et al. (2021) concentrate on the creation of a BIM-enabled building lifecycle management system that would improve communication between the various project teams and include the lifetime processes of buildings. One of the main findings of this research is the proposal of an information transferring mechanism between the three main project stages (design, construction, and operation) which presents the different type of information that should be delivered in the BIM models. The three BIM models that are the subject of this research are the As-Designed, As-Constructed, and As-Maintained models, and this mechanism outlines the broad categories of information that should be contained in each of these. However, the research focuses only on providing the general type of information that is distributed through the project stages without identifying who is responsible for creating and sharing this information.

Finally, a more solid approach has been achieved by Xu et al. (2014) who propose a framework for providing a platform for information management, by identifying the information components and information flow during a project's lifecycle. The information required during the three main project stages (design, construction, and operation) is listed in detail and linked to its source, such as the type of design from which it can be extracted. Additionally, as this study perceives BIM as a key component of allowing lifecycle information management, consideration is given to the kind of data that a BIM database should have in order to streamline the entire process. However, no emphasis is given to the different formats of information used and shared across the different project stages or the parties that are responsible for delivering and distributing this information.

Given this context, several aspects need to be addressed simultaneously in order to develop more efficient workflows for information management allowing for digitization across the whole lifecycle. More specifically, for successfully approaching this topic, not only the sequence of the procedures to be followed but also the type and format of information as well as its distribution across the different parties involved in the whole lifecycle should be considered.

## 1.2 Research Goal

Therefore, this graduation research aims at the development of a process map to determine more efficient workflows to be followed, by linking the distributed information between the different actors involved throughout the several project stages.

The development of such a map will not only serve as a guideline, enhancing the actors' communication by providing them with better visualization of the whole procedure, yet it will also display the evolution of the information during the several project stages. This thesis outcome will provide organizations with an information management solution, enhancing the way they manage and process their information.

This research is carried out in collaboration with Netherlands Airport Consultants (NACO), an airport consultancy specializing in master planning, airport design, construction and civil engineering, downtime works and maintenance, smart aviation, and special airport systems. Many projects that are carried out in the AECO industry concern the airport domain, with each project possessing unique characteristics. The case of an airport project that is examined in this graduation research considers the Amsterdam Airport Schiphol (AAS), the biggest airport in the Netherlands and among the most prominent ones in Europe. NACO has been closely collaborating with AAS since the initial development of the airport's master plan. Since then, NACO has been engaged in several and complex projects, providing a range of services to the airport including master planning, schematic, preliminary, and final designs, as well as tender documents, cost estimations, and finally architectural supervision.

However, despite the uniqueness of each airport project and while considering the broader context of digital transformation, each organization aims at improving its information management. Therefore, this design-oriented research will serve as a basis to provide a guide that can be used for multiple projects, thus fitting for a generic purpose.

## 1.3 Research Questions

The following research question has been established based on the research project's objective:

***"How can the workflows for information management be defined to allow digitization across the whole lifecycle"***

In order to be able to provide a solid answer to the aforementioned research question, several aspects of the information management and information flow ought to be examined. Therefore, the following sub-questions have been formed:

- Sub-Question 1: What are the processes followed to provide the deliverables needed for each project stage?
- Sub-Question 2: What kind of information, and by whom, is generated and delivered at each project stage?
- Sub-Question 3: What type of formats/platforms are used to store the information?
- Sub-Question 4: How can the organizations' digital ambitions be aligned with the process?

## 1.4 The importance of the Thesis

After the graduation research is concluded, the findings will contribute to the research community both from a scientifically, practical as well as societal perspective. The thesis will contribute to the existing literature already by focusing on the integration of multiple aspects when designing workflows for information management. Concerning the practical importance of the thesis, the findings will propose improved information management workflows which can be followed during a project. However, it is important to mention that as the workflows will not be designed solely for a specific asset, they can be also applied to other projects of a similar scale, thus benefiting the construction industry overall. Finally, this research will also be of significant importance from a social perspective. Long-term time and cost savings could be achieved as a result of the development of more efficient workflows for information management. Moreover, a project execution, which is aligned with the overall objectives of digital transformation will result in less information waste, which is subsequently translated into saving in using and printing paper-based documents, thus achieving a more sustainable solution.

## 1.5 Thesis Structure

This section briefly describes the steps that were followed during the conduction of the graduation research in order to achieve the final objective.

The first chapter contains the introduction of the topic, providing information on the current situation with regard to digital transformation and information management. The existing research gap is identified along with the research goal and research questions. Finally, the importance of the thesis is outlined.

The second chapter sheds the light on the theoretical background of the research, where relevant topics to the research are discussed. This provides a crucial insight into concepts and terms that are used throughout the research, thus reducing the risk of misinterpretations.

Subsequently, the research methodology and data collection are described in chapter three, where the case study is described. This chapter is divided into two parts, with the first consisting of the documentation review, provided by AAS, and the context of conducted semi-structured interviews. Following, the findings deriving from both the documentation and corresponding interviews are presented.

Chapter four includes all the steps that are followed after the data analysis in order to design the final process map. More specifically, describing the workflows that are followed throughout the whole lifecycle of a simple object as a door is the starting point. Through the additional contribution of the semi-structured interviews, the process map is eventually created.

Chapter five discusses the findings of the research after collecting and analyzing the information obtained from the documentation review and semi-structured interviews. Moreover, emphasis is also given to comparing the thesis outcome with the findings of the existing literature, and research limitations are described.

The last chapter presents the main conclusions that are derived from this graduation research as well as the answers to the research question and sub-questions. The theoretical and practical contribution is discussed, and recommendations both for future research, for the industry, and the company are given.

The thesis structure is illustrated in the following graph as shown in Figure 3.

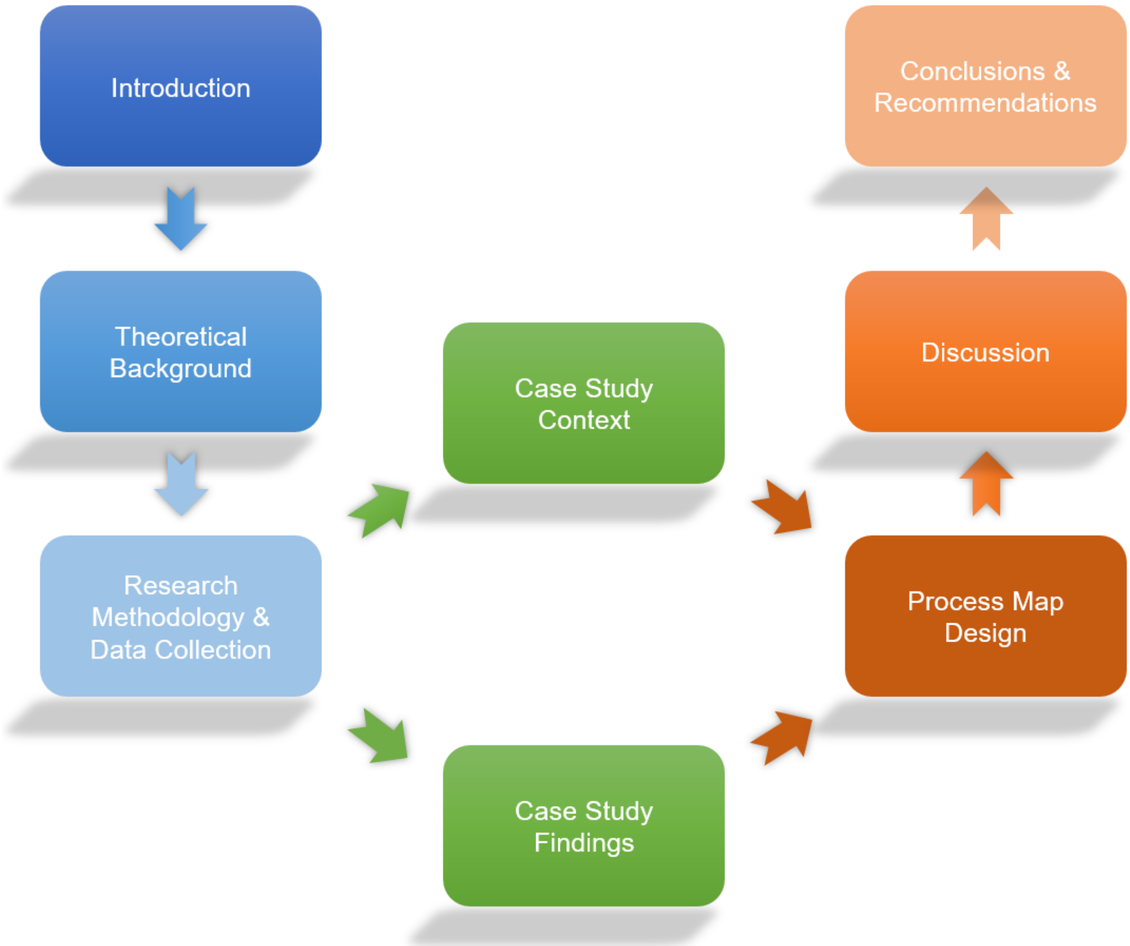


*Figure 3 - Thesis Structure*

# 2. Theoretical Background

In this chapter, the Theoretical Background of the research is discussed. Concepts such as digital transformation, BIM, information management, and project stages are analyzed. Following, information is given on the ISO 19650 standards and Information Management (IM) Protocol.

## 2.1 Digital Transformation & Building Information Modelling

Organizations operating in the construction industry must constantly innovate and improve their efficiency, as the market is highly competitive. Therefore, there is a growing need for digital transformation efforts and strategies. As a result, a large and rather complex set of data can be collected, processed, and analyzed (World Business Council for Sustainable Development, 2021). As described by Mokhtar et al. (2020), the generation, access, and consumption of data and information by organizations, especially digital data and information, has been significantly changed by digital transformation. Such a type of digital connection creates shared value and traceability is made possible by digital solutions throughout the lifecycle (World Business Council for Sustainable Development, 2021), while these digital technologies are increasingly being used during the project's design, construction, and operational phases.

More specifically, BIM, as a digital technology, is perceived to be a crucial facilitator of digital transformation in the AECO industry. Hooper & Ekholm (2010), state that BIM could be described as parametric modelling, used to assist the project lifecycle by sharing important data and information across actors to enhance the project's outcomes, such as cost, time, and quality. The history of BIM can be traced back to 1975 when the concepts of parametric design and 3D representation were first described. As the years passed and technology evolved and eventually matured, various parametric modelling design software was developed. The first milestone was the 2D Computer Aided Design (CAD), which set the basis for the development of other software and platforms, such as Graphisoft ArchiCAD and Autodesk Revit. Therefore, BIM evolved into an essential tool for the 3D visual representation of a project prior to its construction, providing indisputable benefits to its users.

However, before BIM is fully implemented, distinctions are made between the various BIM maturity levels (Dakhil et al., 2015), which define the applicable modelling levels. As shown in Figure 4, four different BIM levels (Level 0-3) have been identified. Level 0 represents the base and simplest level of generating information, as only paper-based 2D CAD documents are used, without sharing the information between project team members. As a result, there is inevitably zero collaboration. Level 1 focuses on partial collaboration, involving the use of both 3D CAD and 2D drawings and the use of a Common Data Environment (CDE) to store, manage and share all the data. Moving to Level 2, its key core is the collaborative working of all team members, who use 3D modelling to produce information. Using a common file type, each member can create and work on its own model, and then the different models can be combined into one single model. Finally, the aim of Level 3 is to promote full integration with a common and unified shared model through a cloud-based environment, accessible to every project team member.

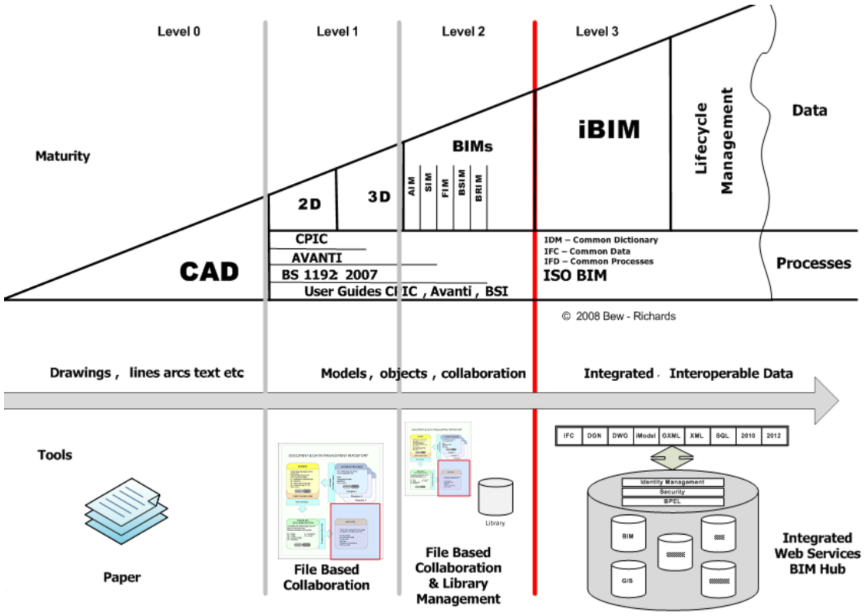


*Figure 4 - BIM Maturity Levels (Department of Business, Innovation and Skills, 2011)*

## 2.2 Information Management

The object-oriented concept is used in BIM to improve the efficiency of information management throughout the building lifecycle (Zhang & Hu, 2011), by providing a continuous flow of information during the whole process (Penttilä, 2006). Moreover, as mentioned by Koutamanis et al. (2021), one of the most interesting features of BIM is the engagement of several actors during the construction process. Hence, it is a crucial element to consider when addressing the concept of information management. Aguiar et al. (2019) mention that BIM may be utilized as a model of an asset's whole lifecycle from its initial design to its final usage. Several authors (Wong & Fan, 2013; Akinade & Oyedele, 2019; Honic et al., 2019; Chan, 2020) also argue that it can simultaneously serve as a useful collaboration platform that gathers all the actors together to achieve transparent project coordination and efficient information exchange. However, in order to promote this multidisciplinary cooperation and increase operational efficiency, it is critical to guarantee that the information can be accessed by many users (Xu et al., 2014).

In the broader context of digital transformation in the Built Environment, the ISO 19650 series of standards define information management concepts as well as information requirements (Boutle et al., 2021).

### 2.2.1 ISO 19650 standard

The ISO 19650 standard aims to structure the organization and digitization of information, which relates to buildings and civil engineering works, including the management of information with the use of BIM (Robitaille et al., 2021). It is portrayed as an international standard of good practice, addressing several fundamental concepts that need to be integrated into a project's workflow. More specifically, these concepts consider the information requirements (what needs to be delivered), the roles and responsibilities within a project team (who needs to deliver) as well as the collaborative production (what are the required steps for a successful delivery).

The ISO 19650 series of standards are published by the International Organization for Standardization, under the heading:

*"Organization and digitization of information about buildings and civil engineering works, including Building Information Modelling - Information management using building information modelling",*

currently consisting of five different documents, as shown in Table 1.

*Table 1 - ISO 19650 standards*

| Document | Concept |
|---|---|
| ISO 19650-1:2018 | Concepts and principles |
| ISO 19650-2:2018 | Delivery phase of the assets |
| ISO 19650-3:2020 | Operational phase of the assets |
| ISO 19650-4 (Under development) | Information exchange |
| ISO 19650-5:2020 | Security-minded approach to information management |

For the purposes of this research and as it concerns the whole lifecycle, the ISO 19650 parts 1, 2, and 3 are examined.

#### *2.2.1.1 ISO 19650-1:2018 - Concepts and principles*

The ISO 19650-1:2018 standard outlines the recommended concepts and guiding principles for business operations in the Built Environment sector, in order to manage and produce information throughout the lifecycle of built assets (mentioned as "information management") when utilizing BIM (ISO, 2018a). Information management relies on every party engaged in the overall process, each one taking responsibility for their respective role.

A common ground for terms has been established as shown in Table 2 and Table 3. In order to avoid misinterpretations, these terms are used in this research.

*Table 2 - General terms (actor-related) as established in ISO 19650-1:2018*

| General Terms | Description |
|---|---|
| Appointing Party | Receiver of information from the Lead Appointed Party |
| Appointed Party | Provider of information |
| Delivery Team | Lead Appointed Party & their Appointed Parties |
| Task Team | Responsible for performing specific tasks |

*Table 3 - General terms (information-related) as established in ISO 19650-1:2018*

| General Terms | Description |
|---|---|
| Organizational Information Requirements (OIR) | Information requirements for organizational objectives |
| Asset Information Requirements (AIR) | Information requirements for an asset's operation |
| Project Information Requirements (PIR) | Information requirements for an asset's delivery |
| Exchange Information Requirements (EIR) | Information requirements related to an appointment |
| Appointment | Agreed instruction for the provision of information |
| Asset Information Model (AIM) | Information model for the operational phase |
| Project Information Model (PIM) | Information model for the delivery phase |

One of the principal elements of this standard is the collaborative production of information, which not only includes the frequent exchange of information but also provides an understanding of what happens to the information once it gets delivered. This is crucial for ensuring that the information is generated for fulfilling a particular objective. In the end, information ought to be useful, thus its content, structure, and format must be taken into account.

For facilitating information management, the CDE concept is defined, consisting of an agreed source of information for any given project or asset (ISO, 2018a). The CDE uses solutions to assist procedures that guarantee the information is managed and easily accessible to actors who need it, at the time they need it.

#### *2.2.1.2 ISO 19650-2:2018 - Delivery phase of the assets*

The ISO 19650-2:2018 standard focuses on enabling the Appointed Party to specify its information requirements during the asset delivery phase, while also offering the right commercial and collaborative environment to the engaged Appointed Parties (ISO, 2018b).

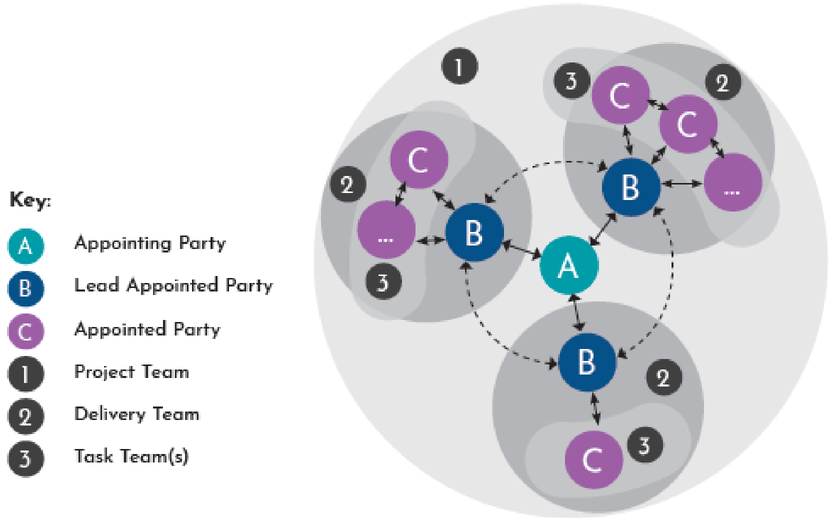


*Figure 5 - Interfaces between parties and teams (Churcher et al., 2020)*

The Appointing Party's duties involve the establishment of the project's information requirements and protocol to be followed during all project appointments as well as the creation of the CDE. The Lead Appointed Party is in charge of coordinating information between the Appointing Party and the corresponding Delivery Team. Finally, the Appointed Party is the one submitting a tender or being hired for a project, capable of producing all the required information.

This standard outlines the requirements for information management in the form of a management process, within the context of the delivery phase of assets (ISO, 2018b). Unexpected information requests from the information receiver will have a detrimental effect on how the information producer works, especially when the project schedule is tight.  Regardless of the project stage, the information management process should be applied for every appointment throughout the delivery phase. Therefore, the information requirements cycle that should be followed is shown in Figure 6.


*Figure 6 - The information requirements cycle (Churcher et al., 2020)*

### *2.2.1.3 ISO 19650-3:2020 - Operational phase of the assets*

The ISO 19650-3:2020 standard focuses on setting the requirements for information management in the form of a management process, within the context of the operational phase of assets (ISO, 2020). The implementation of this standard enables the Appointing Party to choose a proportionate approach depending on the implementation's costs and benefits (Churcher et al., 2021). It concerns the transition of an asset from the project phase towards the operational phase, focusing on the smooth transfer of information from the PIM to the AIM.

As highlighted in the ISO 19650-3:2020, there are two main categories of trigger events, defining the preparatory activities to be followed (Churcher et al., 2021). As defined in ISO (2018a), a trigger event is either a foreseeable or an unforeseeable event, resulting in changes to an asset or its status during its lifecycle. A simplified representation of a sequence of trigger events for an asset during its operational phase is shown in Figure 7.

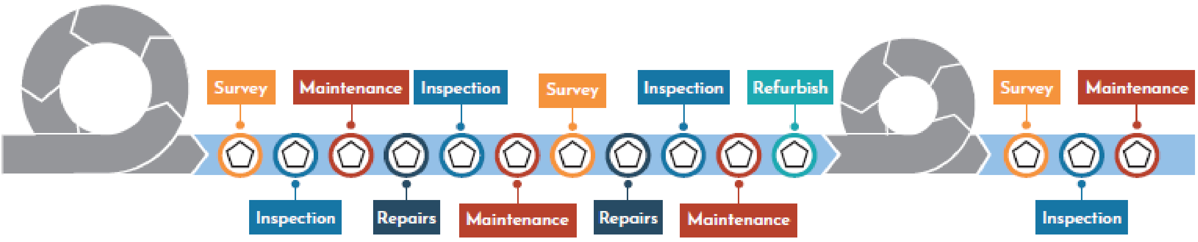


*Figure 7 - Trigger events during the operational phase of the lifecycle (Churcher et al., 2021)*

Although several possible trigger events can be identified, they can be essentially divided and grouped into four main categories, as illustrated in Figure 8.

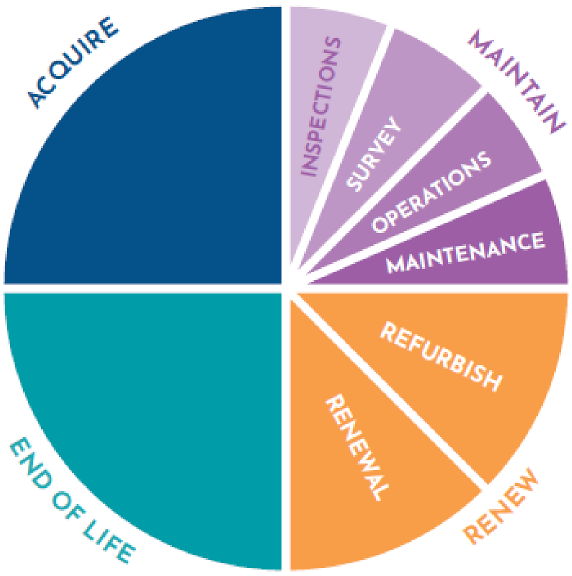


*Figure 8 - Categorization of trigger events (Churcher et al., 2021)*

In order to provide a solid response to a trigger event, the information required needs to be accessible and easily comprehended. The information delivered in the PIM should be imported and eventually integrated into the AIM, following a combination of manual validation and automated verification process to verify its accuracy.

## 2.2.2 Information Requirements

As explained previously, ISO 19650 establishes the standards for information management throughout the lifecycle of an asset, providing guidance on the formulation of information requirements. According to European Federation of Engineering Consultancy Associations (2020), information requirements are used to define the information that an asset or project supply chain members must deliver as part of their tasks and will be saved in the asset information model or the project information model. As shown in Table 3, four different information requirements are identified. The OIR and AIR exist outside of the design and construction project delivery, while the PIR and EIR exist during the design and construction project delivery.

More specifically, OIR provide an understanding of the high-level information needed regarding assets throughout their lifecycle, being the starting point for all information management activities (Bolpagni & Hooper, 2020). They are formulated by the Appointing Party, aiming in supporting strategic business decisions that will eventually lead to the creation of the AIM. Subsequently, AIR are generated from OIR by the Appointing Party and more particularly from the asset and facilities management team. These requirements outline the specific information required by the Appointing Party and their stakeholders to manage the assets throughout their whole lifecycle (Bolpagni & Hooper, 2020).

Furthermore, PIR are also partly generated from OIR, facilitating the comprehension of the high-level information that is required from the Appointing Party throughout a design and construction project (Bolpagni & Hooper, 2020). It is important to mention that only one set of PIR exists per project. Finally, for the Appointing Party or the Lead Appointed Party to fulfill essential activities during the project and the operational phase, it is crucial that the right information is supplied to them (Bolpagni & Hooper, 2020). For this purpose, the EIR are set at an early stage to define and document the information needed to be delivered for the development of the project. Therefore, the goal of the EIR is to guarantee that Appointing Party's information needs are clearly specified at the start of the process, thus offering a common ground for collaboration among all actors in order to manage and eventually deliver their requirements.

An overview of the several information requirements and their interrelation is presented in Figure 9.

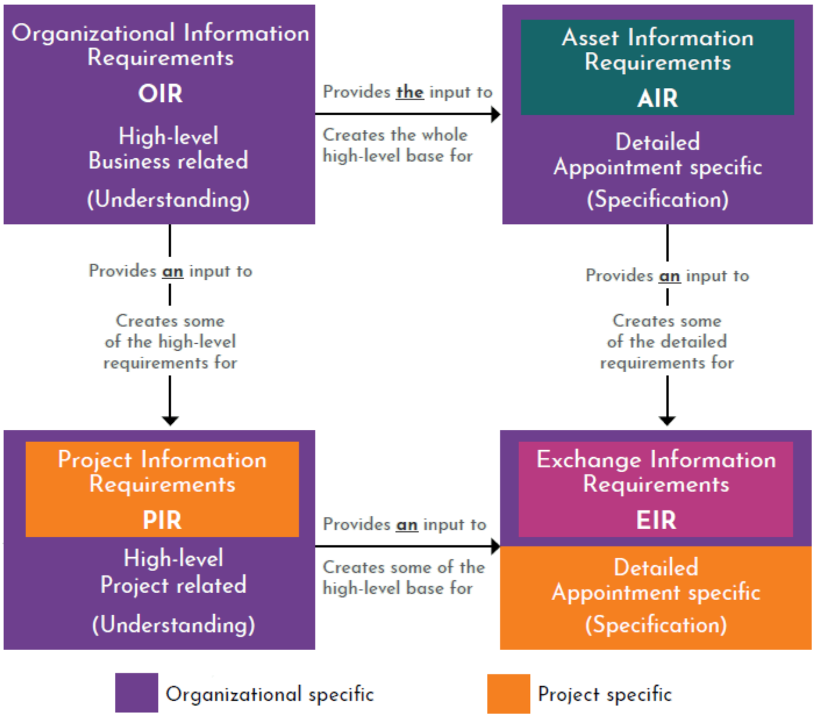


*Figure 9 - Interrelation of information requirements (Bolpagni & Hooper, 2020)*

## 2.2.3 Information Management Protocol

In order to support the information management processes, an Information Management Protocol should be created. The purpose of this document is to achieve uniformity regarding the information management procedure in the exchange of asset information. The Information Management Protocol needs to be included in each contract or appointment between the engaged process and is created by the Appointing Party, in most cases.

The main topics covered in this document refer to the coordination and resolution of conflicts, obligations of the Appointing and Appointed Party, CDE solution and workflow to be followed as well as management of information (Croft et al., 2020). More specifically, an information delivery plan is proposed, together with the information exchange moments. Moreover, with regard to information management, the level of information need, the version of the information model, and the format of files to be shared are also determined. Finally, the roles, tasks, and responsibilities of each party are properly defined, in order to avoid any potential liability concerns.

## 2.3 Common Data Environment solution

As mentioned above, ISO 19650-1:2018 proposes a CDE solution and workflow to be used for managing information during the project delivery and later asset management (ISO, 2018a). Not only CDE acts as a repository for information storage, yet it also aids in project management, sharing, and collaboration by making the information available to every team member. Usually when dealing with large or complex assets, or with widely dispersed teams, the entire information model is not typically held in one place. Collaborative working based on information containers, i.e. files, enables the distribution of the CDE workflow across several computer systems or technological platforms. Therefore, the CDE solution can be described as a software or online tool that enables management and information sharing in BIM projects.

One of the primary characteristics that set a CDE apart from a regular file manager is the existence of certain metadata. The term metadata refers to a set of data that gives information about other data and according to ISO (2018a) these should at least include:

- An information container, i.e. file, unique ID
- A revision code
- A status code
- A classification code

Each information container may be in a different state during each project stage. As a result, each information container is assigned a status code that may be used to describe its current state. Within the CDE solution proposed by the ISO 19650-1:2018, four different states are identified:

- “Work In Progress” state
- “Shared” state
- “Published” state
- “Archive” state

More specifically, during the “Work In Progress” state, the Appointed Party produces the deliverables and shares this information. Therefore, no other member of the project team can neither access or see this information (Fugas, 2020). After that, a transition state in which the information container is checked in regard to project requirements, standards, and procedures occurs (ISO, 2018a). This concerns the check/review/approve transitions stage. Following, the goal of the subsequent state, i.e. “Shared” state, is to facilitate the collaborative development of the information model within the Delivery Team. This implies that the information shared can be visible to other appropriate project teams, in order to be used for coordination with their own information. However, the deliverables are visible and accessible to everyone, yet not editable (Fugas, 2020). If any changes ought to be made and editing is necessary, the respective information container should be returned to the “Work In Progress” state so that its author (Appointed Party) may make the necessary changes and resubmit it. Subsequently, during the review/authorize transition, all information containers are assessed based on coordination, completeness, and accuracy against the relevant information requirements (ISO, 2018a). Therefore, an information container's status is changed to “Published” state if it satisfies the information criteria. If any information container does not fulfill these requirements, it must return to “Work In Progress” state for revision and resubmission. Information that has been given permission to be used, for instance during the construction of a new project or the operation of an asset, is placed in the “Published” state (ISO, 2018a). This concerns only information verified and authorized to use (Fugas, 2020). Finally, the journal of all information containers that have been exchanged and published during the information management process, as well as an audit trail of their creation, are kept in the “Archive” state (ISO, 2018a). This state could assist in resolving a disagreement that might occur between the various parties engaged in the process.

An overview of the CDE concept is visualized in Figure 10.

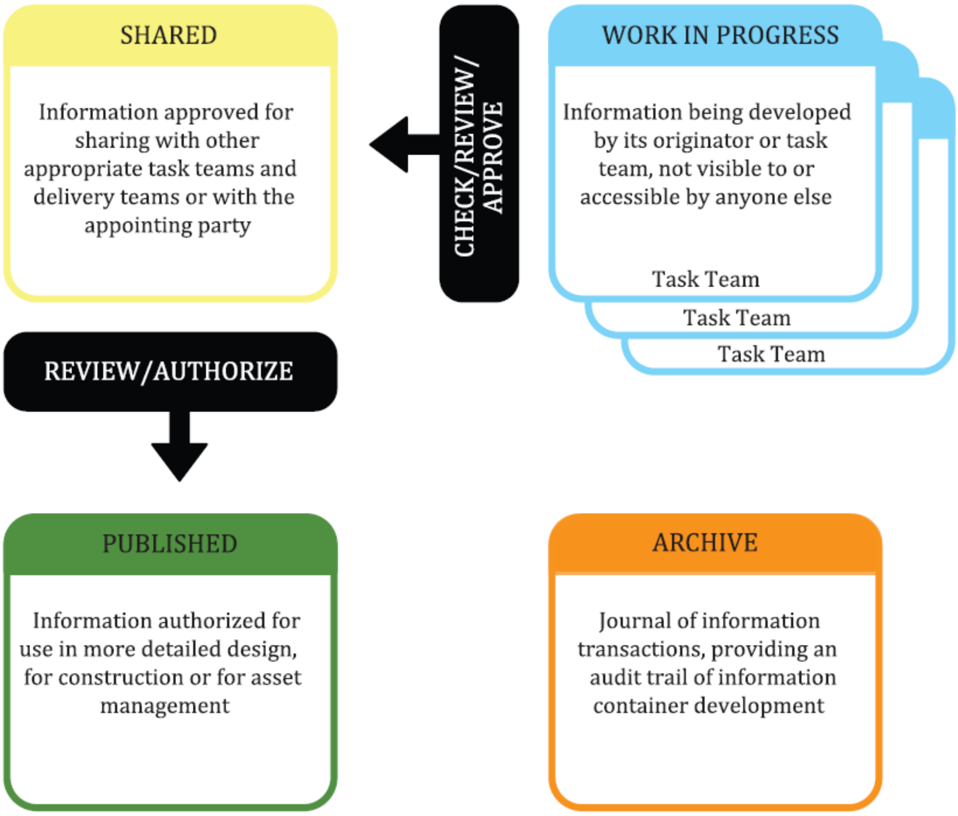


*Figure 10 - Common Data Environment concept (ISO, 2018a)*

## 2.4 Project Stages

Numerous plans of work are employed globally to guide clients through the stages of briefing, design, construction, handover, and use and in the majority of the countries, these plans of work are created by professional institutes or sector bodies (RIBA Plan of Work, 2020). The important points that distinguish the international plans of work can be summarized as follows:

- Some include tendering stages while others focus more on design
- Between two and four design stages are used
- Not all plans of work include the Briefing phase
- Not all plans of work take into account the building's life after construction

While there are differences between each of the plans of work, they all lean towards a common objective, to enable consistency from one stage to another, by providing the project team with a guide. For the purposes of this research, the RIBA Plan of Work 2020 is used, as it concerns one of the most recently published plans of work. The several project stages identified are illustrated in Figure 11.

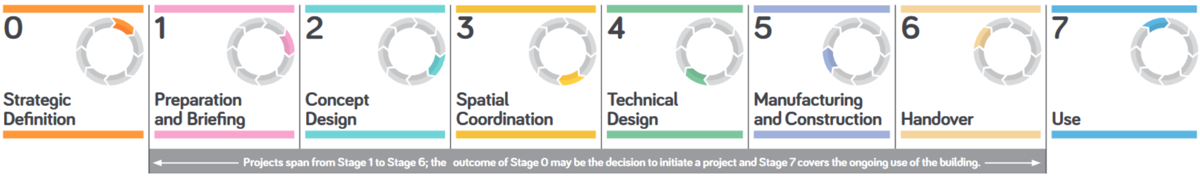


*Figure 11 - Project Stages (RIBA Plan of Work, 2020)*

During the Strategic Definition, the client's requirements are confirmed and at the Preparation and Briefing stage, the project brief is approved by the Appointing Party. Subsequently, the following three project stages refer to the design stage, where during Concept Design, the architectural concept is approved by the Appointing Party, followed by the spatial coordination of architectural and engineering information, which occurs during the Spatial Coordination stage. During the Technical Design stage, completion of all design information required for manufacturing and construction takes place. During the next stage, the manufacturing, construction, and commissioning are completed, followed by the Handover stage. Finally, the key elements of the Use stage consist of the efficient use, operation, and maintenance of the asset.

# 3. Research Methodology & Data Collection

In this chapter, the Research Methodology and Data Collection of the research are discussed. The case study context is given, consisting of the documentation review and semi-structured interviews. The different documents used, such as the Information Management Protocol, Exchange Information Requirements, Data Dictionary Schiphol (DDS), and the accompanied EIR Table are also analyzed. Furthermore, the reasons leading to the selection of the semi-structured interviews as part of the research methodology are presented, together with the participants' selection and context of shared questions.

## 3.1 Case Study Context

The case study approach enables thorough, in-depth examinations of complicated issues in the context of real-life settings. According to Yin (2009), this research methodology can be used to examine, explain, or analyze events or phenomena in their daily context. For this reason, a case study is often described as a "naturalistic" design, as opposed to an "experimental" design, which tries to control and manipulate the variable(s) of interest (Crowe et al., 2011). The key characteristics of the use of a case study are presented below (Lohman, 2022):

- Bounded case, defined in time, space, and activity
- Context-based study of a phenomenon
- In-depth investigation
- Multiple sources of evidence
- Research question depending also on non-numerical data

This research is conducted in collaboration with NACO, concerning an airport project, being identified as a practice-oriented research. The advantage of using a case study for practice-oriented research is that it is more flexible than other approaches. Such an approach focuses on the examination of the relationship between phenomena, context, and people while also enabling the capacity to accurately capture the participants' context. Moreover, it offers the freedom of choosing the desired method of collecting data, using interviews, documents, observations, questionnaires, etc. As a result, the origins of the phenomena are more clearly understood and are easier to explain to a non-specialist audience (Lohman, 2022). Furthermore, the case study's focus on an airport-specific project makes the findings more easily applicable to the field.

The case study in this thesis research focuses on the examination of documents provided by the AAS, as well as interviews, which are further analyzed below. Overall airports are considered complex organizations and more specifically, AAS needs to manage simultaneously multiple infrastructure with large passenger flows. AAS must therefore keep track of all of its assets in order to facilitate all of these ongoing operations and further maintenance activities. Since old assets are replaced and new ones are added every year, it is evident that a great amount of information must be stored and accessed whenever needed. However, in order to achieve consistency in every asset's information and to reduce any mistakes made, a proper information management procedure should be followed across the whole lifecycle, from the initial preparation and design to the construction, handover, and final use of the asset. This would not only lead to reducing time and cost during the project stages where the Design Appointed Party and Constructor Appointed Party are engaged, but it would also aid AAS in executing better asset management.

## 3.1.1 Documentation

The available documents that are analyzed in this research are the Information Management Protocol, Exchange Information Requirements, and the DDS accompanied by the EIR Table. An overview of each of the aforementioned document's content is provided below.

### *3.1.1.1 AAS Information Management Protocol*

The Information Management Protocol is considered a process-oriented document as it describes the way that a project should operate, including also the contractual agreements that must be followed regarding how the client and contractor should collaborate. It is composed by the Asset Management department of AAS prior to the start of each project in order to support the airport's vision on Asset Information Management and Digital Asset Information. AAS is working towards establishing BIM as an integral tool for the airport to develop assets, manage the knowledge about these assets in a structured way and eventually utilize it as a knowledge basis for asset management. As multiple stakeholders will use and exchange knowledge with the PIM and AIM model during the entire asset lifecycle, they inevitably need to follow a common path and work together in accordance with the AAS Information Management Protocol. Their approach towards the information delivery cycle is developed on the basis of the information management process that is proposed on ISO 19650-1:2018, as illustrated in Figure 12.

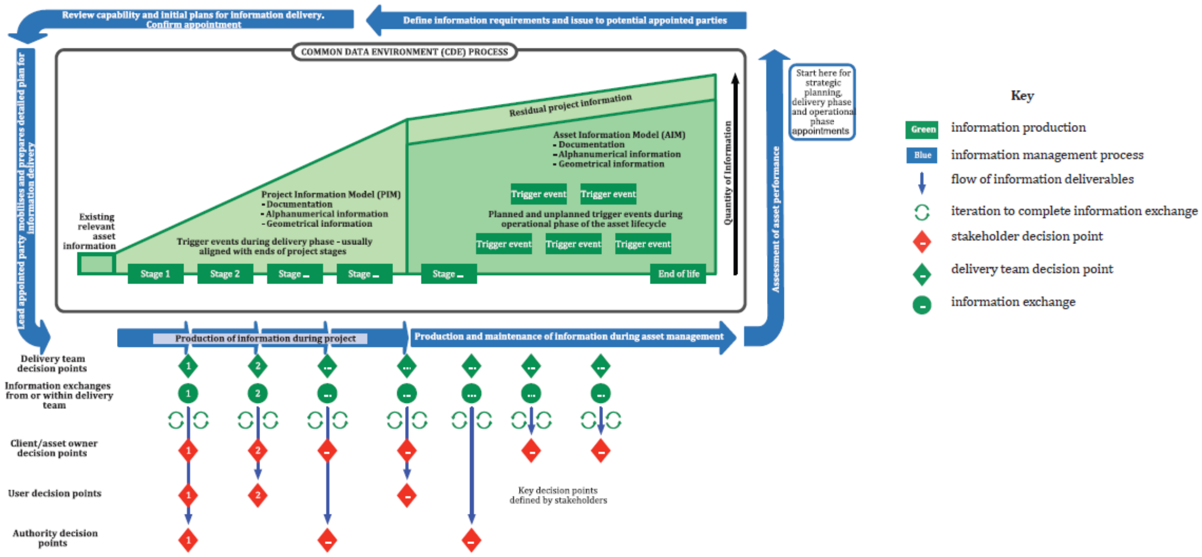


*Figure 12 - Overview of the information management process (ISO, 2018a)*

There are several coordination moments per project stage, during which information is exchanged and each project stage is concluded with a formal information delivery. Therefore, data is extracted from the building information model and presented to the client at key milestones to guarantee that the project is validated and regulated appropriately as it progresses. In most cases, the Appointed Party provides information to the Appointing Party, yet there are also moments where the opposite occurs. AAS considers six project stages as well as seven different information exchange moments, as presented in Figure 13. It is important to mention that the content of each information exchange is determined prior to the tender phase of the project by means of the Project EIR, and is analyzed in the following sections.

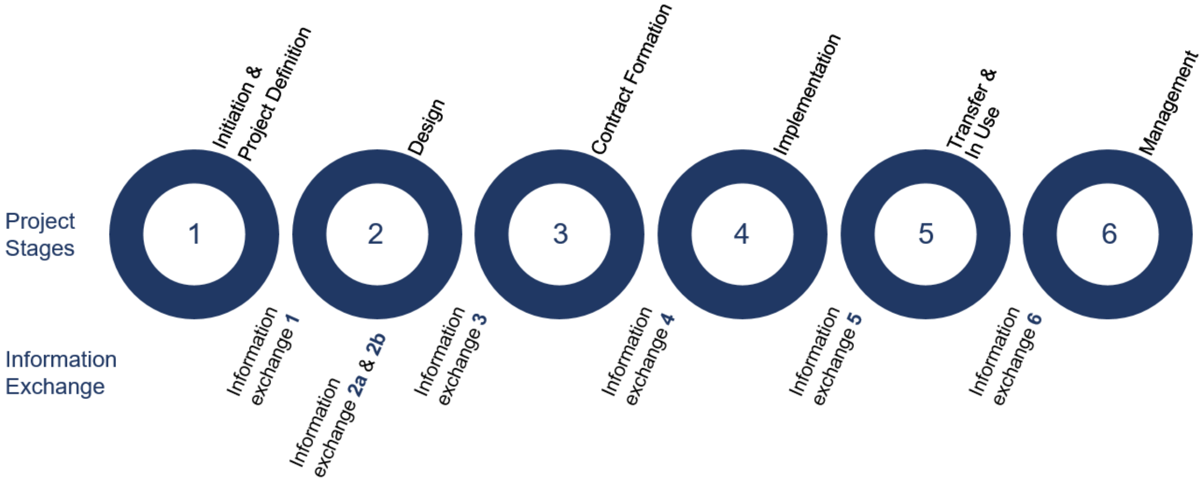


*Figure 13 - AAS Project stages & Information exchange*

Moreover, the roles, tasks, and responsibilities are included in the Information Management Protocol. In order to steer the collaboration on information management in the right direction, it is important to properly coordinate the tasks and responsibilities of the various parties. An overview of the typical roles involved in projects initiated by AAS is presented in Figure 14.

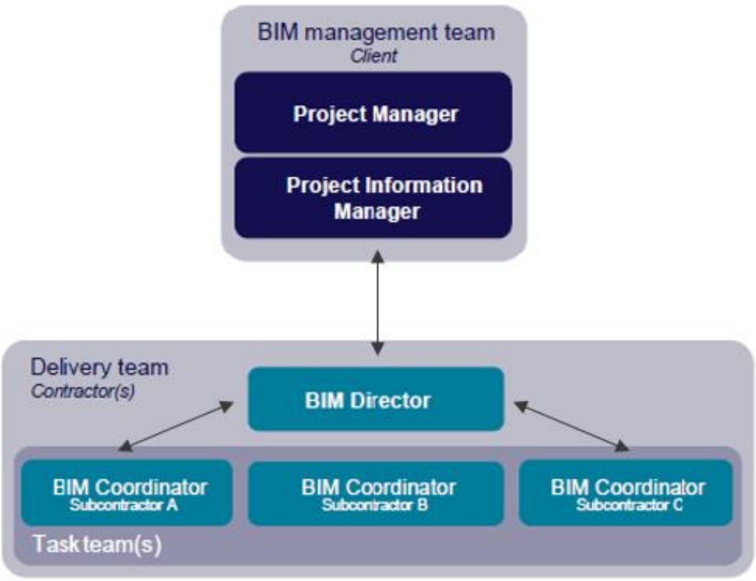


*Figure 14 - Overview of roles' division*

Both the BIM management team, on behalf of the Appointing Party, and the Delivery Team form the Project Team. However, it is crucial to mention that within the broader context of the Delivery Team, the Constructor Appointed Party is also included, being responsible for the actual construction and final project handover to the Appointing Party. In this research and in order to avoid any misunderstandings, the Delivery Team is separated into two categories, the Design Appointed Party who is responsible for carrying out the design, and the Constructor Appointed Party who is responsible for the actual construction.

Another aspect discussed in the AAS Information Management Protocol is the use of an exchange platform, essential for the exchange of information products per project. Access to the exchange platform is granted by the Appointing Party to the Appointed Party, including any sub-contractors. This exchange environment keeps also a version history, where the date and upload data for each version are registered, enabling the retrieval of a previous version of a file.

#### *3.1.1.2 AAS Exchange Information Requirements*

AAS requires accurate, consistent, standard, and organized asset information in order to perform asset management effectively throughout the whole lifecycle. Therefore, in order to ensure clarity over which information is supplied when and regarding the fundamental principles that apply, the EIR are set by the Appointing Party, prior to the start of a project. This document's overall objective is to define which objects, properties, and documents must be delivered during each information exchange, as well as the standards and norms that apply to objects, the required information and properties for each object, and finally the format in which the information must be delivered.

Prior to defining and specifying the information needed, it is crucial to understand the interrelation and cohesion of the requirements, documents, created models, and teams involved in the overall process. Regarding the documents, the Information Management Protocol acts as a starting point which together with the BIM Execution Plan (BEP), which is a document created by the Lead Appointed Party, describe how the project will work. This document lays down the mutual working and coordination agreements, as indicated in the Information Management Protocol, as well as the times of delivery of the required models. The EIR then outlines which products must be provided and how, in the various stages of the lifecycle, while simultaneously setting the requirements for the PIM. These requirements may also be established for the AIM regarding the nature of BIM models, BIM extracts, drawings and documents to be delivered as well as their ownership and use. In order to better understand the context of the requirements, it is important to comprehend the nature of PIM and AIM.

As mentioned before, the PIM is the information model created during the delivery phase, which is the part of the lifecycle when an asset is designed, constructed, and commissioned. The information requirements are expressed in terms of the project stages that both the Appointing and Appointed Parties have decided to use, including a long-term archive of the project, details of project geometry, location of equipment, performance requirements during project design, method of construction, scheduling, costing as well as information regarding installed systems, components, and equipment, as well as details of required maintenance during project construction. On the contrary, the AIM is the information model created during the operational phase, which is the part of the lifecycle when an asset is used, operated, and maintained. The information requirements are expressed in terms of foreseeable lifecycle trigger events such as planned or reactive maintenance, fire equipment inspection, component replacement, or change of asset management provider. Equipment registries, cumulative maintenance costs, installation and maintenance dates, information on property ownership, and other details that the Appointing Party considers important and intends to manage systematically, may be contained in the model.

The relationship between the aforementioned documents, models, and engaged teams is presented in Figure 15.

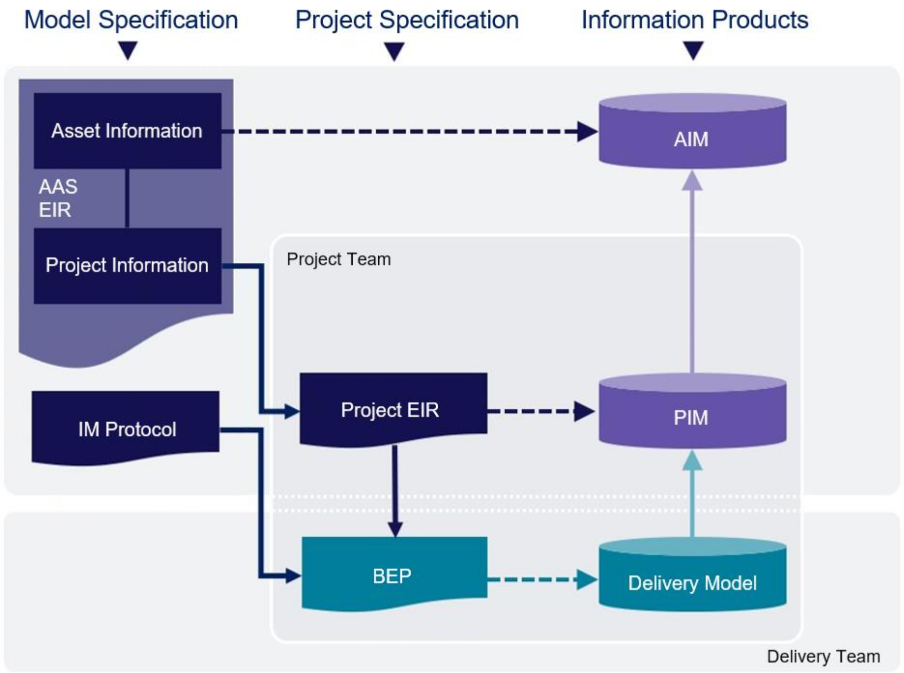


*Figure 15 - Relationship between documents, models and engaged teams*

The Appointed Party has the liberty to divide the produced BIM models into smaller, more specific ones that are shared with the Appointing Party throughout the information exchange moments. However, to ensure that they are appropriately positioned in relation to one another when they are integrated into an aggregate BIM model, all sub-models must be positioned and orientated in accordance with the uniform coordination system that AAS has established.

The EIR is accompanied by a number of appendices that provide complementary information on the information requirements. The DDS and the EIR Table are two of the appendices that are examined and utilized in this research.

#### *3.1.1.3 Data Dictionary Schiphol & EIR Table*

The DDS is a platform established by AAS which contains the description and specifications of all information products requested at each information exchange. More specifically, this includes the content, the standards with which the products must comply, as well as the format of delivery. Furthermore, the DDS provides also access to an overview of each registered asset's generic and specific characteristics, which are dependent on the asset type. Finally, it includes guidelines for the correct decomposition/coding and classification of the objects included, according to the applicable standards of the AAS. It is important to mention that access to DDS needs to be requested and is solely granted to the team members that are involved each time in the project, thus the Delivery Team. AAS has access to DDS regardless of the situation since it serves as the Appointing Party.

The EIR Table supports the DDS and contains an overview of information products to be delivered per information exchange moments as well as the template file registered.

### 3.1.2 Semi-structured Interviews

In order to get a complementary, yet more detailed insight into the way that the different parties engaged throughout the project stages, produce, interpret and share information with each other, semi-structured interviews are selected as part of the research methodology. The main goal of utilizing semi-structured interviews as part of the data collection is to gain important information from key participants with knowledge of the subject discussed (DeJonckheere & Vaughn, 2019). This form of interview is preferred, instead of structured interviews, as it provides a better approach to answering the research question and sub-questions. As this study is considered a practice-oriented research, any closed responses should be avoided in order to focus on obtaining information based on the experience and beliefs of the respondents, by means of qualitative, open-ended data. Furthermore, according to DeJonckheere & Vaughn (2019), the characteristics of loose and flexible structure, iterative process instead of generating new questions for each participant, the ability to schedule in advance, and the deep exploration of participants' thoughts are some additional advantages of this method.

Table 4 provides a summary of the steps that ought to be followed according to DeJonckheere & Vaughn (2019) in order to carefully design and conduct the semi-structured interviews.

*Table 4 - Steps from designing to conducting semi-structured interviews*

| Steps | Description |
|---|---|
| Step 1 | Establishment of purpose and scope of research |
| Step 2 | Participant selection |
| Step 3 | Consideration of ethical issues |
| Step 4 | Planning and organization of time and necessary resources |
| Step 5 | Formulation of questions and interview guide |
| Step 6 | Establishment of trust |
| Step 7 | Interview conduction |

The purpose of the interviews is to get the participants' view on the information management processes that are used in a project, while also taking into account the type and format of information needed, as well as the organizations' digital ambitions. Therefore, the participants are selected in such a way as to provide a sample of the three major parties engaged throughout the project stages. Two participants with different roles in the Appointing Party domain, three participants with different roles in the Design Appointed Party domain and finally, two participants with different roles in the Constructor Appointed Party domain were chosen. As for the ethical issues, the interviewees were informed prior to the start of the interview of the study purpose and research outcome and were assured that their answers would not be used for any other purposes. Moreover, despite all of the interviews being conducted in a virtual environment, they were not recorded, as another way of preventing any concerns over ethical issues.

The questions were formulated in such a way that the interview could last approximately one hour and were shared with the participants beforehand. Moreover, in order to avoid any confusion over the project stages and to establish a common ground, they were informed that the RIBA Plan of Work (2020) project stages have been used in this research. Prior to answering the questions, each participant was asked to briefly describe his background and professional experience. According to the subject that was covered, the questions were divided into three main categories (Information and Documentation, Information requirements, BIM use, and Project stages). However, it should be mentioned that there was a slight differentiation in the questions that were distributed to the three major parties since some subjects were more relevant to certain parties.

Overall, the questions shared with the representatives of Appointing Party aimed at identifying the process of defining the information requirements as well as the challenges of sharing and receiving information from the other parties involved in the process. Moreover, questions regarding the desirable format of information, information storage, and digital ambitions were also part of the interview. Subsequently, the questions shared with the representatives of the Design Appointed Party and Constructor Appointed Party aimed at understanding the process and potential challenges of producing and sharing the deliverables. Furthermore, questions with regard to the format of information, information storage as well as the digital ambitions and collaboration between all the parties involved throughout the process were also asked. The exact format and type of questions that have been used in the semi-structured interviews, as well as the list of interviewees, can be found in Appendices I and II respectively.

Therefore, the adoption of semi-structured interviews as part of the research methodology gave the opportunity of gaining important insight into the participants' perspectives on the information management processes, which complementary to the documentation review, would lead to the design of a more solid process map.

## 3.2 Case Study Findings

The case study findings focus on addressing the four proposed sub-questions. The documentation review provides a solid answer to the processes that are followed as well as the general type of information needed per project stage and the usual formats used. Moreover, the different parties involved throughout the whole process are presented. The analysis of the semi-structured interviews, with the responses being grouped in broader categories and subsequently by engaged party, provide complementary information on the first three sub-questions. Moreover, the platforms used for information storage are defined in greater detail, as well as the role division of the parties involved. Finally, digital ambitions are also discussed, thus answering the final sub-question.

### 3.2.1 Documentation

The examination of the AAS Information Management Protocol, Exchange Information Requirements as well as the Schiphol's Data Dictionary and corresponding EIR Table enable the analysis of the processes and determination of type and format of an asset's information through the several project stages. Consequently, the first three sub-questions may be addressed.

#### *3.2.1.1 AAS Information Management Protocol*

Considering the different roles that are involved in the process, forming the Project Team, their tasks and responsibilities ought to be determined. This is a crucial preliminary step for this research since it aids in gaining a better and more detailed understanding of the team division and eventually the overall information that each member handles.

More specifically, within the Delivery Team, the Lead Appointed Party (mentioned as "BIM Director" in Figure 13) is responsible for creating the BEP to ensure the successful application of BIM within the project. Therefore, its tasks also include recording the working and coordination agreements and coordinating the BIM process. The Lead Appointed Party is also responsible for the overall coordination of all aspect models and the thorough examination of their accuracy, thoroughness, and quality in accordance with the project's requirements. Each Appointed Party is responsible for producing the information related to its tasks and reporting it to the Lead Appointed Party. The feasibility, aesthetic design, calculations, and manufacturability are tasks that need to be fulfilled by the Delivery Team.

On behalf of the Appointing Party, the BIM Management Team consists of the Project Manager of the project, who is guided and supported by the Project Information Manager for BIM-related issues. More specifically, the Project Manager is accountable for making decisions and approving documents and proposals. The Project Information Manager collaborates with the Project Manager and BIM specialists of the Delivery Team for the development of a well-functioning process with structured BIM models and qualitative information in accordance with the Information Management Protocol and the corresponding EIR. Moreover, the Project Information Manager verifies the accuracy and completeness of the information models before reporting any issues or findings back to the Lead Appointing Party and subsequently to the corresponding Appointed Party.

After defining the several parties involved in the process, the context of the different information exchanges needs to be analyzed. The parties responsible for the production of information and the recipients of information, per information exchange, are presented in Table 5.

*Table 5 - Overview of AAS information exchange and involved parties*

| Information Exchange | Sender | Receiver |
|---|---|---|
| Information Exchange 1 | Appointing Party | Design Appointed Party |
| Information Exchange 2a | Design Appointed Party | Appointing Party |
| Information Exchange 2b | Design Appointed Party | Appointing Party |
| Information Exchange 3 | Design Appointed Party | Appointing Party |
| Information Exchange 4 | Appointing Party | Constructor Appointed Party |
| Information Exchange 5 | Constructor Appointed Party | Appointing Party |
| Information Exchange 6 | Constructor Appointed Party | Appointing Party |

As presented in the previous table, three main parties are involved during the whole process, each one possessing a different role in the information exchange moments. Therefore, each information exchange's context and main activities of the corresponding project stage are examined in order to gain a better understanding of the process. Therefore, an answer is proved to the first sub-question.

### Initiation & Project Definition Stage

The first stage aims at identifying and documenting the expectations, needs, and high-level goals of the Appointing Party while simultaneously examining the project's viability in order to satisfy these demands. The main output of this stage is the development of the Information Management Protocol and a customized version of the Exchange Information Requirements based on the project's needs. Moreover, based on the project's EIR, it is determined which source of information is required for the project. The existing information products, such as documents, lists, and drawings are supplied by the Appointing Party, specifying also the asset attributes that must be provided by the Appointed Party.

At the end of this stage, information exchange 1 occurs between the Appointing Party (information sender) and the Design Appointed Party (information receiver).

### Design Stage

AAS has identified four different sub-phases during the main Design stage.

The primary objective of the first phase is to create a global representation of the project that provides a thorough understanding of the solutions on an urban scale and the main shape and main layout of the buildings as well. There is no information exchange following the completion of the phase.

The purpose of the second phase is to create a global representation of the project that accurately depicts its location, the functional and spatial structure, uses, utilities, architectural appearance, and integration of structural and installation elements. At the end of the second phase, information exchange 2a occurs between the Design Appointed Party (information sender) and the Appointing Party (information receiver). The submitted models and data are examined by the Appointing Party for content quality, accuracy, and completeness.

The third phase aims at developing a detailed representation of the project to provide an accurate representation of the appearance, the internal and external structure, the use of materials, the finishing and detailing, the structural design, and the nature and capacity of the installations. At the end of the second phase, information exchange 2b occurs between the Design Appointed Party (information sender) and the Appointing Party (information receiver). The Appointing Party then reviews the delivered models and data for content quality, correctness, and completeness.

The fourth phase includes the elaboration and technical specification of the project in all its aspects so that the final price for the execution can be calculated. At the end of the second phase, information exchange 3 occurs between the Design Appointed Party (information sender) and the Appointing Party (information receiver). The Appointing Party once again reviews the delivered models and data for content quality, correctness and completeness and if no objections are raised, a unique code is generated for each new asset developed.

Contract Formation Stage

In this phase, the actual work that needs to be conducted is contractually specified. At the end of this stage, information exchange 4 occurs between the Appointing Party (information sender) and the Constructor Appointed Party (information receiver) in order to initiate the actual construction.

Implementation Stage

AAS has identified three different sub-phases during the main Implementation stage.

The primary objective of the first phase is to determine the method to be followed for the project realization. During this phase, the Appointing Party assesses whether all the work is still being developed according to the initial project requirements. There is no information exchange following the completion of the phase.

The purpose of the second phase is to proceed with the actual realization of the project on-site. During this phase, the Appointing Party assesses whether all the work is still being developed according to the initial project requirements. There is no information exchange following the completion of the phase.

The third phase aims at reporting the inspection of the completed work to assess if it is complete and safe for use. At the end of this stage, information exchange 5 occurs between the Constructor Appointed Party (information sender) and the Appointing

Party (information receiver). The Appointing Party reviews the delivered models and data for content quality, correctness, and completeness

Transfer & In Use Stage

This stage aims at transferring the final information products in order to gain the final acceptance of the actual work carried out. The Appointing Party conducts a final review for content quality, accuracy, and completeness of the provided data. At the end of this stage, information exchange 6 (the final one) occurs between the Constructor Appointed Party (information sender) and the Appointing Party (information receiver). The project is then put to use.

Management Stage

The purpose of this stage is to use the geographic and non-geographical information and data in the Appointing Party's information systems to produce an optimal return on the assets based on a balance of function, costs, and risks. Additionally, the information may also be utilized to monitor and improve the operation and performance of the assets produced. As this stage is considered the last one, there is no information exchange following the completion of the phase.

The analysis of the content of each project stage as described by AAS, provides an insight into the processes that need to be followed, describing also the information context that is produced and delivered.

Moreover, another issue described in the AAS Information Management Protocol is the transfer of digital files. More specifically, the BIM source file consists of several separate models that are coordinated with each other. Therefore, all the different models that are created by each Appointed Party are gathered and delivered to the information receiver. Last but not least, AAS uses a platform to exchange information products. During each information exchange, the corresponding sender uploads the numerous information exchange items to the platform for review by the Project Team. No external parties can access it and each participant has certain rights associated with their role within the project. Since this exchange platform facilitates access to earlier versions of the uploaded files, there is less chance that the information will become mixed up leading to data loss and eventually project delays.

#### *3.2.1.2 AAS Exchange Information Requirements*

One of the basic topics addressed in the AAS EIR is the transfer of digital files. The required form of the information product depends on the asset and information exchange moment and is specified in the DDS. Generally, the delivered information products are derived directly from the BIM model or to the greatest extent feasible linked to it, making them available via this model. Regarding the BIM files, all source files as well as any related extracts such as drawings, lists, IFC extracts, documentation, etc. are transferred completely and without limitations. Moreover, each delivered information product ought to be accompanied by a file register, containing a list of all delivered files and associated data.

AAS requests information for each asset that is represented in the models and subsequently stores the data in its asset information systems. With regard to this information, there is a distinction between general asset characteristics that apply to all asset types and specific asset characteristics that are dependent on the type of asset. However, regardless of the type of asset, each object in every BIM model ought to contain a unique code, as mentioned before, which is retained when the model is updated or revised. Many of these assets, together with the accompanying characteristics, unique codes, and information required, may already be found in the DDS. It is important to mention that the Appointed Party is responsible for generating and assigning a unique code to each new object that is created in the BIM model whenever a new asset that is not included in the DDS is developed. In that case, the Appointed Party should also provide an asset list of all the new assets, which is generated from the BIM model.

Following, the level of information need that is requested by the AAS during each information exchange moment is thoroughly analyzed in EIR. Starting from the geometrical information, the level of information need of model elements within a BIM model indicates what dimensional, spatial, quantitative, qualitative, and other information has been added to a model object and also how detailed the information is. The targeted level of information need for each information exchange, regarding the geometric information, is listed below. Therefore, an answer is provided to the second sub-question.

#### Information Exchange 1

This information exchange refers to the delivery of information requirements from the Appointing Party to the Lead Appointed Party. The DDS is also provided as part of the appendices, thus geometrical information is provided for the objects registered. However, no modelling is required at this point.

#### Information Exchange 2a

Since the project stage prior to information exchange 2a consists of the preliminary design, objects are modelled in both coarse and grouping forms, but they merely act as space reservations. The geometrical information attached consists of global dimensions, quantities, shape, location, and orientations.

#### Information Exchange 2b

Following the more detailed design, objects and their grouping are modelled in a detailed way, while also being mutually coordinated. They are also materialized and accurate in terms of dimensions, quantities, shape, location, and orientations.

#### Information Exchange 3

With the technical design having been executed, objects and their grouping are modelled on a more technical level, including parts such as supports and connections necessary for the coordination of the supported objects. At this stage of information exchange and without the aid of non-geometrical information, such as notes or reports, the model may be used to directly measure the size, quantity, shape, location, and orientation of the object.

### Information Exchange 4

This information exchange refers to the formation of official agreements, specifying the work to be followed, yet no modelling or object information is required at this point.

### Information Exchange 5

After the project has been commissioned, all the objects are mutually coordinated in order to depict the completed project as it has actually been realized. Moreover, they are also materialized and accurate in terms of dimensions, quantities, shape, location, and orientations. This information exchange comprises of a thorough presentation of the project that gives a good understanding of its delivery form, internal and external structure, exact use of material, finish and detailing, structural design, and last but not least the nature and capacity of installations.

### Information Exchange 6

For his information exchange the same level of information need as described above in information exchange 5.

*Table 6 - Overview of geometrical information requested by AAS per information exchange*

| Information | Information Exchange | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2a | 2b | 3 | 4 | 5 | 6 |
| Dimensions | - | x | x | x | - | x | x |
| Quantity | - | x | x | x | - | x | x |
| Shape | - | x | x | x | - | x | x |
| Location | - | x | x | x | - | x | x |
| Orientation | - | x | x | x | - | x | x |
| Coordination | - | - | x | x | - | x | x |
| Size | - | - | - | x | - | x | x |
| Supports | - | - | - | x | - | - | - |
| Connections | - | - | - | x | - | - | - |
| Structure | - | - | - | - | - | x | x |
| Material | - | - | - | - | - | x | x |
| Finish | - | - | - | - | - | x | x |
| Detailing | - | - | - | - | - | x | x |
| Structural | - | - | - | - | - | x | x |
| Installations | - | - | - | - | - | x | x |

Moreover, with regard to the non-geometrical information, the L level of information need of model elements within a BIM is associated with the features that are linked to an object and their attached value. The targeted level of information need for each information exchange, regarding the non-geometrical information, is listed below.

Information Exchange 1

This information exchange refers to the delivery of information requirements from the Appointing Party to the Lead Appointed Party. The DDS is also provided as part of the appendices, thus non-geometrical information is provided for the objects registered. However, no modelling is required at this point.

Information Exchange 2a

Since the project stage prior to information exchange 2a consists of the preliminary design, the non-geometrical information associated with the objects refers to basic properties with regard to the interpretation of the design principles, as well as the basic properties of the object.

Information Exchange 2b

Following the more detailed design, the objects should be enhanced with performance requirements in addition to the basic properties from the prior information exchange. This information concerns the global technical elaboration and specification of the structure in all its aspects, based on which global cost and system calculations can be estimated.

Information Exchange 3

With the technical design having been executed, non-geometrical information should be attached to the objects in a way that the design can be considered to be the technical starting point. Therefore, validated information for coordination and performance requirements should be provided to objects in order for the object to fulfill the project's performance requirements. This information concerns the technical elaboration and specification of the construction in all of its aspects so that a final price and contract can be determined.

Information Exchange 4

This information exchange refers to the formation of official agreements, specifying the work to be followed, yet no object information is required at this point.

Information Exchange 5

After the project has been commissioned, the non-geometrical information attached relates to the properties regarding the interpretation of the design principles, as well as the basic properties of the object, and last but not least, the properties for managing the object during the final stage.

Information Exchange 6

For his information exchange the same level of information need is achieved, as described above in information exchange 5.

*Table 7 - Overview of non-geometrical information requested by AAS per information exchange*

| Information | Information Exchange | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2a | 2b | 3 | 4 | 5 | 6 |
| Basic Properties | - | x | x | x | - | x | x |
| Interpretation of Design Principles | - | x | x | x | - | x | x |
| Technical Elaboration | - | - | x | x | - | - | - |
| Technical Specification | - | - | x | x | - | - | - |
| Properties related to Management | - | - | - | - | - | x | x |

### *3.2.1.3 Data Dictionary Schiphol & EIR Table*

DDS can be characterized as a virtual library, which contains all the objects that are modelled throughout the various AAS projects. Therefore, it serves as a basis where all the information requirements per asset are demonstrated. More precisely, four primary categories relating to each asset may be accessed and analyzed, as it can be observed through a more detailed review of the platform. More specifically, those are the following:

- **General characteristics**, including the label and coding of each, the asset's definition, and the type of object when modelling
- **Properties**, including asset characteristics, the asset's relationship with other assets, and the information products requested per information exchange
- **Incoming Properties**, including some specific asset characteristics
- **History**, including all the modifications that have been made

For the purpose of this research and as the main focus lies on information management, the first two categories are analyzed. The general characteristics provide a more detailed understanding of an asset's definition so that its functionality can be determined. Subsequently, the information products extracted from the properties, provide a good representation of the products that are requested from the Delivery Team during the several information exchange moments.

Furthermore, the DDS and the EIR Table can be used simultaneously in order to create a detailed list of the exact documents to be requested from the Appointed Party. More specifically, the EIR Table provides a better overview of the document's type and content per chosen asset and information exchange moment. This table lists numerous documents, yet they are organized into broader categories according to their context. The identified categories are the following:

- **A**: Applications, permits, assignments
- **B**: Calculations
- **C**: Certificates of approval/defectiveness

- **D**: Dates, Lists
- **E**: Material and supplier information
- **F**: Models
- **G**: Multimedia
- **H**: Plans
- **I**: Project Documents
- **J**: Reports of inspections, measurements, and controls
- **K**: Technical diagrams
- **L**: Technical drawings

However, not all of these categories are required during each information exchange moment. The correspondence between these categories and the information exchange moments are presented in Table 8.

*Table 8 - Overview of document's categories per information exchange as requested by AAS*

| Categories | Information Exchange | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2a | 2b | 3 | 4 | 5 | 6 |
| A | x | - | x | x | x | x | x |
| B | x | x | x | x | x | x | x |
| C | x | x | x | x | x | x | x |
| D | x | x | x | x | x | x | x |
| E | x | x | x | x | x | x | x |
| F | x | x | x | x | x | x | x |
| G | x | x | x | x | - | x | x |
| H | x | x | x | x | x | x | x |
| I | x | x | x | x | x | x | x |
| G | x | - | x | - | x | x | x |
| K | x | x | x | x | x | x | x |
| L | x | x | x | x | x | x | x |

Upon selection of an asset, the information products to be delivered can be identified. This overview in combination with the information gathered from the Information Management Protocol and Exchange Information Requirements shed the light on the processes as well as on the type, format of information, and responsible parties for its distribution during the information exchange moments, thus providing an answer to the first three sub-questions.

### 3.2.2 Semi-structured Interviews

In total seven semi-structured interviews were completed, with the sample of participants being as diverse as possible. Different roles within the same organization and external parties were interviewed in order to obtain a better insight into the way that parties collaborate throughout the whole lifecycle. The conduction of the interviews aimed at providing complementary information on the first three sub-questions regarding the processes, type of information and its distribution, as well as format and platforms used. The expertise of all the professionals involved during the different project stages would be of great added value, since it would aid in thoroughly comprehending how the construction industry operates in practice, in addition to the already applicable standards. Lastly, the final sub-question, regarding each organization's digital ambitions, may also be addressed.

Although some questions were altered depending on the parties that were interviewed, the semi-structured interview findings are presented in categories. Therefore, the questions can be grouped with regard to the topic that is being addressed as the participants provide answers to a similar topic, yet from a different perspective.

As a first step, an overview of the participants and their roles is illustrated in Table 9. Their contact details can be found in Appendix II.

*Table 9 - Overview of participants' roles*

| Interviewees | Corresponding Party | Role | Role explanation |
|---|---|---|---|
| Interviewee no.1 | Design Appointed Party *(NACO)* | Lead Engineer Airport Building Design | Involved in Technical Design stage, being at the "end of the line" |
| Interviewee no.2 | Appointing Party *(AAS)* | BIM Advisor | Involved in Use stage but also in commissioning of new projects. Provides strategic advice and guidance on how to bring certain thoughts into practice |
| Interviewee no.3 | Appointing Party *(AAS)* | Asset Owner | Owner of automatic (closing) installations, referring to both the asset and information attached to it |
| Interviewee no.4 | Design Appointed Party *(Royal HaskoningDHV)* | Project Manager | Point of contact for the Appointing Party, also performing feasibility studies. In a big project also engaged in the design stages |
| Interviewee no.5 | Constructor Appointed Party *(SPIE Nederland)* | Information - BIM Manger | Focusing on construction of installations |
| Interviewee no.6 | Design Appointed Party *(NACO)* | BIM Manager | Lead Appointed Party, also responsible for the creation of BEP |
| Interviewee no.7 | Constructor Appointed Party *(Heijmans N.V.)* | BIM Coordinator | Responsible for digital processes, engaged in both Project and Asset Management departments |

As it is shown in the aforementioned table, all of the participants hold different backgrounds and are engaged in different stages of the process. Therefore, the interdependencies between the different parties engaged can also be examined. However, it is important to mention that Interviewee no. 7 provides information both on behalf of the Constructor Appointed Party as the company is also able to execute projects, yet its main role is to serve as the maintenance contractor of AAS. However, the responses are included in the Constructor Appointed Party section and subsequently placed appropriately in the final outcome.

Subsequently, the questions are categorized into the following groups, with the responses being given in the same sequence as the engagement of the three main parties in the process. Consequently, the responses from the Appointing Party are provided first, then those from the Design Appointed Party, and lastly those from the Constructor Appointed Party.

- **Q.1: What is the perception of information management, information requirements definition, and EIR as a means of their establishment?**

  **Interviewee no. 2:** There are high ambitions in defining all the information requirements but gathering everything is intense and time-consuming. The EIR is helpful but it is mostly focused on the asset management stage. Therefore, there could be a CDE at the beginning of a project in order to integrate multiple parties and share information with each other.

  **Interviewee no. 3:** Information management is a challenge as AAS requires a lot, thus often certain aspects might be missing. For example, information needs to be stored and traced back but also verified on the field. Regarding the information requirements, standards that refer to the information model are essential. Overall every project requires the same information, yet later during the design stages more complex information is needed. The EIR present adequately the type of information as well as the type of deliverables and goals that ought to be achieved.

  **Interviewee no. 1:** The information requirements definition is quite a broad subject. However, it already existed in the past, yet requirements were not defined in paper. Now, tools are used and information requirements are stored in different ways and formats. The same can be applied to all types of projects, yet some additional requirements must be applied in order to make a project unique. The EIR support adequately the information requirements, yet the problem is that for a different type of buildings there are several different assets that need to be defined. Therefore, the process that should be followed starts with defining the project, describing the type of assets that need to be designed, defining the type of design (rough or detailed), and finally the main components that compose this asset.

  **Interviewee no. 4:** Defining the information requirements is very helpful especially if you want to ensure a good process. It prevents misunderstandings otherwise the different parties would interpret them themselves and then the Appointing Party would argue that they do not comply with what they have requested. The EIR might be a big document, yet it is helpful for all the advisor parties as it clarifies the deliverables.

  **Interviewee no. 6:** Establishing the information requirements is essential as it gives the starting point. The better the EIR are defined, the better project is delivered in the end. However, EIR tend to focus mostly on the handover and other information that the designer or contractor requires is not often included.

**Interviewee no. 5:** Defining the information requirements is a very important and controlled work and should be coherent. However, there is often a gap between the parties that are involved during the design and the ones involved in the construction. The requirements are adequate as they are represented in the EIR, yet they use a lot of forms. Therefore, they need to be connected to each other.

**Interviewee no. 7:** Establishing the information requirements is the most important step in the process. However, the EIR are not always adequate as some information might be missing. In this case, the parties that receive the EIR need to do research on what disciplines the Appointing Party wants to include and then create a list with the information that needs to be requested. In case this information is not supplied to them then they need to communicate again with the Appointing Party.

- **Q.2: What are the organization's role division and responsibilities?**

**Interviewee no. 2:** There are two different departments in AAS, the Asset Management department and the Project Management department. The first one forms the requirements and delivers them to the other department for translating them into project-specific. The Project Management department is also responsible for handing over the information from the project to the asset phase and during the handover checks the deliverables as well. The Asset Management department performs only the high inspection of the process.

**Interviewee no. 3:** The Asset Management department is responsible for approving the physical design and defining the type of information that they want to achieve while also managing the information in the systems. The Project Management department is responsible for delivering the information and checking its quality as it is important to ensure that all the information products are in line with what is actually constructed.

**Interviewee no. 4:** In a bigger project, a Project Manager is required, accompanied by the Project Architect. Other roles involve the BIM Manager who creates the BEP and is responsible for the overall coordination, the BIM Coordinator as well as BIM Modellers.

- **Q.3: What is the necessary information to be established?**

**Interviewee no. 3:** It is important to focus on functionalities in order to ensure that every time the right type of asset can be selected. Other types of information that need to comply with the law ought to be added, e.g. specifications.

**Interviewee no. 6:** Information about the as-built situation and already existing information is crucial. This could be achieved if the Appointing Party hands over the AIM model, 3D scans, and any other type of as-built data. Moreover, geometrical and non-geometrical requirements and scope are required, along with the BIM Protocol and information about the CDE, the role of the advisor, level of information, and level of detail.

**Interviewee no. 5:** Most of the time what is already provided is good but the transition from the design to construction ought to be checked. The information missing refers to the as-built information. Most of the existing information is outdated and needs to be transferred in a digital form. A model containing this information should be created and should be constantly updated with information from the actual construction.

**Interviewee no. 7:** It is important to get information related to maintenance. However, the maintenance engineers are already aware of the basic information required to maintain an asset.

- **Q.4: What are the difficulties when defining and sharing the information requirements?**

**Interviewee no. 2:** Currently the requirements are defined based on the output that the Appointing Party wishes to deliver. However, the information should be used and thus reused as the cost increases every time information is recreated. The information may not always be on the optimal level or it can even be missing. Finally, not all processes are adequately defined, more specifically when considering information validation.

**Interviewee no. 3:** The main difficulty is that in the end the right product needs to be delivered.

**Interviewee no. 1:** If information requirements are not established in a document, they have to be interpreted based on the level of experience. However, documents with similar information already existed in the past.

**Interviewee no. 4:** The Delivery Team may phase difficulties if the requirements are not clear or if there is information missing. Moreover, when several stakeholders are engaged with each one providing his own requirements, this results in a conflict.

**Interviewee no. 6:** If information requirements are not established in a document, they can also be interpreted from office and corporate standards which are extracts of the ISO 19650 standards. This is also possible by applying best practices and then asking the Appointing Party for validation. However, the main difficulties that might occur when receiving the information requirements are actually not receiving information or receiving contradictory information that does not match in the different formats that are delivered, something that occurs with the as-built information. Moreover, it might be the case that the requirements are not well thought through or the Appointing Party might be over asking.

- **Q.5: How this procedure can be improved?**

**Interviewee no. 2:** It is important to keep track of the information in order to reuse it, while also considering the history, decisions made and requirements to be used in a new project. It is important to perform quality control when information is delivered, as parties to whom the information is shared need to be able to trust it in order to avoid redoing the same tasks. There is no standard to ensure that, yet a team can be appointed in order to perform quality checks and verify the information's accuracy. Moreover, each information product supplied by the Delivery Team must meet the requirements and this party is responsible for the validation plan. Finally, it is important to ensure that the right party is engaged throughout the correct project stage and define the right workflow for approval.

**Interviewee no. 4:** Every advisor needs to review the requirements to make decisions. Everyone should work on the same type of document and be able to track the changes made.

**Interviewee no. 6:** More collaboration is needed between the parties in the Preparation and Briefing stage. A client's representative might be also appointed as a counterpart.

- **Q.6: What is the type and format of the deliverables that are produced and subsequently shared?**

**Interviewee no. 2:** Not everything can be put in BIM. Schematics, BIM models, CAD formats, and documentation with standards are equally important.

**Interviewee no. 3:** At the end of the Handover stage, an overview of the asset list, as well as documents are expected to be delivered by the manufacturer. The BIM model is also required from the design team. It is very important to make relations between the documents and the physical assets, thus AAS has created a platform where by selecting an asset, the documentation connected to it is shown.

**Interviewee no. 5:** At the end of Manufacturing & Construction stage information with regard to legal issues and manuals for the objects are delivered, as well as IFC models that are completed with all the parameters and validated. During the Handover stage, nothing major should be done. Ideally, the deliverables should follow a more open structure, yet this should be addressed in the future.

**Interviewee no. 7:** At the end of Manufacturing & Construction stage testing/documentation/certificates are delivered as it is the most important stage in order to check if the project has all the deliverables. First, the concept version is delivered, then the Appointing Party applies remarks and finally, the final version is handed over. During the Handover stage, all the deliverables are shared, meaning the documentation to build from the end of the Design stage and everything from the Manufacturing & Construction stage. However, that does not imply that they will meet the maintenance requirements.

- **Q.7: What are the difficulties when producing the deliverables?**

**Interviewee no. 1:** It is important to focus on the distribution of information from one person to another as the tools and simplicity to place the appropriate data in the correct place are missing. Moreover, the integration of the various sub-models created by the different teams engaged during the design stages (Building, Structure, and Installations team) need to be successfully integrated. BIM can be seen as a growing pain as products are still delivered in two forms, both as paper (reports) and models. This leads to information doubling as models include certain information which is repeated in other documents. Furthermore, documents that contain information about the representation of an asset, schedule, drawing with description, material, number, and technical description have no life connection with the model. That leads to repetition of some information and even mismatch.

**Interviewee no. 4:** During the review, a lot of stakeholders may want to alter part of the requirements and the design. However, changes are difficult due to the tight schedules, technical obligations, and from a financial perspective as well.

**Interviewee no. 6:** Sometimes the contractor is not content with what is delivered to him. Also, depending on the delivery teams that are engaged, there might be some challenges if they are on a different BIM level as efforts might have been underestimated.

**Interviewee no. 5:** Especially in large and complex projects the requirements that the different parties request may not be in balance, because the designer might focus on aesthetics while the contractor desires a feasible and solid construction.

**Interviewee no. 7:** Regarding the as-built asset deviating from the original design, this might occur only in terms of its position, not the asset itself. Therefore, this does not affect the calculations or maintenance.

- **Q.8: How this procedure can be improved?**

**Interviewee no. 1:** Emphasis should be given to the right team division with adequate engineering skills so that the members understand the deliverables produced in order to save time. Moreover, the information should be extracted from the BIM models in order to avoid doubling, yet it is crucial to understand that not everything can be controlled.

**Interviewee no. 4:** It should be ensured that the review process is well clarified. Firstly, the requirements should be placed in the same document that everyone is working on. In the following review process, everyone places comments and makes changes and in the end, the final documents are produced.

**Interviewee no. 6:** The contractor should be more engaged in the process, yet this would also leave more room for complaints. Also, if the main advisory firm is responsible for hiring the individual delivery teams they could also perform an assessment.

**Interviewee no. 5:** In order to avoid a situation where the as-built asset deviates from the original design, the contractor has to check the models from the design and if there is information missing then he needs to redesign the model. Otherwise, he keeps the information that is useful for the construction and recreates the rest. Moreover, everyone engaged in the process should use the same platform from the beginning of the project in order to save time and review based on a schedule. Furthermore, the Appointing Party needs to define the scope more precisely in order to avoid over asking for information and make everything more manageable.

- **Q.9: What are the difficulties when sharing and receiving the deliverables?**

  **Interviewee no. 2:** Due to the natural characteristics of the project (time and cost), the parties tend to lose the information requirements when they want to meet certain deadlines. Therefore, the deliverables sometimes deviate from what is actually expected to be delivered.

  **Interviewee no. 3:** Sometimes the Appointing Party complicates situations as the other parties may not be able to understand what they are requesting.

  **Interviewee no. 4:** It might be the case that what is actually constructed deviates from the design that has been delivered.

  **Interviewee no. 5:** There is a big difference between the architecture and the real construction. Generally, the models are reused but for certain objects, the information might be missing or needs to be redesigned. Moreover, nowadays projects are constructed and information is added later on, being time-consuming. Furthermore, different software is also used among the different parties, thus the information may not be always designed at a proper level. When considering the deliverables to be shared back to the Appointing Party, if everything is done correctly then there should not be a problem.

  **Interviewee no. 7:** It is important to ensure that the drawings received during the Manufacturing & Construction stage are the correct ones as the engineering is based on the architectural design. In the end, the as-built asset must be the same as the design. When sharing the final deliverables at the end of the Handover stage, it might be the case that the requirements of the maintenance department are not met. This occurs as Heijmans N.V., which is responsible for carrying out all the maintenance activities, is also divided into two departments. The Project Management department gets the project from the AAS Project Management department. This could be a result of some requirements having been removed from a financial perspective.

- **Q.10: How this procedure can be improved?**

  **Interviewee no. 2:** It is of course possible to derive from the initial agreements but the right people need to be involved and the right agreements ought to be made.

  **Interviewee no. 3:** The collaboration should be improved. Usually, more emphasis is given to the physical asset and not the information that is required. Information should be important as it facilitates asset management later on. Moreover, someone should be appointed to perform quality checks and actually fix the mistakes.

  **Interviewee no. 4:** In order to avoid producing assets that deviate from the design the Appointing Party needs to engage the advisor through the whole process. If it is not defined in a contract at the beginning, a new proposal can be made. Furthermore, the advisors also make rounds on the sight to see what is actually constructed and advise the Appointing Party on any deviations that they spot.

**Interviewee no. 5:** The Constructor Appointed Party needs to be engaged sooner in the process in order to guarantee a real buildable model. Everyone should be engaged from the very first step as the information should be integral. Moreover, the needs ought to be discussed from the beginning and a live connection between the project and information should be made in order to be able to track the changes and witness the development in time. Also, the same software could be used from the beginning.

**Interviewee no. 7:** After the Manufacturing & Construction stage, a review phase occurs where everything that the Constructor Appointed Party has built is recorded in drawings. When addressing the need to meet the maintenance requirements, all of them should be discussed earlier in the process in order to save time. Also, someone within the maintenance contractor should be engaged in both departments in order to have a clear overview of all the requirements. In order to solve these issues, all the information should be combined into one main model, e.g. AIM, containing all the information requirements.

- **Q.11: How is the information stored?**

**Interviewee no. 2:** Prior to the start of a project a CDE is created, where every party involved in the project has access to. This is not used when the project is finished. After that, for maintenance and operation use there is another interface, only accessible to the Appointing Party, where every asset is unique and for any change made a message is sent with regard to geometry, documents, and properties.

**Interviewee no. 1:** Every time it is a different environment to learn as there are always other parties involved. It is impractical to only use one tool for information exchange, so a second environment is used internally. CDE is a place to deliver to the external party and the working environment the one used internally for network and data storage as well as collaboration.

**Interviewee no. 4:** Before the final handover of deliverables, they are stored internally.

**Interviewee no. 6:** The ISO 19650 proposes a solution for information storage which is also followed. As a first step, “Work In Progress” stores all the information internally. Then, in the “Shared” environment, everyone works with each other models and the Appointing Party has access to it. In the “Published” environment, the final deliverables after the review are placed. Sometimes, the Appointing Party involves the contractor as a reviewer, depending on the type of contract.

**Interviewee no. 5:** The same ISO 19650 CDE approach is applied. They have a CDE where the working models, Revit, etc. are shared. Also, they have the “Shared” environment where they share the information with the Appointing Party and then it gets published. The advisors still don’t have access to the “Shared” environment as the phases are separated, although they should be informed more.

**Interviewee no. 7:** The same ISO19650 CDE approach is applied.

As the answers provided to the questions are rather extended, even after grouping them into bigger categories, the following table is created. Table 10 provides a clear overview of the participants' responses, organized by parties.

*Table 10 - Overview of participants' responses, organized by parties*

| Questions | Parties | | |
|---|---|---|---|
| | Appointing Party | Design Appointed Party | Constructor Appointed Party |
| Q.1 | - EIR: helpful, yet a challenge due to the amount of information. Mostly focused on the asset management<br>- Similar information for every project, with some modifications<br>- Need for collaboration between all the parties from the beginning | - EIR: the starting point, essential for a good process, yet mostly focused on the handover | - EIR: information might be missing. Also, often requirements not matching between the design and construction |
| Q.2 | - Two departments<br>- Project Management: creation of project-specific requirements, information handover, and quality check<br>- Asset Management: definition of requirements, physical design approval, high inspection of process | - Usually: BIM Manager, BIM Coordinator, BIM Modellers<br>In bigger projects: Also Project Manager and Project Architect | |
| Q.3 | - Functionalities<br>- Information that complies with the law | - Information of as-built situation<br>- Geometrical and non-geometrical requirements<br>- Scope, information referring to advisor's role, CDE, BIM Protocol, level of information, and detail | - Information related to maintenance<br>- Often as-built information missing. Need for update and transferring in a digital form |
| Q.4 | - Currently information requirements based on output<br>- Need for reuse of information<br>- Processes not well defined<br>- Missing information or not on optimal level | - Missing or now well-defined information<br>- Contradictory information, mostly happening with as-built information<br>- Information requirements contradictory, not well defined or extensive | |

| | | | |
|---|---|---|---|
| Q.5 | - Keep track of information, also history, decisions made, and requirements<br>- Quality control check when information is delivered<br>- Ensure that requirements are met prior to delivering information<br>- Engagement of correct actors | - Ensure that requirements are met prior to delivering information<br>- Track changes if working on the same document<br>- More collaboration needed | |
| Q.6 | - Schematics, BIM models, CAD formats, and documentation with standards. All equally important<br>- End of Handover stage: overview of asset list and documentation delivered by the manufacturer. Also, design from the design team<br>- Establishment of relations between documents and physical assets | | - End of Manufacturing & Construction stage: information related to legal issues, manuals, testing, certificates, IFC model completed with all parameters and validated<br>- End of Handover stage: handover of final version |
| Q.7 | | - Alteration of information requirements or design due to large amount of stakeholders engaged<br>- Integration of sub-models into one<br>- Information doubling resulting from the use of two forms<br>- No life connection of the model | - Imbalance between information requirements from different parties |
| Q.8 | | - Right team division<br>- Information extracted from BIM models<br>- Well-defined review process<br>- Engagement of Constructor Appointed Party in the process | - Design verification from Constructor Appointed Party<br>- Use of same platform<br>- Well-defined scope by the Appointing Party |
| Q.9 | - Information requirements not included<br>- Difficulties in other parties understanding the information requirements requested | - Deviation between design and construction | - Difference between design and construction<br>- Missing information<br>- Different software used among parties<br>- Added information after construction of project |

| | | | |
|---|---|---|---|
| | | | - Final deliverables not meeting the maintenance requirements |
| Q.10 | - Possibility of deviation from initial agreements. Need for engagement of correct people<br>- Improvement of collaboration<br>- More emphasis on information as well as physical asset<br>- Need for quality checks | - Engagement of advisor throughout the whole process | - Engagement of the Constructor Appointed Party from the beginning<br>- Live connection of project and information<br>- Track changes and development in real time<br>- Use of same software<br>- Earlier discussion on the maintenance requirements<br>- Information combined in one main model |
| Q.11 | - CDE at the start of the project, accessible to every party involved<br>- Different interfaces for maintenance and operation use | -ISO 19650 CDE approach<br>- Work In Progress state: internal storage of information<br>- Shared state: access to models also from the Appointing Party<br>- Published state: final deliverables after review<br>- Constructor Appointed Party might be placed as a reviewer as well | - ISO 19650 CDE approach<br>- Shared state: still not accessible to advisors. Should be informed more |

This overview of participants' responses to the aforementioned questions aid in thoroughly understanding the procedure that is followed during the whole lifecycle of an airport project. Moreover, complementary information is provided on the type of information, the exact parties responsible for its distribution as well as the format and platforms used. Therefore, the processes for information management may be specified in more detail by integrating these responses with the information gathered from the documentation. Finally, the interviewees discuss the subject of digital ambitions by mentioning either practices already followed or by suggesting future recommendations. Therefore, the final sub-question may be addressed as well.

A more thorough analysis of the participants' responses reveals the need for precisely defining the information requirements prior to the start of a project. This step enables the Appointing Party to translate the organization's higher aims into more precise requirements that are related to the assets to be specified. It also aids the Appointed Parties engaged in the process in comprehending what is specifically required during each information exchange moment. Therefore, the process of defining the information requirements is mutually beneficial to the parties and is further supported by the development of the Exchange Information Requirements document.

Furthermore, it can be observed that each participant provides a different response in relation to his performed role during the process when discussing the topic of the required information to be established. Each party desires its requirements to be sufficiently established at the beginning of the process in order to limit the misunderstandings which would potentially lead to project delays and subsequently a cost overrun. Additionally, if the information requirements for each project stage are clearly stated before the start of the project, conflicts might be reduced since parties would not be able to object to or misinterpret the requirements later on in the process. This would also address some of the challenges that are identified during the interviews and refer to the definition and sharing of information requirements as well as the subsequent production of deliverables. However, as the currently used EIR contain a vast amount of information, all the participants agreed that collaboration should be also improved during the initial project stages so that the information requirements could be collectively created. Moreover, the overall collaboration should be improved during all the project stages, especially between the Design and Constructor Appointed Party, to prevent the design of unfeasible objects and/or future deviations of the as-built asset from the original design. However, these practices are not currently in use and are provided by the participants as part of suggestions for future improvement of the overall procedure.

Another important aspect mentioned in the interviews is the format of the deliverables. Although the participants reveal that both documentation and models are currently used, as it is still impossible to extract all the information from the models, there is an urgent need to create connections between the deliverables and the physical assets. This connection is particularly in line with the Appointing Party's digital ambitions, which relate to the reuse of information once a project is completed. Moreover, such a practice could also aid the Appointed Parties in reducing time when designing or constructing an object/asset as the attached information could be more easily located, including the changes made as well. However, as stated in the interviews, this is something to take into account in the long term and it concerns a suggestion for future improvement.

Finally, it is observed that all the parties make use of the ISO 19650 approach when establishing their Common Data Environment. Each party is allowed to select its platform or software of preference for internal storage and deliverables. However, all parties should place their deliverables for review in the Appointing Party’s CDE, as described in the Information Management Protocol.

The following table presents the information gathered by the semi-structured interviews in relation to the research sub-questions. Table 11 is organized in such a way as to provide an overview of everything that occurs within the project stages that each party is involved in, either process or information related. Moreover, the digital ambitions of the corresponding party are listed as well.

*Table 11 - Overview of participants' responses in relation to the research sub-questions*

| Research Sub-Question | Parties | | |
|---|---|---|---|
| | Appointing Party | Design Appointed Party | Constructor Appointed Party |
| **Sub-Question 1:** *Processes* | - Information requirements definition<br>- Project-specific requirements<br>- Information handover and check<br>- Physical design approval | - Deliverables check before handing them over<br>- Requirements should be met before deliverables' handover | - Design verification from Constructor Appointed Party |
| **Sub-Question 2:** *Type of information & responsible parties* | - Functionalities<br>- Information that complies with the law<br>- Maintenance<br>- End of Handover stage: overview of asset list and documentation delivered by the manufacturer. Also, design from the design team<br>- Project Management and Asset Management department | - Information on as-built situation<br>- Geometrical and non-geometrical requirements<br>- BIM Manager, BIM Coordinator, BIM Modellers<br>In bigger projects: Also Project Manager and Project Architect | - End of Manufacturing & Construction stage: information related to legal issues, manuals, testing, certificates, IFC model completed with all parameters and validated<br>- End of Handover stage: handover of final version |
| **Sub-Question 3:** *Type of formats & platforms* | - Schematics, BIM models, CAD formats, and documentation with standards<br>- CDE at the start of the project, accessible to every party involved<br>- Different interfaces for maintenance and operation use | -ISO 19650 CDE approach<br>- Work In Progress state: internal storage of information<br>- Shared state: access to models also from the Appointing Party<br>- Published state: final deliverables after review<br>- Constructor Appointed Party might be placed as a reviewer as well | - ISO 19650 CDE approach |

| | | | |
|---|---|---|---|
| **Sub-Question 4:** *Digital ambitions* | - Information reuse<br>- Improvement of collaboration from the beginning<br>- Establishment of relations between documents and physical assets<br>- Keeping track of information | - Life connection to the model<br>- Working on same document, keeping track of changes<br>- Information extracted from BIM models<br>- Engagement of Constructor Appointed Party in the process<br>- Engagement of advisor throughout the whole process | - Transferring of as-built information to a digital form<br>- Use of the same platform & software<br>- Engagement of the Constructor Appointed Party from the beginning<br>- Live connection of project and information<br>- Track changes and development in real time<br>- Earlier discussion on the maintenance requirements<br>- Information combined in one main model<br>- Shared state accessible to advisors |

# 4. Process Map Design

Both the documentation review and the findings of the semi-structured interviews provide a clear overview of the procedure that is currently applied in organizations in accordance with the ISO 19650 standards. Moreover, the research findings offer a brief description of the information distributed during each project stage along with its format and platforms used. The distribution of roles and responsibilities is also examined and finally, each party's and subsequently organization's digital ambitions are discussed. Therefore, a process map is suggested as a way of integrating all these aspects into one single entity that can be utilized as a guide in the construction industry. However, it is important to mention that despite the documentation focusing on the examination of data from an airport project, and the interviewees being involved in projects that are carried out in the airport domain, the aim of the final outcome is a process map that may still apply to a variety of projects.

A process map is considered to be the most effective approach as it can be described as a method used for diagrammatically capturing each step and decision in a process. Therefore, it can provide a direct answer to the main research question, which also refers to the definition of workflows. However, in cases such as an airport project, a large number of objects and subsequently assets are created, thus a vast amount of information is required. Naturally, it is both inefficient and impractical to create a process map for every project-related entity. Therefore, this research attempts to provide a process map that includes all the essential processes for information management to be followed, in order to facilitate digitization across the whole lifecycle. The steps shown in Figure 16 have been followed, in order to effectively generate the final process map.

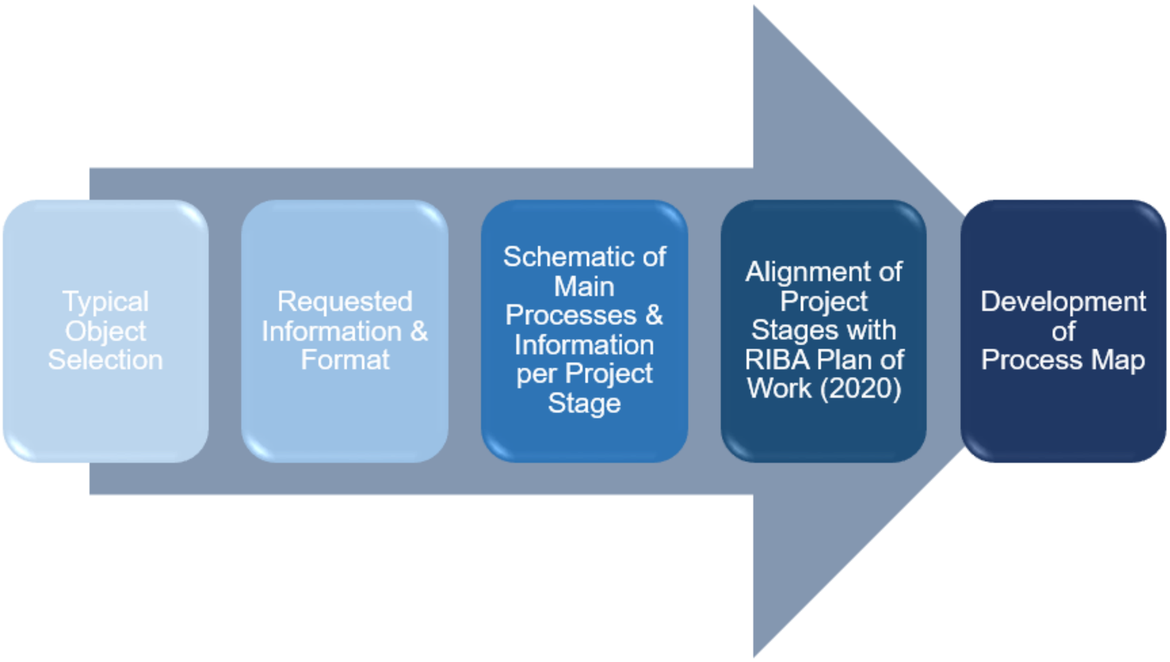


*Figure 16 - Process map creation steps*

## 4.1 Typical Object Selection

The first step towards designing the generalized process map is the selection of a typical asset that can be found in several projects, regardless of the project's domain. In light of the fact that a door is frequently built as part of a construction project and subsequently maintained, it is selected as the representative object on the basis of which the generalized process map is developed.

A door could be perceived as a simple, one-dimensional object, the analysis of which does not display much interest. However, that is not the case as it is a rather complex object instead. More specifically, despite the fact that its primary objective is to grant access to several rooms, both indoors and outside, it must adhere to a number of crucial requirements.

Strength, stability, safety, security, and privacy are the most important functional requirements. The door must therefore contain a significant amount of information in order to meet all of these specifications. An overview of the functional requirements and general type of information needed is illustrated in Figure 17.

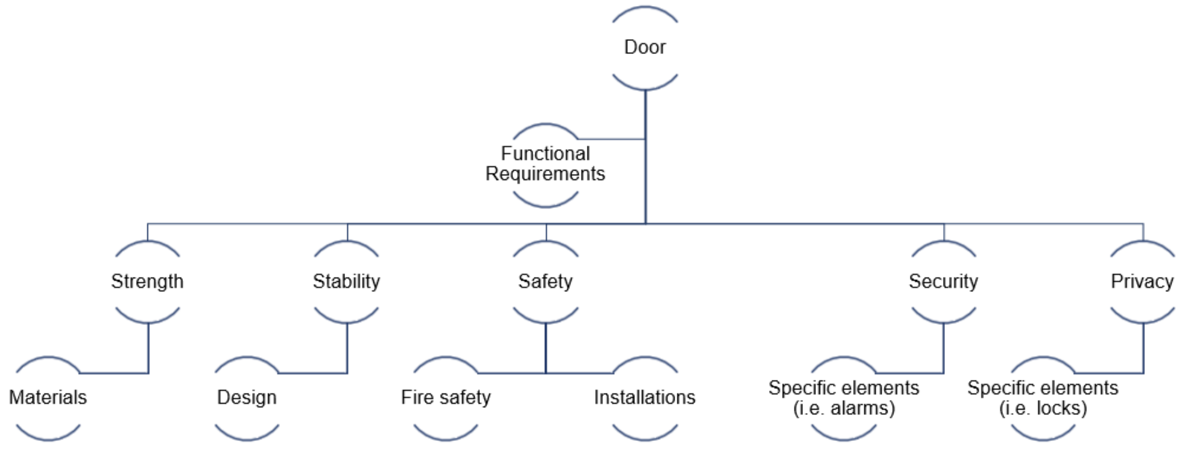


*Figure 17 - Functional requirements of a door and general type of information needed*

Subsequently, maintenance activities ought to be carried out after a door is constructed and operated. Therefore, information regarding the schedule and materials (stock and suppliers) should be identified as well.

Finally, it is important to consider that depending on the project's scale, several assets of the same category might be created. More particularly and in airport projects, many doors of different types are constructed, varying in different characteristics. Some of these may refer to external, internal, overhead, manually operated, automatic, sliding, revolving, folding, double, interchangeable, and speed gates, which are also the ones identified in this case.

Therefore, a method of distinguishing them already from the start of the design should be established, in order to subsequently facilitate their operation and maintenance.

## 4.2 Requested Information & Format

As previously mentioned in Chapter 3, the Data Dictionary Schiphol is the application used by AAS to publish its asset-information requirements and contains information regarding its properties, definition, information products, requested format, etc. The DDS is published in an online environment where every stakeholder engaged in the project has access to this information in a user-friendly way, enabling him to easily understand the information product needed for each registered asset and per project stage. The EIR Table is also generated from the current version of DDS, providing also a template that includes the document register per requested object and subsequently asset. In order to use the DDS for the purpose of this graduation research, access was granted by the AAS. Based on the use of both the DDS and EIR Table, the type of information needed for each type of door registered in the database as well as its format could be specified.

As also presented in Chapter 3, the requested deliverables are categorized in broader categories in accordance with their general context. In this case and when examining all types of doors, the following nine categories are identified:

- **A**: Applications, permits, assignments
- **B**: Calculations
- **C**: Certificates of approval/defectiveness
- **D**: Dates, Lists
- **E**: Material and supplier information
- **H**: Plans
- **J**: Reports of inspections, measurements, and controls
- **K**: Technical diagrams
- **L:** Technical drawings

It is important to mention that with the exception of a few extra features that depend on certain specific characteristics, all of the various door types mentioned in the DDS request the same type of information. However, in order to provide a more detailed overview of all the types of deliverables needed, every type of information is included. These categories are further divided into smaller ones, with each one containing a variety of information. Each smaller category is then labelled to facilitate information retrieval.

Among the most important categories is category L, referring to the technical drawings. As extracted by the DDS and EIR Table, these drawings include floor plans, details drawings, view drawings, sections, and fixture drawings and are requested in every information exchange moment apart from the end of Implementation stage (information exchange 5). In this step, the division of project stages is in accordance with the ones used by AAS as the conversion to the RIBA Plan of Work (2020) occurs at a later step. These documents refer to the ones created by the Appointed Party responsible for the design and not the specific ones created by the Constructor Appointed Party. Therefore, the fact that they are developed at a different level of detail during each phase of the design, supports the request for drawings at each of these information exchange moments. Another important category to mention is category K which includes the technical diagrams. Doors as assets do not function individually, yet have other elements and installations attached to them, requiring also information. The deliverables included in this category refer to technical diagrams regarding the door's various installations and contain information such as representations of installations, an overview of connections and components as well as their interconnections with the door.

On the other hand, the Constructor Appointed Party is responsible for providing the deliverables falling under category J, meaning the reports of inspection measurements, and controls. These deliverables contain information with regard to the performed condition of installations, any changes made to the door, fire safety, demonstration of fulfillment of legal requirements, etc. This information can only be provided after the door has been constructed. Moreover, the Constructor Appointed Party must also provide some deliverables of category E, regarding the material and supplier information, as the constructed door might be deviating from the one originally designed. These deliverables include information about the complete specifications of material, asset, and space, incorporating also fire properties of the applied materials. Furthermore, the settings of all installation components as they should be set up in a working situation need to be also delivered.

During the final Transfer stage (information exchange 6), some other documents should be also handed over. These refer to maintenance instructions which should contain a complete program in which all inspections, replacements, and overhauls are planned. Moreover, a complete list of all parts of the door or attached elements that can fail and are replaceable is also provided in the spare parts list, together with the supplier information. Furthermore, the official warranty certificates are delivered together with manuals on operating and control instructions.

A complete overview of the information deliverables for the door per project stage, as described in the DDS, is presented in Appendix III.

Finally, the format of information to be delivered is also available in DDS, depending on the type of information requested per category. Different formats are used as information is shared in the format of documents and models. Overall, PDF documents are shared, containing either reports, instructions, lists, or diagrams. However, technical diagrams are also shared in CAD formats in order to be able to comprehend all the different interdependencies. Meanwhile, technical drawings are delivered in a variety of forms, from PDF documents to CAD files and IFC models.

A complete overview of the content and information deliverables for the door, as described in the DDS, is also presented in Appendix III.

## 4.3 Diagram of Information per Information Exchange

As described in Chapter 3, the EIR provide an overview of the geometrical and non-geometrical information requested per information exchange during each project. Furthermore, the examination of the DDS and EIR Table gives a more detailed understanding of the type of information to be delivered per project stage as well as the format used. Therefore, for the typical object of the door, a first attempt is made to combine and eventually integrate all this information into a diagram. It is important to mention that the development of the diagram does not follow a specific notation language as its sole purpose is to clarify the type of information that is needed during each project stage, starting from the Design until the Transfer & In Use stage. In this step, the division of project stages is still in accordance with the ones used by AAS as the conversion to the RIBA Plan of Work (2020) occurs at the next step.

During information exchange 2a, following the initial design, information with regard to the generic door representation is distributed. This includes the location, orientation, and estimation of the door's shape and dimensions per type of door. Moreover, material and colour are also suggested. Following, information referring to the systems and installations attached to the door ought to be determined. This considers a description of the systems, i.e. structural, mechanical, electrical, etc., a schematic representation of the installations, and an overview of the main cable routes. These entities, meaning the door and the installations, and systems, are integrated in order to provide information regarding their location and approximate quantities. Non-geometrical information concerning the basic properties and design principles is also delivered.

During information exchange 2b, following the more detailed design, information with regard to the detailed door representation is distributed. This includes the definitive location and dimensions, coordination, as well as characteristics of each type of door. Moreover, materials, finishes, and colour are also selected. Following, the information referring to the systems and installations at this stage considers the detailed representation of installations, their location with respect to the door as well as their capacity and coding. Furthermore, the quantity of components of installations as well as their type, their location with respect to the door, and finally the coding is also needed. Therefore, this information exchange deals with the integrated representation of the door with its attached installations and systems. Non-geometrical information regarding basic properties, design principles as well as technical elaboration and specifications are also delivered.

During information exchange 3, following the technical design, information with regard to the detailed technical representation of the door is distributed. This includes technical data, bill of quantities, and exact price calculations. Moreover, material specifications and material properties, including fire safety are also included. Following, the geometrical information referring to the systems and installations at this stage considers more detailed calculations of installation components, the location of cable routes, and detailed representation of the connection of the installations with respect to the door. Other non-geometrical information regarding exact price calculations and installations' performed condition is also delivered.

During information exchange 5, following the implementation, information with regard to the as-built door representation is distributed. This includes the details on the settings of the door and its components and installations as they are constructed. Information with respect to safety and security is also delivered, e.g. certifications and checklists, inspections, etc. Furthermore, details for the functioning of the door and its installations are also part of the deliverables.

Finally, during information exchange 6, during the official transfer of the project, the as-built representation is handed over, consisting of the detailed calculations and coding of installations as well as the detailed technical data and representation of the door and the components attached to it. Moreover, operating and control instructions are also delivered. These refer to a list of actions for the optimal function of the door and the installations, a list and order of actions to secure the installations in case of a hazard as well as a general list of test procedures to be followed. Maintenance instructions are also distributed. These consider an overview and schedule of inspections, replacements and overhauls planned, location and data of adjustment and measurement points. Furthermore, a suggestion on stock is also provided along with an overview of the spare parts list, including supplier information, model number, price, quantity, and delivery time.

As can be observed, the information requested for a door can also be applied to other objects. During every project, an object along with its installations and components attached to it will need to be designed, constructed, and eventually maintained. Therefore, the information that is presented in this section can be used for general purposes as well. Moreover, the type information needed is extracted from both the EIR, which is a document stating the geometrical and non-geometrical information to be delivered regardless of the type of object, as well as the DDS and EIR Table which provides a more detailed analysis of the requested information.

A complete overview of the diagram of the information delivered during each information exchange for the door is presented in Appendix IV.

## 4.4 Alignment of Project Stages with RIBA Plan of Work (2020)

During the previous steps, the project stages were defined using the EIR that AAS develops in its projects. These project stages, are developed based on the Dutch standards DNR-STB and thus are used exclusively for projects within the Netherlands. However, the goal of this research is to develop a process map that could be comprehensible to everyone regardless of the location of the project and the reader's familiarization with specific standards. Furthermore, a more unified approach regarding the project stages is encouraged, as the thesis also aims to benefit the academic community.

Therefore, and as mentioned in Chapter 2, the RIBA Plan of Work 2020 is used. Moreover, as described by Churcher et al. (2020), the proposed unified plan of work used in the ISO 19650 standards aligns with the project stages developed by RIBA, thus this decision can be further supported.

However, as all the information obtained from the previous documents is based on the project stages used by AAS, it is crucial to align them with the ones in the RIBA Plan of Work 2020. The correspondence between the two variations of project stages is achieved by linking the main activities performed during each of them. The procurement, which occurs during the Contract Formation stage, according to the EIR provided by AAS, is quite flexible and is not assigned a numbered stage (Designing Buildings Ltd, 2020). As a result, it is assumed that this stage is a part of the Technical Design project stage of the RIBA Plan of Work 2020. Figure 18 illustrates the correspondence between the two variants of project stages.

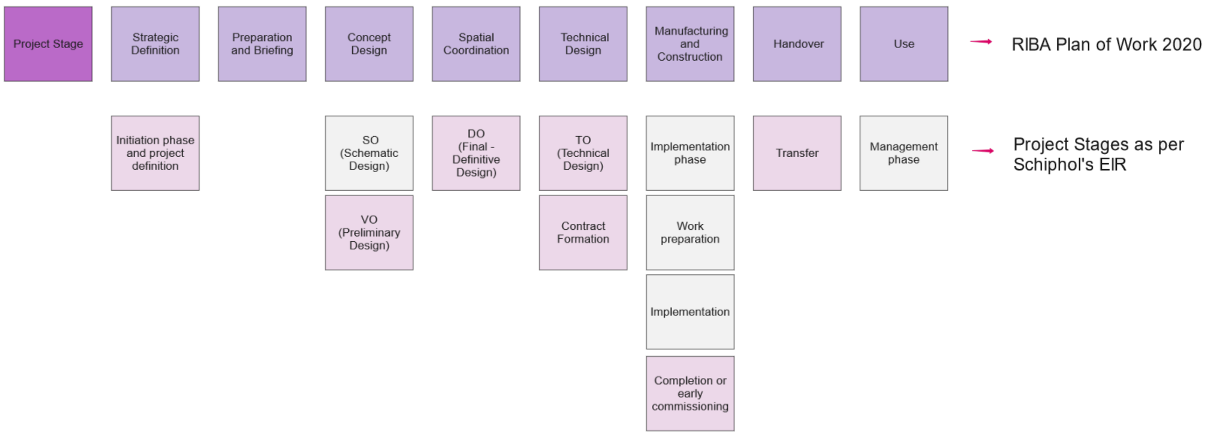


*Figure 18 - Alignment of Project Stages according to RIBA Plan of Work 2020*

## 4.5 Process Map Development

The final step consists of the development of the process map based on the information gathered from the existing documentation used in the AAS case study and semi-structured interviews. As described in the previous steps, the type of information is already established based on the findings of the EIR, DDS, and EIR Table for the representative object of a door. However, as already mentioned, this information can be applied to other objects as well, as it considers the basic type of geometrical and non-geometrical information requested during each project. The proposed process map is designed following the practices that are used in the case study and thus reflects the current situation. Moreover, the interviewees gave their insight into the existing tools and procedures that are also implemented during the project stages. However, as this development could be seen as a dynamic process that might alter in response to technological advancements, some recommendations with regard to a future enhancement of the whole procedure are also given.

The process map intends to provide an integrated approach to the processes followed during the whole lifecycle of a designed and thus constructed entity, along with the demonstration of the various parties that are engaged throughout these procedures.

Moreover, the type of information that is created and shared with the respective party during each project stage is also illustrated, as well as the different formats and platforms used for information storage. Therefore, by incorporating all these aspects, the workflows for information management can be defined in a more detailed way, while also considering each party's digital ambitions.

The reason behind choosing a process map as the most efficient way of representation is the numerous advantages that it provides to such a type of research. First of all, the processes are documented in an understandable and straightforward format, thus providing guidance for the procedures to be followed (Harris, 2021). The process map benefits the organizations that make use of it as well, as capturing the workflows enables the preservation of knowledge that could otherwise be lost. Finally, it provides guidance to all the interconnected activities as it is easier to navigate.

Focusing on its development, the proposed process map is organized in two axes. The horizontal axis presents the sequence of project stages which as described in the previous section, align with the RIBA Plan of Work 2020. At the end of each project stage and in accordance with the information obtained from the IM Protocol, as mentioned in Chapter 3, an information exchange occurs. On the other hand, the vertical axis lists the several parties involved throughout the whole lifecycle. As also mentioned in Chapter 3, three main parties are identified: Appointing Party, Design Appointed Party, and Constructor Appointed Party. With the aid of the semi-structured interviews' findings, a further division of the different roles involved within the Appointing Party is possible. More specifically, within every organization responsible for the initiation and tendering of a project, two different departments exist. Prior to the beginning of a project, the Asset Management department is in charge of establishing the higher level requirements, i.e. OIR, which are then translated into the AIR as described in Chapter 2 during the Preparation and Briefing stage. The Project Management department is responsible for every action within the current project, including the adjustment of aforementioned requirements into project-specific ones, i.e. PIR. The complete overview of the activities by each department is shown later.

The Maintenance Contractor is also included in the broader category of Appointing Party as it is responsible for carrying out all the maintenance activities regarding the asset. However, depending on the project and contracts formed within the Appointing Party's organization, the Maintenance Contractor could either be a party operating internally in the organization or an external contractor. Regarding the examined AAS case study, the Maintenance Contractor is indeed an external party, yet for simplicity reasons, this role is depicted under the Appointing Party category.

Subsequently, the Design Appointed Party includes two general sub-categories in the process map illustration. The Lead Appointed Party is, as thoroughly described in Chapters 2 and 3, responsible for the creation of the BEP document based on the EIR delivered by the Appointing Party and the overall coordination of activities as well as integration of the design models into a single one, i.e. PIM. The Appointed Party mentioned in the proposed process map, includes all the different task teams involved in the several design stages, e.g. the building, structural and installations teams. For simplicity reasons, these teams are considered the Appointed Party in general. Finally, the Constructor Appointed Party is engaged during the Manufacturing & Construction stage, where the project implementation occurs as well as during the final handover of completed deliverables, i.e. during the Handover stage.

An overview of the two axes, x and y with the displayed project stages and parties is presented in Figure 19.

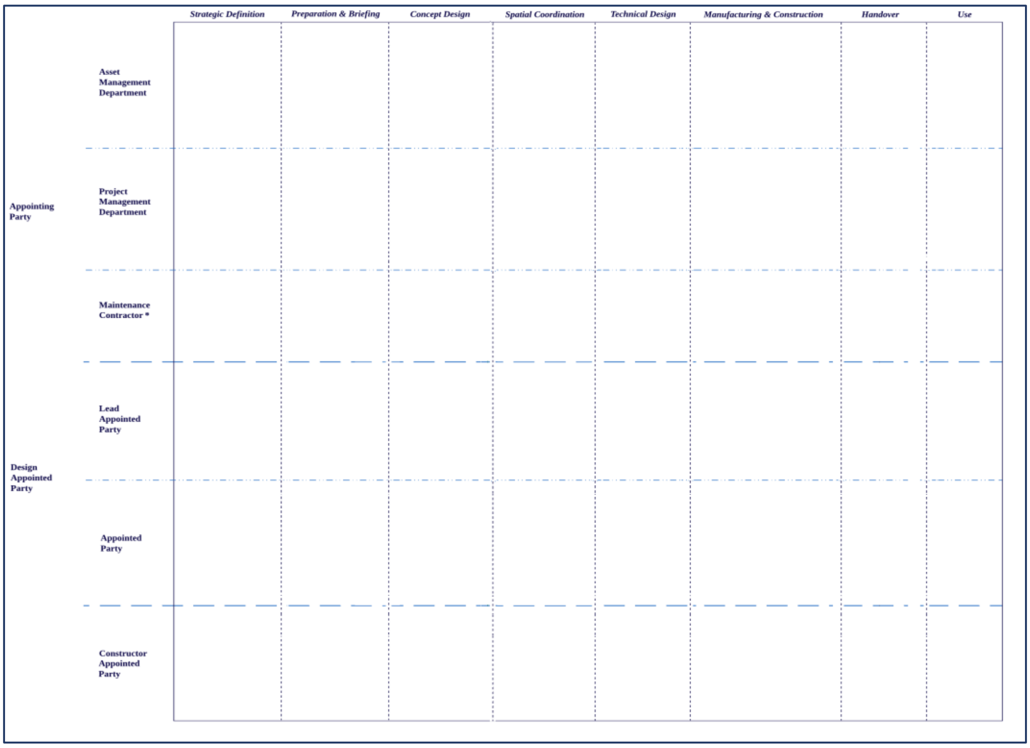


*Figure 19 - Project stages and engaged parties as displayed in the process map*

After the layout is established, an appropriate notation language is selected. As the process map intends to incorporate both processes as well as information, formats, and platforms used, a variety of symbols are utilized.

Each element used in the process map can be illustrated with the aid of distinct symbols, which are also organized into categories depending on their meaning and use. These categories refer to process and operation symbols, branching and control of flow symbols, input and output symbols, file and information storage symbols, and finally data processing symbols. More specifically, the symbols that are used in this research are presented in Figure 20.

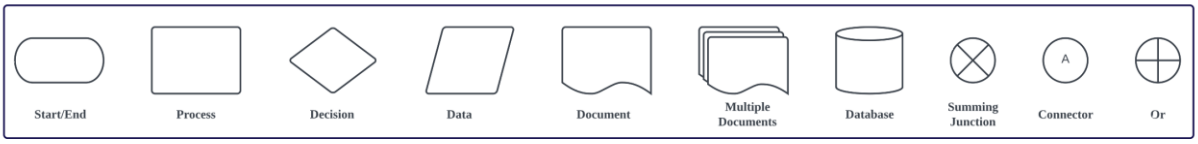


*Figure 20 - Process symbols used as a notation language in the process map*

The symbols fall under the first four categories and their content is given in the following table.

*Table 12 - Explanation of process symbols used in the process map*

| Symbols | Category | Explanation |
|---|---|---|
| Start / End | Branching & Control | Representation of the entry and exit points of the process map |
| Process | Process & Operation | Representation of a necessary action, task, or operation |
| Decision | Branching & Control | Representation of the point at which a decision ought to be made. The decision symbol is usually followed by arrows indicating yes, no, true or false |
| Data | Input & Output | Representation of information entering or leaving the process |
| Document | Input & Output | Process step where a generation of a document or a report occurs |
| Multiple Documents | Input & Output | Process step where a generation of multiple documents or a report occurs |
| Database | File & Information | Database with a standard structure for information storage |
| Summing Junction | Branching & Control | Representation of the moment when several sub-process are merged into one single process |
| Connector | Branching & Control | Connection to a different section of the process map |
| Or | Branching & Control | Representation of the point at which a process diverges, typically for more than two branches |

After the symbols are defined, the actual development of the process map commences.

## Strategic Definition Stage

As mentioned above, during this initial stage, the Organizational Information Requirements are defined by the Asset Management department within the Appointing Party’s organization. Therefore, this step is considered the start of the process map.

## Preparation & Briefing Stage

Moving to the Preparation & Briefing stage, the Asset Management department converts its OIR into more specific Asset Information Requirements which are then delivered to the Project Management department. Following the definition of the Project Information Requirements, the overall information requirements can then be established. This is considered a crucial step within the process, as every interviewee agreed that their definition is essential as it provides the starting point of a good process. However, before proceeding to the next steps, the Project Management department ought to carefully decide what requirements should be requested considering the project's timeline as well, in order to avoid the handover of extensive lists. Moreover, they need to be well-defined and comprehensible by all the parties to ensure that the actual deliverables will comply with the expected ones.

Subsequently, the two main documents that have also been examined in this research are produced, i.e. the Exchange Information Requirements and the Information Management Protocol. The development of these documents was considered by the interviewees an essential step as they provide a specific list of all the expected information requirements, as well as information management processes to be followed by all the parties. Moreover, both documents determine the necessary steps to facilitate digitization. However, as mentioned by several interviewees, all the parties should be involved in the development of these requirements in a collaborative environment. By working simultaneously on the same document each party could get the opportunity of reviewing the information requirements and propose alterations by making remarks before they are published. However, this practice that is still not in use, yet if implemented, it would further contribute to the efforts towards digital transformation.

Important information can be extracted from these two documents, regarding the objects and subsequently future assets mentioned. First of all, the definition of the expected objects can be determined as well as their functions. As mentioned during the interviews, the optimal process that should be followed during this stage starts with the project definition, which is then followed by the description and type of expected assets as well as their main components. By implementing such a procedure, valuable time could be saved in the interpretation of requested information deliverables. Moreover, and as mentioned in Chapter 2, the Common Data Environment to be used by all the parties in order to place their deliverables for review is also defined, i.e. the Project CDE. This concerns the CDE which is determined by the Appointing Party and will be used during the "Shared" and "Published" states.

After having delivered the EIR and IM Protocol during the first information exchange, the Lead Appointed Party creates the BIM Execution Plan, on behalf of the Design Appointed Party, stating the workflows that will be followed internally in order to meet all the requirements imposed by the Appointing Party. Following the completion of these procedures, the project can officially begin.

For the Asset and Project Management departments, as well as the Lead Appointed Party, both the Strategic Definition and the Preparation & Briefing stages are illustrated in Figure 21. The Maintenance Contractor, Appointed Party, and the Constructor Appointed Party are not engaged in these stages.

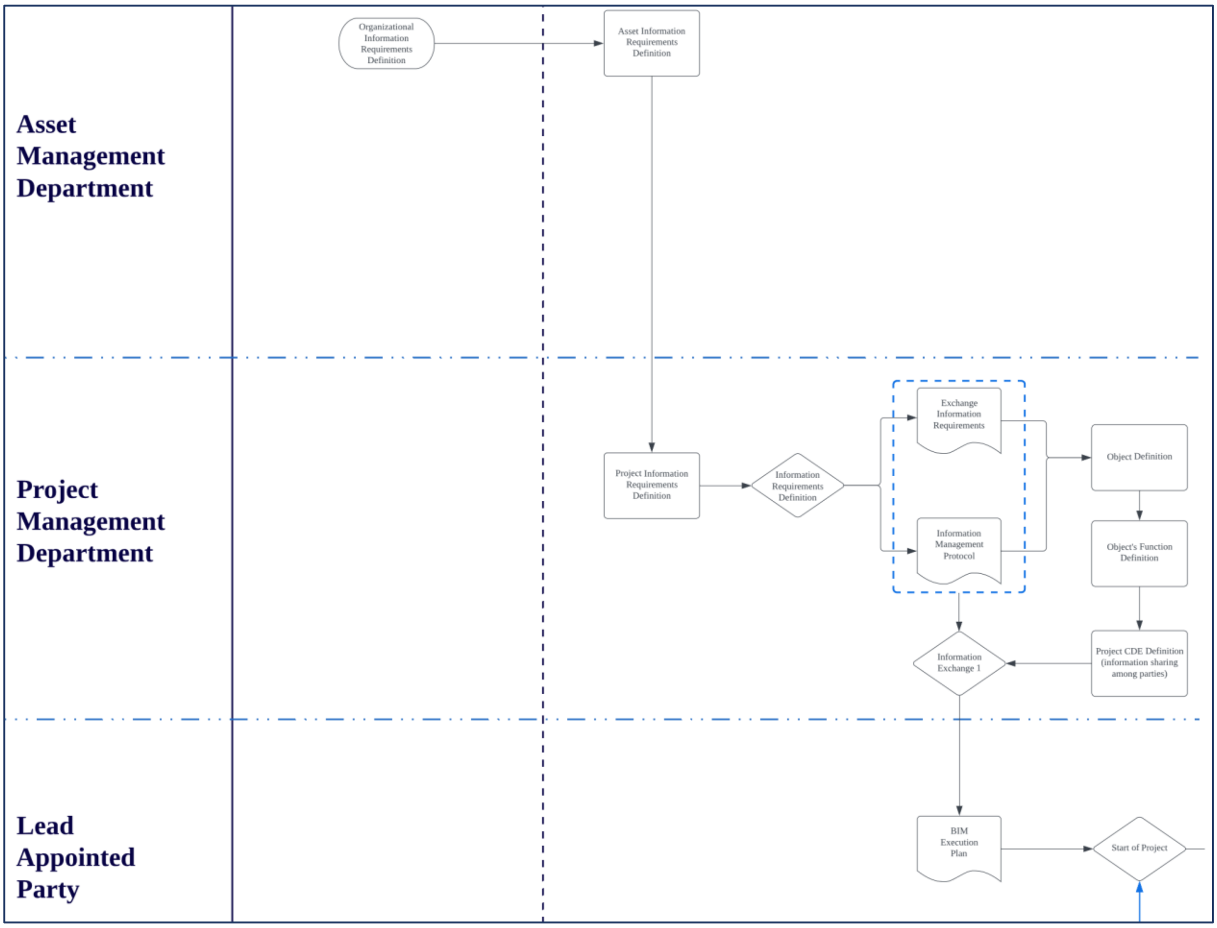


*Figure 21 - Illustration of the activities performed during the Strategic Definition and Preparation & Briefing stages*

## Concept Design Stage

Following the start of the project, the CDE to be used for internal information sharing is determined. The participants that were interviewed from both the Design Appointed Party and Constructor Appointed Party mentioned that they use the ISO 19650 CDE solution, which consists of four different stages. Therefore, this approach is also used in the process map as it also aligns with the ISO 19650 standards. The Lead Appointed Party is responsible for coordinating all the activities and task teams involved in the overall design stage and then the first step of the design begins.

One of the common digital ambitions of all the parties engaged in the process is the use of information models. It naturally flows that the larger a project is, the bigger the number of objects that need to be designed and then traced back if any changes are requested. Therefore, the classification of each object is required at the beginning of the design to aid in distinguishing it from the others and facilitate the detection of the relevant information in the provided models and documents.

The following steps consider the generic object representation along with the schematic representation of accompanying installations and systems. These two design processes involve the distribution of information as described thoroughly in Chapter 3 as well as sub-chapters 4.2 and 4.3. The final outcome of both processes is the generation of models, i.e. the conceptual model and the installation model, as well as the creation of complementary documents, which refer to the non-geometrical information needed at this stage. As mentioned in the interviews, the creation of two different types of documents, which incorporate the same type of information may lead to confusion and information doubling. However, the industry has not yet developed a reliable method for extracting every kind of information out of a BIM model. As a current approach to minimize the impact of this problem, the classification of each object with a unique code is strongly suggested at the moment, as it would at least facilitate the accurate detection of information per object.

Regarding the information storage, at this stage, the Design Appointed Party works within the internal CDE. According to the ISO approach, this considers the "Work In Progress" state where the various tasks teams develop their design models and documentation and place them there. However, it is important to state that every interviewee, regardless of his position within the process, mentioned that the overall collaboration should be improved by engaging multiple parties from the beginning. This could entail the Design Appointed Party granting the Constructor Appointed Party access to the internal environment, an action that would further satisfy their digital ambitions.

After the conceptual design, including both models and documents, is finished, the Lead Appointed Party is responsible for checking its quality. This internal step is very important as well because as mentioned by some interviewees, the Design Appointed Party ought to ensure that the deliverables meet all the requirements before sharing them back to the Appointing Party. Subsequently, after the deliverables of this stage are checked, they are integrated into one single model, i.e. the Project Information Model, which along with the corresponding documentation, is placed in the Project CDE in order to be shared with the Appointing Party. This consists of the "Shared" state. After giving permission for the "Shared" state, the second information exchange occurs. The Project Management department, which has also access to this environment, performs a quality check on the deliverables and if any changes ought to be made, issues the redesign of specific parts. This procedure is illustrated with a red arrow in the process map. If everything is approved, then the Asset Management department is informed and information is placed on another CDE, solely accessible to the Appointing Party, i.e. the Appointing Party's CDE, which consists of the "Archive" state according to the ISO 19650 approach. Then the following project stage, i.e. the Spatial Coordination stage is ready to commence, as illustrated with the green arrow.

For the Design Appointed Party overall, the Conceptual stage is illustrated in Figure 22. Following, the same project stage for the Asset and Project Management departments is illustrated in Figure 23. The Maintenance Contractor and the Constructor Appointed Party are not engaged in this stage.

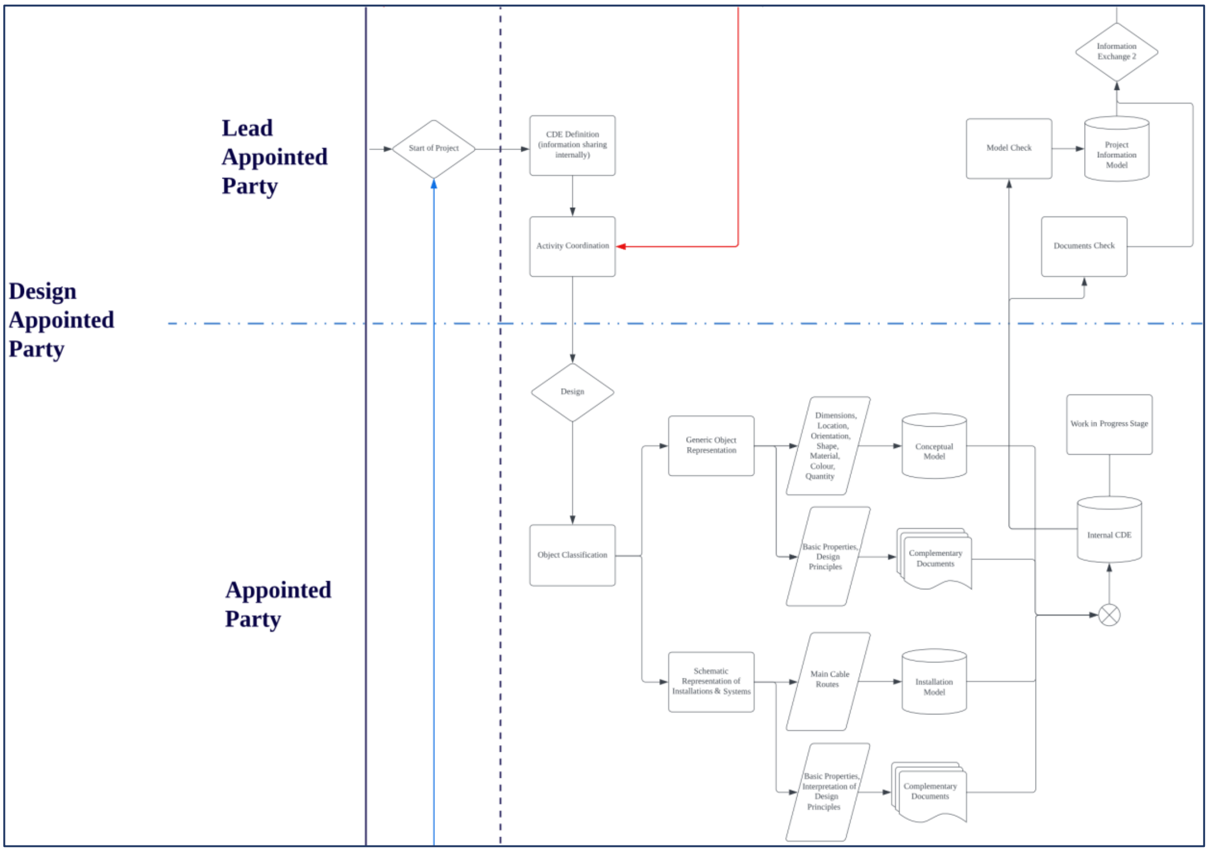


*Figure 22 - Illustration of the activities performed by the Design Appointed Party during the Conceptual Design stage*

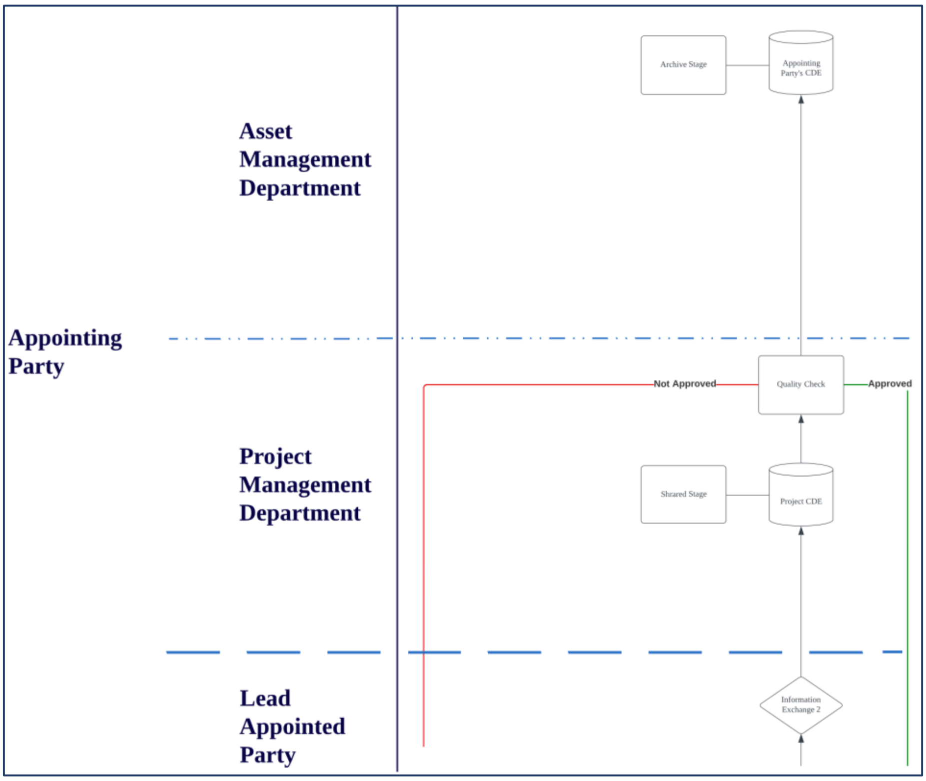


*Figure 23 - Illustration of the activities performed by the Appointing Party during the Conceptual Design stage*

## Spatial Coordination Stage

During the Spatial Coordination stage, the same actions are followed, yet in a different level of detail. The Lead Appointed Party initiates the coordination of activities and the following steps consider the detailed object representation along with the detailed representation of accompanying installations and systems. These two design processes involve the distribution of information as described thoroughly in Chapter 3 as well as sub-chapters 4.2 and 4.3. The final outcome of both processes is the generation of models, i.e. the design model and the installation model, as well as the creation of complementary documents which refer to the non-geometrical information needed at this stage. The aforementioned deliverables are already placed in the internal CDE and are under the “Work In Progress” state, as changes are still being made. They are then distributed to the Lead Appointed Party for the quality check and are subsequently integrated into the PIM, which together with the corresponding documentation, are placed in the Project CDE.

The deliverables are directly placed under the “Shared” state and the third information exchange occurs, where the same procedure is followed as described in the previous project stage. If any changes ought to be made, the Project Management department issues the redesign of specific parts, as illustrated with a red arrow. If everything is approved, then the Asset Management department is informed and information is placed on the Appointing Party’s CDE, which refers to the “Archive” state. Then the following project stage, i.e. the Technical Design stage is ready to commence, as illustrated with the green arrow.

For the Design Appointed Party overall, the Spatial Coordination stage is illustrated in Figure 24. Following, the same project stage for the Asset and Project Management departments is illustrated in Figure 25. The Maintenance Contractor and the Constructor Appointed Party are not engaged in this stage.

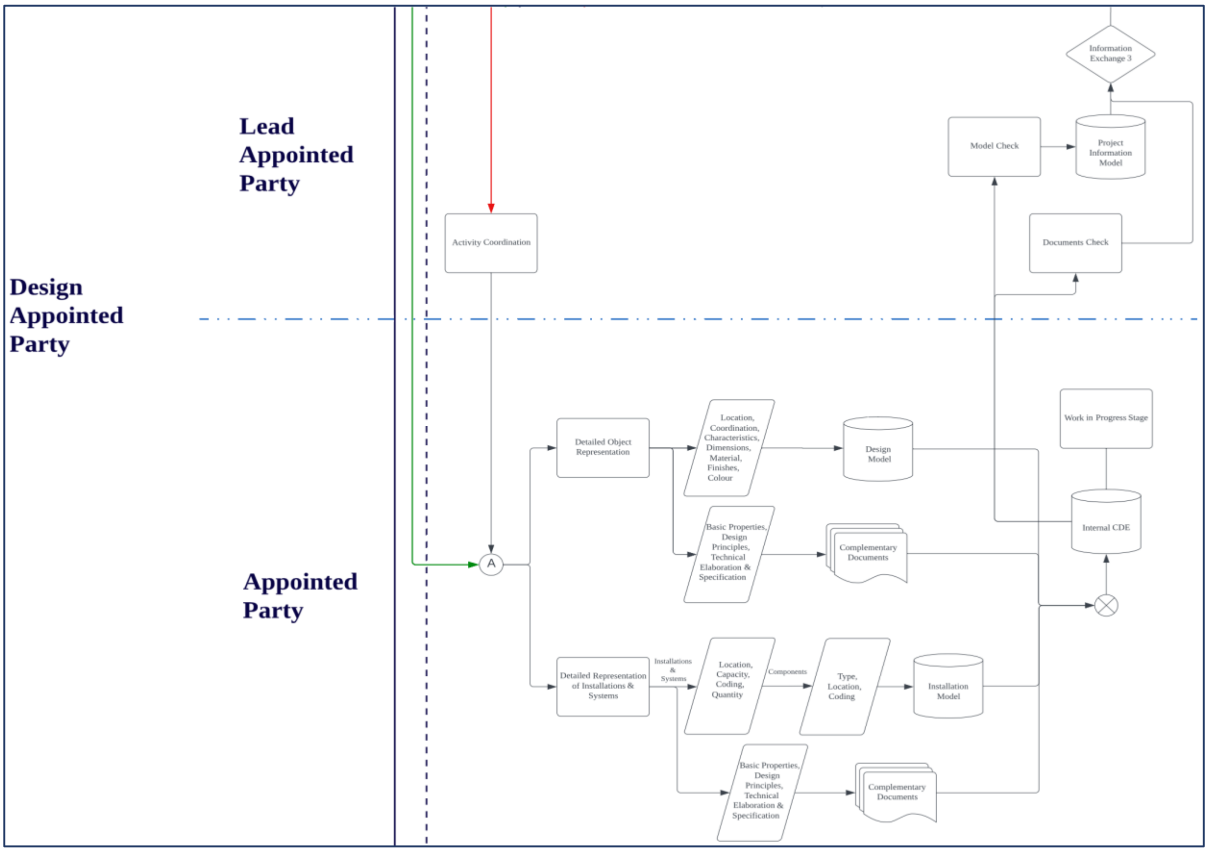


*Figure 24 - Illustration of the activities performed by the Design Appointed Party during the Spatial Coordination stage*

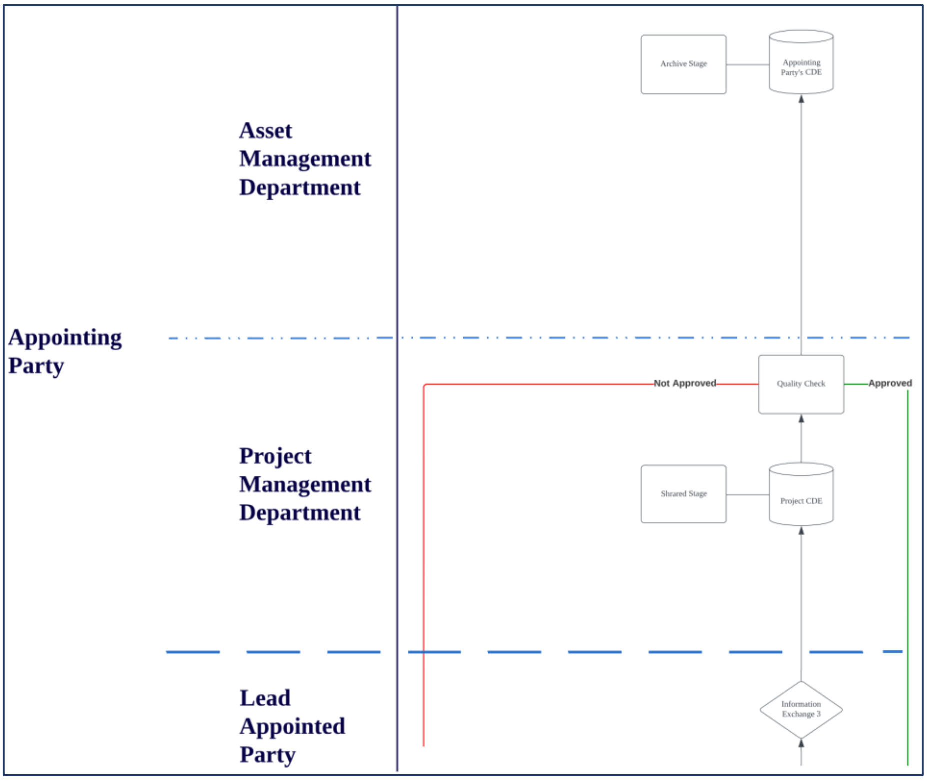


*Figure 25 - Illustration of the activities performed by the Appointing Party during the Spatial Coordination stage*

## Technical Design Stage

During the Technical Design stage, the same actions are followed, yet in a different level of detail. The Lead Appointed Party initiates the coordination of activities and the following steps consider the technical object representation along with the detailed representation of accompanying installations and systems. These two design processes involve the distribution of information as described thoroughly in Chapter 3 as well as sub-chapters 4.2 and 4.3. The final outcome of both processes is the generation of models, i.e. the detailed installation model, as well as the creation of technical documents, which refer to the non-geometrical information needed at this stage.

The aforementioned deliverables are already placed in the internal CDE, under the “Work In Progress” state, and then distributed to the Lead Appointed Party for the quality check. Subsequently, after the deliverables of this stage are checked, they are integrated into the PIM, which is placed in the Project CDE, along with the corresponding documentation. Upon placing the deliverables in the Project CDE, under the “Shared” state, the fourth information exchange occurs, where the same procedure is followed as described in the previous design project stages. If any changes ought to be made, the Project Management department issues the elaboration on technical representation, as illustrated with a red arrow. If everything is approved, then the deliverables are placed under the third stage, i.e. the “Published” state, and the Asset Management department is informed. The information placed there consists of the final version of the deliverables and is authorized for use in the following stages. Depending on the type of project, the Constructor Appointed Party may already have access to this environment, which contains the essential information to be used during the construction. Such an action would further enhance the collaboration between the parties. As the deliverables consist of the final version of models and documents, they are also stored in the internal CDE of the Design Appointed Party, under the “Archive” state. Following, information is also stored on the Appointing Party’s CDE, under the “Archive” state. Then the following project stage, i.e. the Manufacturing & Construction stage is ready to commence.

This is the stage where typically the Design Appointed Party concludes its tasks. However, as mentioned by the interviewees and in line with their digital ambitions overall, this party should be also engaged in the upcoming project stage as the involved teams are responsible for the creation of the design and are aware of all the details. This engagement as well as the collaboration within the same platform and use of the same software (if possible), would also aid in detecting any deviations of the as-built object from the designed one, earlier in the process. Therefore, a significant amount of time and cost could be saved.

For the Design Appointed Party overall, the Technical Design stage is illustrated in Figure 26. Following, the same project stage for the Asset and Project Management departments is illustrated in Figure 27. The Maintenance Contractor and the Constructor Appointed Party are not engaged in this stage.

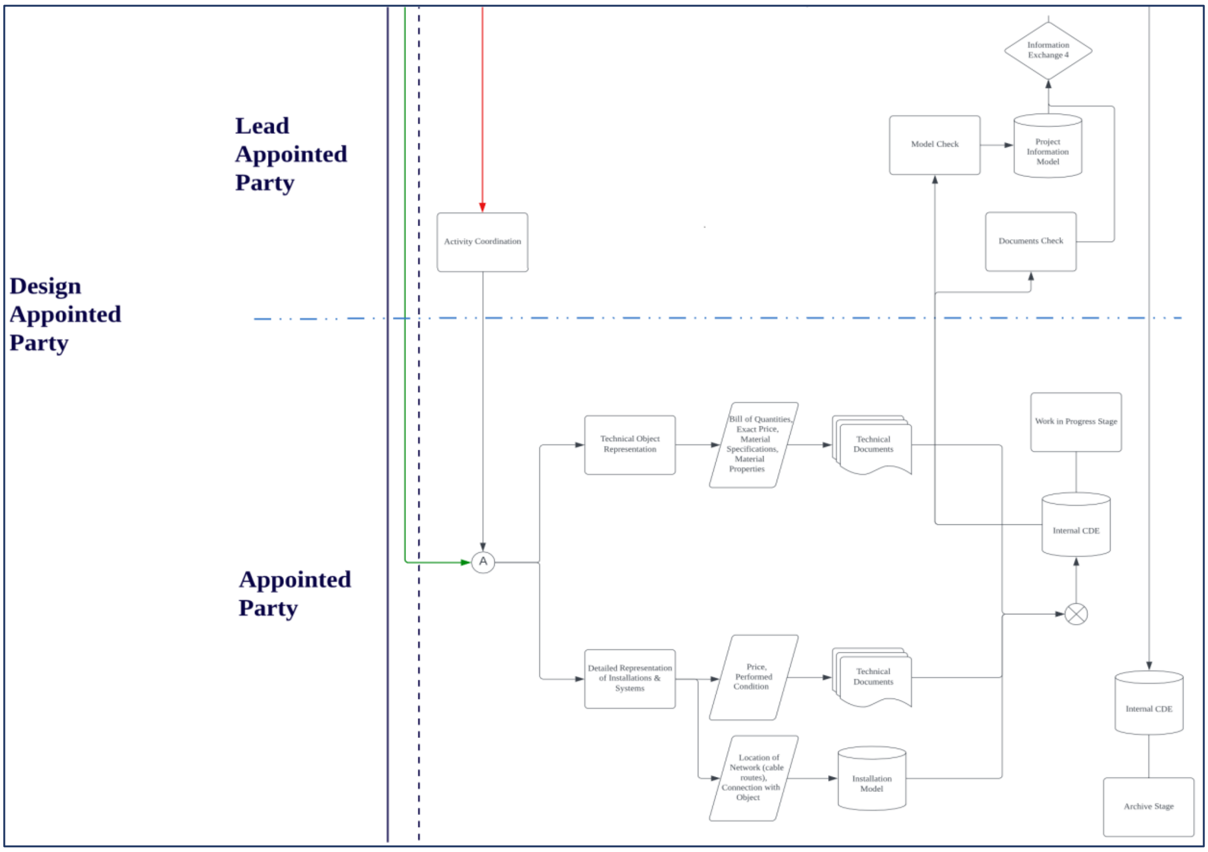


*Figure 26 - Illustration of the activities performed by the Design Appointed Party during the Technical Design stage*

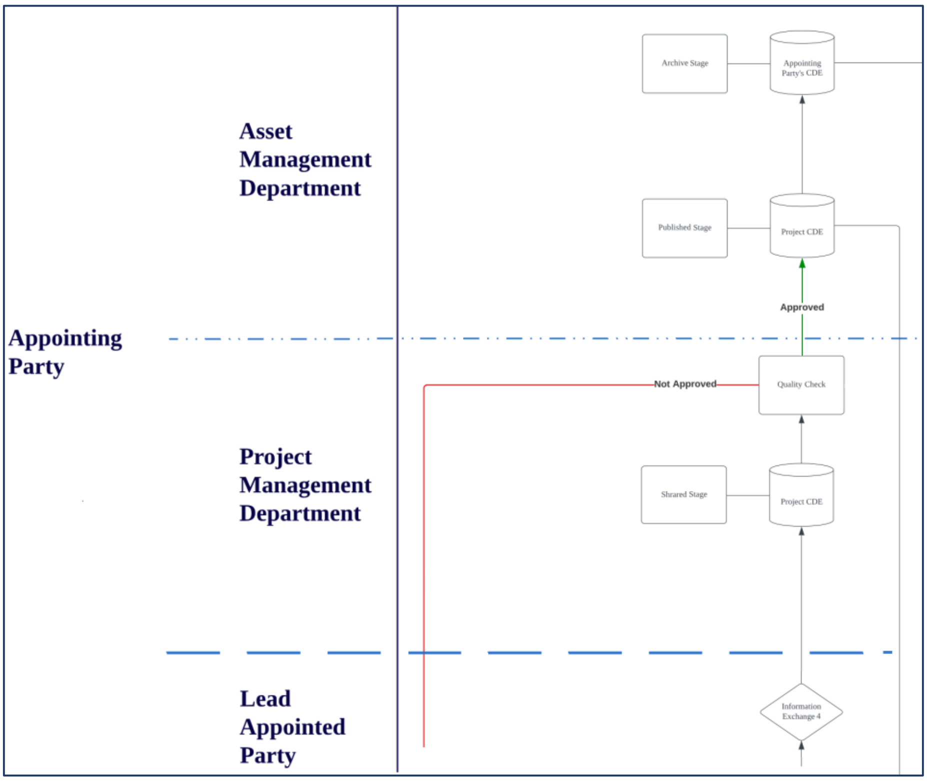


*Figure 27 - Illustration of the activities performed by the Appointing Party during the Technical Design stage*

## Manufacturing & Construction Stage

During this stage, the actual construction of the respective designed object occurs. The Constructor Appointed Party who is responsible for carrying out the implementation gets the design deliverables during the fifth information exchange, during the handover of the official agreements. Therefore, it may start the construction on the basis of the design models and documents. However, as also mentioned by the interviewees, in some cases what is presented in a design may need to be constructed in a different way. Moreover, some designs may either miss some information or information could not be on the optimal level in order to begin the construction. These challenges may be resolved if both parties, i.e. the Design Appointed Party and Constructor Appointed Party, have access to the models already from the start of the design stages in order to mutually share knowledge and ideas.

The Constructor Appointed Party is in charge of producing the as-built information, as described thoroughly in Chapter 3 as well as sub-chapters 4.2 and 4.3. As a first step, the CDE to be used for internal information sharing is determined and then the construction may start. The as-built model is developed based on the final version of the design model shared during the information exchange and is complemented by detailed as-built drawings. The final outcome of this process is the generation of the as-built model as well as the creation of construction documents that refer to the non-geometrical information needed at this stage. However, in larger projects where other assets already exist, it is vital for the Constructor Appointed Party to be aware of any information about the other as-built assets in order to fully comprehend all the interdependencies and be able to construct without causing any damages. Therefore, and as mentioned in the interviews, one of the digital ambitions of this party is the transfer of already existing as-built information into a digital form, provided by the corresponding Appointing Party. Although this process requires time and major collaboration, some steps have been taken towards realizing this goal. Furthermore, there is also the ambition of the live connection of project and information to track the development in real time. However, this practice that is still not in use, yet if implemented, it would further contribute to the efforts towards digital transformation.

The Constructor Appointed Party is also responsible for the creation of operating and control as well as maintenance instructions for the constructed asset. According to the DDS and EIR Table and as presented in sub-charters 4.2 and 4.3, this information is part of the following information exchange. However, as mentioned by the interviewees, all the deliverables should be handed over at the end of the Manufacturing & Construction stage, with the Handover stage representing only the official handover of the final versions. Therefore, this information is included in this stage. Moreover, at this stage, there is also the need for satisfying the maintenance requirements, as mentioned in the findings of the interviews. In order to avoid any alterations made to the as-built design at this stage of the process, these requirements should be clearly established and discussed at the start of the project. The aforementioned deliverables are already placed in the internal CDE, under the “Work In Progress” state, and then placed in the Project CDE, under the “Shared” state. Then, the sixth information exchange occurs, following the same procedure as described in the previous project stages. If any changes ought to be made, the Project Management department issues the elaboration on the construction, operating, or maintenance documents, as illustrated with a red arrow. If everything is approved, the information is also stored on the Appointing Party's CDE, consisting of the "Archive" state, and the following project stage, i.e. the Handover stage is ready to commence.

For the Constructor Appointed Party, the Manufacturing & Construction stage is illustrated in Figure 28. Following, the same project stage for the Asset and Project Management departments is illustrated in Figure 29. The Maintenance Contractor and the Design Appointed Party are not engaged in this stage.

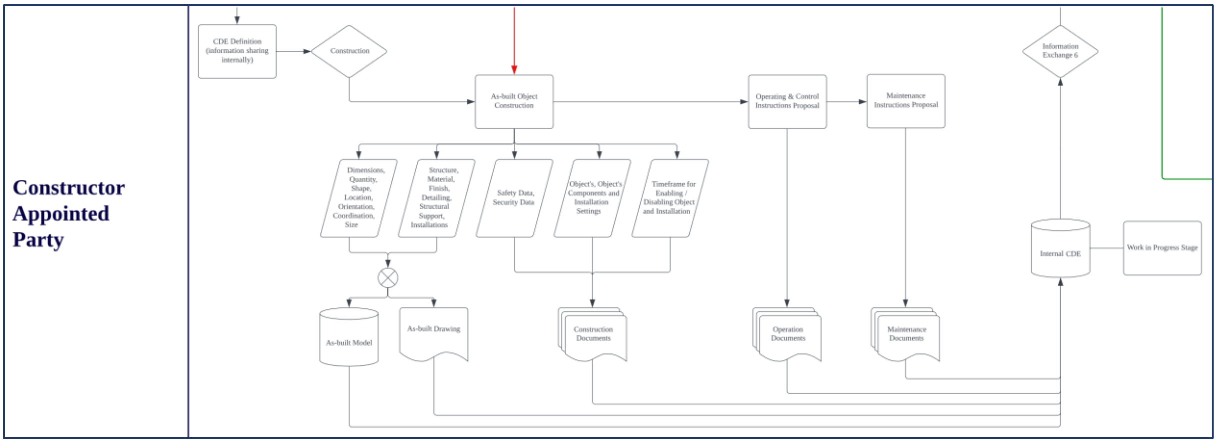


*Figure 28 - Illustration of the activities performed by the Constructor Appointed Party during the Manufacturing & Construction stage*

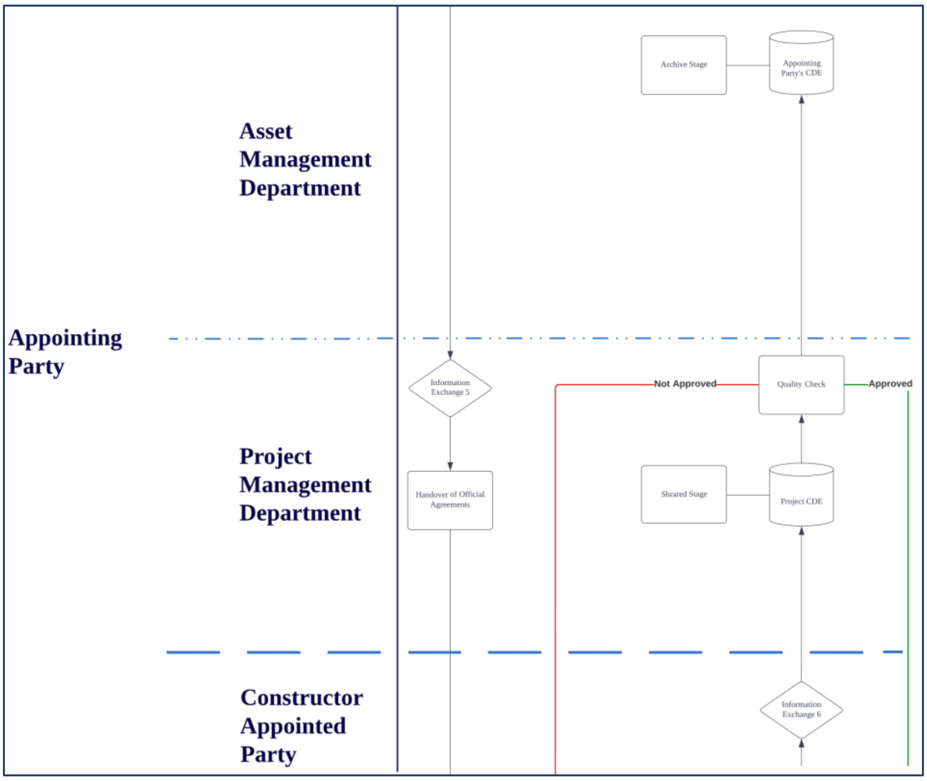


*Figure 29 - Illustration of the activities performed by the Appointing Party during the Manufacturing & Construction stage*

## Handover Stage

At the end of this stage, the seventh and last information exchange occurs. As mentioned above and in line with the findings of the interviews, the final version of all the deliverables produced is handed over. This includes any documentation regarding the construction, operation, and maintenance proposals, as well as the final as-built design which incorporates all the changes that are made to the object during the construction. In the end, the as-built asset must be the same as the one depicted in the design model. If any changes are requested during the previous information exchange, the updated deliverables are placed on the Project CDE, under the “Shared” state for a quality check and then the status is changed into the “Published” state. As these deliverables consist of the final version of models and documents, they are also stored in the internal CDE of the Constructor Appointed Party, under the “Archive” state. Following, information is also stored on the Appointing Party’s CDE, under the “Archive” state.

For the Asset and Project Management departments, as well as the Constructor Appointed Party, the Handover stage is illustrated in Figure 30.

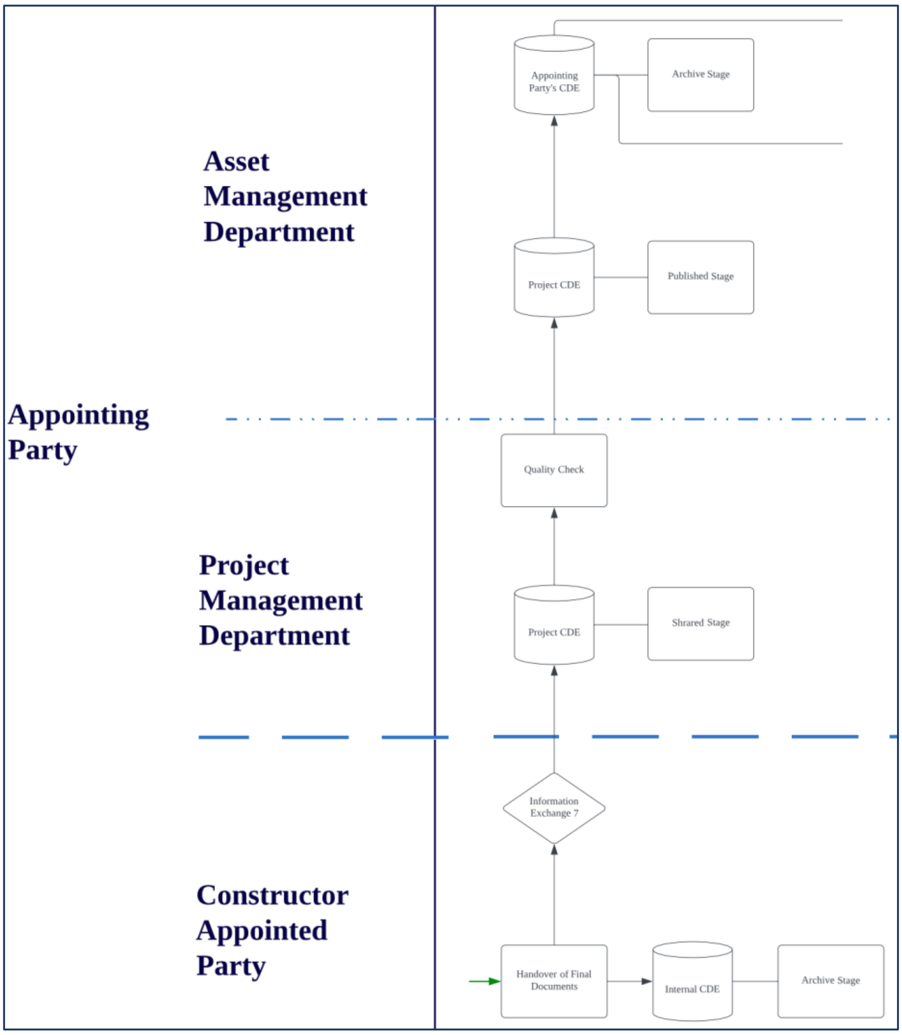


*Figure 30 - Illustration of the activities performed during the Handover stage*

## Use Stage

During this stage, the actual asset is put into use. The activities performed during the Use stage include both the operation and maintenance of the asset. Regarding its operation, the operation documents that are provided during the previous stages are used, including the information described in Chapter 3 as well as sub-chapters 4.2 and 4.3. Moreover, the party responsible for the maintenance, being either an internal actor or an external party as discussed earlier, also utilizes the maintenance documents that are previously provided. An important aspect to consider in this stage is the development of the Asset Information Model, which includes all the representation of the as-built asset together with the installations and components. Moreover, the development of a general-integrated AIM, including all the as-built assets, is among the digital ambitions mentioned in the interviews as such a model will enable the integration of information into a single model, thus also enhancing information reuse in the next project. However, such a process is time-consuming, especially within larger projects with several assets, yet gradually this approach is adopted within the organizations. As a result, the end of the project, i.e. the end of use which is the endpoint of this process map, could lead to the start of a new one by utilizing the already existing information and requirements. This, according to the proposed process map, refers to leveraging the details of the as-built asset and any accompanying systems and installations to produce a new similar asset.

For the Asset Management department, as well as the Maintenance Contractor, the Use stage is illustrated in Figure 31.

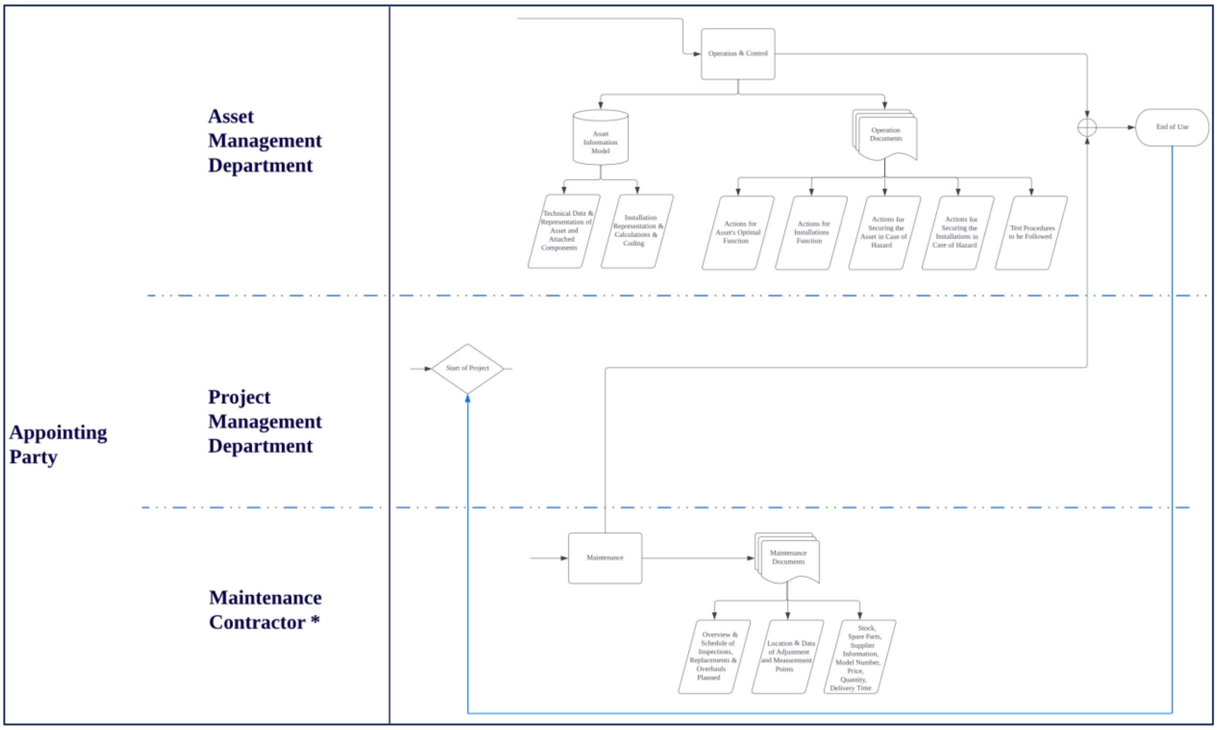


*Figure 31 - Illustration of the activities performed during the Use stage*

Concluding, a complete overview of the designed process map can be found in Appendix V.

Following the process map design, certain aspects are of great importance and need to be addressed. First of all, as it is mentioned at the beginning of sub-chapter 4.5, the process map is designed based on existing practices currently used in the construction industry. Therefore, it includes processes that organizations experienced with BIM implementation already use. As a result, it depicts a current situation in which everything shown in the process map may be accomplished without the need for technological advancements. However, as this is not considered static, yet it can be seen as a rather dynamic process, some future recommendations are included during the process map design. These refer to a further enhancement of the overall process, by implementing also the future digital ambitions of the organizations. Some future, direct or long-term measures might need to be taken in order to put these recommendations into practice, yet if implemented, the overall workflows could be further improved.

Another aspect to be considered is the way that information is presented. The proposed process map includes the basic information that needs to be produced and subsequently transferred during each information exchange and project stage, along with its corresponding format. Therefore, it provides an overview of what should be delivered according to the information requirements that are produced at the beginning of the process. However, it is crucial that this information can be standardized in order to further improve this procedure. Especially, in large and complex projects, there is a vast amount of information that is produced by various teams during all the project stages. More specifically, even when referring to a single object and subsequently asset, this information is interconnected. It is produced and then updated as the process evolves during the later project stages. Therefore, it is important to consider an effective method of standardizing the information so that it can be tracked as it is produced and subsequently transferred across task teams, and then distributed to the other parties as well. However, as this process map considers the first attempt of presenting an integrated outcome of the information management processes and focuses more on the illustration of workflows, this level of detail and standardization is not addressed.

Finally, it is important to note that everyone involved in the process is allowed to select the CDE platforms and providers that will be utilized throughout the project. However, this refers solely to the internal CDE as the Project CDE to be used for information sharing between the Appointed Parties and the Appointing Party is determined by the latter one, in the Information Management Protocol. As the process map is designed to fit a generic purpose, no exact platforms are presented, focusing only on the illustration of the correct states in which the deliverables should be put at each project stage. Some of the more active platforms used for CDE environments within the Built Environment, are Autodesk BIM 360, Bimsync, Trimble Connect, BIMcloud, etc.

# 5. Discussion

This chapter discusses the findings of this graduation research following the collection and analysis of the data as well as the resulting development of the process map. The results of this graduation research are compared to the existing literature. Some remarks on the case study utilized are also made along with justifications for the selection of the door as a representative object. Moreover, the application of the process map in the construction industry is also discussed, together with the incorporation of digital ambitions. Finally, the research limitations are also mentioned.

## 5.1 Comparison with Existing Literature

Studies conducted in the academic community have been dealing with the issue of information management. Most researchers propose a framework or a system in general while illustrating just one component of information management processes. More specifically, some of the proposed frameworks follow a more general approach by providing just the basic context of information management. This approach is efficient as a first step in getting acquainted with all the concepts revolving around information management such as the overall sequence of activities relating to the creation and distribution of information as well as information users that are engaged throughout the process. However, this framework does not go into a more detailed analysis of the workflows. Another suggested outcome demonstrates the various parties engaged throughout the process, as well as their respective duties, yet does not mention the type of information distributed. Finally, the opposite approach is also followed, concentrating on the overall type of information required during the project stages, yet without determining the parties who are producing and distributing this information or the formats and platforms used. The last two proposed outcomes go into a more detailed analysis of the various parties that are involved during the project stages and the information that is distributed between them respectively. Therefore, it could be said that they provide a more elaborate approach to the topic addressed, yet they consist of two different systems that would still need to be combined to provide a more complete result. Consequently, it may be stated that the solutions proposed tend to address only one aspect without offering a comprehensive picture of the procedures, parties engaged, information, formats, and platforms used as well as their interdependencies.

The four main aspects that are present in all the aforementioned approaches are the sequence of activities, engaged parties, type of information, and project stages. However, when considering information sharing, it is crucial that it is linked with information storage, formats, and platforms used. That becomes even more important when operating in a digital environment, striving to enhance the digital transformation of the construction industry, where all of these different parameters such as a Common Data Environment, different information models, etc. become present. Therefore, these aspects should be also part of the overall information management definition, which is something that was missing from the previous research.

Therefore, this graduation research aimed at covering the aforementioned research gap by providing a more consolidated method of defining the workflows of information management. Aspects such as the sequence of activities, parties involved, distributed information as well as formats and platforms used were combined and led to the creation of a single outcome.

## 5.2 Case Study

The case study utilized in this graduation research considers the examination of documentation provided by an airport, which can be identified as a complex organization, as well as interviews with professionals involved in a number of projects this airport is actively working on. With regard to information management, Amsterdam Airport Schiphol is one of the most technologically advanced airports in the industry. AAS not only determines its information requirements prior to the start of each project and communicates them to the involved parties using documents like the Information Management Protocol and the Exchange Information Requirements, but it has also developed a database, i.e. the DDS, where all of these requirements and necessary deliverables for each registered asset can be found. However, this database primarily focuses on deliverables and data as an output rather than detailed procedures or involved parties. As a result, it could be said that although knowledge regarding the procedure and necessary information exists, there are still no complete processes registered, rather than discrete sources of information which may complicate the comprehension of the overall workflows to be followed. This statement is also underpinned by the findings of the semi-structured interviews, where the lack of well-defined processes was among the challenges identified.

## 5.3 Typical Object Selection

For the successful approach to defining the workflows for information management to be followed, the type of information required during each project stage ought to be determined. The EIR as a document provides a certain amount of information on this aspect, yet it mostly concerns the division of geometrical and non-geometrical type of information. This information is rather broad and does not dive into the details required for each project stage. Therefore, the examination of the DDS and EIR Table is necessary. However, both sources include a vast amount of registered assets and thus one object had to be selected in order to proceed. A door was selected as the representative object since it is a non-airport-specific item that may be found in any project, regardless of its domain of execution.

The type of information included in the process map is not limited to doors and may be applied to other objects as well. Furthermore, in line with the main research question, the proposed process map mostly focuses on the sequence of activities and workflows for information management rather than on providing precise, in-depth information depending on the type of object. As a result, there are not many differences in the information required for the objects in general at this level of detail used for the design.

## 5.4 Application of the Process Map in the Construction Industry

As mentioned above, the process map focuses on the demonstration of workflows of information management for the enhancement of digitization. Several organizations in the construction industry, regardless of their corresponding domain, consider information management an essential aspect of digital transformation. The process map provides an integrated approach to the essential steps that ought to be followed when considering digitization, from the team division and necessary roles to the formats and platforms used for information storage. Moreover, it considers the processes that occur within the lifecycle of any project, regardless of the field that it belongs. Furthermore, as already stated, the information presented applies to any object, making it suitable for a variety of purposes. Therefore, the proposed process map may serve as a guide for any organization that embarks on this digital transition or simply wishes to improve its working practices.

This process map can be seen as an important step in connecting the start and the end of a process. The illustration of activities begins with the initial identification of the high, organizational requirements and concludes with the stage at which an asset is actually put into use, thus fulfilling all these requirements. More specifically, the initial information requirements are defined in such a way as to depict the future operation and maintenance requirements that ought to be satisfied. Furthermore, even if the end-user is not represented in the process map, as it is intended for organizations, it might be argued that these information requirements also comprise the end user's requirements. This particularly applies to requirements regarding safety, security, aesthetics, etc., which are taken into account from the very first beginning of the process.

Following the discussion of the process map application to the construction industry, the question of how and why should a party use it arises. First of all, the selected format of process map design aids in better visualizing all the activities from the beginning until the end of the process by also identifying all the parties that are engaged in every stage. Therefore, all the information management workflows are presented in a clear, comprehensive way together with all the important type of information being distributed. Given that certain members of an organization, either within the Appointing or Appointed Parties, may have little to no knowledge of the subject, this saves valuable time that would otherwise be spent thoroughly explaining and comprehending every step that must be taken in the process. Moreover, the suggested process map may also be used as a reference by organizations that aim at improving their information management efficiency, yet are not so advanced in the field of digital transformation. This approach can provide them with all the necessary steps to be followed, according to standards, preventing misunderstandings about the tasks to be pursued, resulting in saving time and cost. Finally, it is important to note that the process map may be used by any organization within the construction industry, regardless of the level of experience, in order to enhance the existing information management practices.

## 5.5 Digital Ambitions

As it is already mentioned, the construction industry has been slower to adopt digital transformation than other industries. However, as the results of the semi-structured interviews indicate, the organizations do have digital ambitions they would like to see realized. These digital ambitions mostly refer to the information use and eventually reuse at the start of a new project and the improvement of collaboration between the different parties involved in the process. This statement is further supported by the fact that considering the dynamic nature of the process with continuous technological advancements, these ambitions would need to be incorporated into future processes. Therefore, the process map is designed in such a way as to aid in incorporating these digital ambitions. The creation of a unified information model by the Appointing Party, i.e. AIM, would aid significantly in the information reuse by capturing the existing as-built information. Moreover, the engagement of all the parties earlier in the process and the use of Common Data Environments accessible to everyone, would also eliminate misinterpretations of the information requirements and reduce mistakes made during the design or actual construction. The updated process map would have to include more parties in certain project stages, e.g. the Constructor Appointed Party during the design stages and Design Appointed Party during the actual construction. The changes would also include additional Common Data Environments, accessible to every party, so the parties could be informed about and review the information models and documentation much earlier in the process. Finally, the creation of the AIM model could not consider solely one asset, yet it could consist of all the as-built assets, integrated into one single model. Therefore, given that the entire as-built model could be accessed, it would be beneficial to share this information with the Design Appointed Party and Constructor Appointed Party earlier in the process, in order to facilitate the elimination of design errors and enhance the construction of new assets. This would imply a change in the process map, with the exchange of such a model, in the initial project stages.

However, it is important to mention that the process of digital transformation is continual, complex, and time-consuming. Furthermore, these digital goals can be achieved more quickly or more slowly depending on the current status and resources of each organization. Moreover, some of the digital ambitions may be introduced directly in the process while others would call for adjustments to the contract formation in order to ensure that all legal requirements are fulfilled. This particularly applies when enabling information sharing among all parties.

## 5.6 Research Limitations

As expected, a graduation research project conducted within the timeframe of six months has some research limitations. Starting with the identification of existing literature, the number of studies that actually focused on describing the processes for information management was limited. Therefore, a literature review could not be used as part of the research methodology since there were insufficient data on the type of information, formats, platforms, and overall workflows followed. As a result, the final outcome was designed solely based on the case study findings, following a more practice-oriented approach.

Another limitation relates to the use of ISO 19650 standards for the terminology applied in the process map as well as the use of the RIBA Plan of Work (2020) for the identification of project stages. Some organizations may use different standards; thus this approach could potentially create confusion when applied. However, this limitation does not imply that the process map cannot be used if other standards or project stages are used within an organization. The most commonly used standards in the construction industry refer to the ISO 19650 and PAS 1192 standards, which are closely related to each other. Similarly, several other project stages may be used, apart from the RIBA Plan of Work (2020), yet the alterations concern the naming of the stages and not the associated concepts. Therefore, the differences that might occur during the implementation of the different standards and project stages do not affect the validity of this design.

Another limitation identified, concerns the sample of interviewees for the conduction of the semi-structured interviews as a result of time constraints. The limited sample size (n=7 participants) may prevent results from being generalized, especially in relation to the specified digital ambitions. However, that is not the case with the findings regarding the other three sub-questions as the interviews only intended to provide complementary information on the already existing findings from the documentation examined. Finally, all participants were involved in projects carried out within the Amsterdam Airport Schiphol, resulting in a potential sample bias. As a result, this may also place certain restrictions on the findings' applicability.

# 6. Conclusions & Recommendations

As digital transformation tends to become the new norm, a gradually increasing number of organizations aim at efficient information management. However, this requires examining several aspects simultaneously in order to achieve a more solid approach to the topic. Therefore, in order to identify more efficient workflows to be followed, this graduation research focuses on the design of a process map which illustrates the procedures, yet also maps the information distributed between the various parties involved, during the different project stages. Several aspects, translated into research sub-questions, and one main research question had to be answered for the successful generation of the final outcome.

## 6.1 Answer to the Research Sub-Questions

In Chapter 1, four questions that aided in answering the main research question have been formulated. The research methodology used, consisting of documentation review and semi-structured interviews, provided an answer to all of them. However, a clear and collective reference to these answers is still required.

### 6.1.1 Research Sub-Question 1

***"What are the processes followed to provide the deliverables needed for each project stage?"***

As a first step, the Organizational Information Requirements are issued during the Strategic Definition stage and subsequently translated into more specific Asset Information Requirements during the Preparation and Briefing stage. Following, they are further developed into Project Information Requirements on the basis of which, the overall information requirements can be defined. Subsequently, the Exchange Information Requirements and Information Management Protocol are created, which contain all the necessary information for the commencement of the project, shared during the first information exchange.

During the Conceptual Design stage, the first step of design, the generic object representation along with the schematic representation of accompanying installations and systems occurs. At the end of this stage, the second information exchange occurs where the deliverables of this stage are shared throughout the corresponding parties. The next project stage considers the Spatial Coordination Design, where the detailed object representation along with the detailed representation of accompanying installations and systems occurs. The same procedure follows at the end, during the third information exchange. The final step of the design considers the technical object representation along with the detailed representation of accompanying installations and systems during the Technical Design stage. The deliverables are once again shared during the fourth information exchange. During each information exchange, the deliverables are reviewed and if not accepted the stage is repeated, while if accepted the next process is issued.

Proceeding into the Manufacturing & Construction stage, the actual construction begins based on the interpretation of the previously shared designs during the fifth information exchange. The designed object is thus developed into an as-built asset and several deliverables referring to it are produced. These are shared at the end of the stage, during the sixth information exchange where they are also reviewed. If everything is accepted, the final deliverables are shared during the Handover stage, during the seventh and last information exchange.

The last project stage, i.e. the Use stage, concerns the actual operation and maintenance of the relevant asset, which can be performed with the aid of the documents delivered during the previous stage. When the termination of either operation or maintenance is decided, the asset is no longer in use.

### 6.1.2 Research Sub-Question 2

***"What kind of information, and by whom, is generated and delivered at each project stage?"***

During the Strategic Definition stage information with regard to the high level objectives of the Appointing Party is formulated by its Asset Management department, subsequently translated into more asset-related requirements. These are then delivered to the Project Management department which adapts them to project-specific information requirements. These requirements are shared with the Lead Appointed Party, on behalf of the Design Appointed Party, and used for the creation of the design.

During the Conceptual Design stage, geometrical and non-geometrical information is created by the Appointed Party. This refers to location, orientation, estimation of the shape, dimensions, and quantities as well as material and colour suggestion. Moreover, a description of the systems attached to the object, a representation of the installations and an overview of the main cable routes is provided. Also, non-geometrical information referring to basic properties and design principles is also produced. This information is then shared back with the Project Management department of the Appointing Party for review. During the Spatial Coordination stage, more detailed information is produced by the Appointed Party. This includes definitive location and dimensions, coordination, characteristics, material, finishes, and colour. A detailed representation of installations and their components as well as their location, capacity, and coding are also created. Non-geometrical information regarding technical elaboration and specifications is also produced. This information as a whole is then shared back to the Project Management department of the Appointing Party for review. During the last design stage, the Technical Design, information such as technical data, bill of quantities, exact price calculations, material specifications and properties, including fire safety are developed. Moreover, detailed calculations of installation components, the location of cable routes, connection, and performed connection of the installations are also among the deliverables.

During the Manufacturing & Construction stage, the Constructor Appointed Party produces information referring to the as-built asset. This includes the details on settings, certifications, checklists, inspections, etc. Furthermore, operating and control instructions are also delivered including a list of actions for the optimal function of the asset and installations, a list and order of actions to secure the installations in case of a hazard as well as a general list of test procedures to be followed. Maintenance instructions are distributed as well, such as an overview and schedule of inspections, replacements and overhauls planned, location and data of adjustment and measurement points. Furthermore, a suggestion on stock is also provided along with an overview of the spare parts list, including supplier information, model number, price, quantity, and delivery time. All the deliverables are shared back to the Project Management department and the Asset Management department and Maintenance Contractor utilize them for the next stage.

### 6.1.3 Research Sub-Question 3

***"What type of formats/platforms are used to store the information?"***

As both geometrical and non-geometrical information is created during the different project stages, they need to be stored using a different format. Therefore, both information models and documents are used. The representation of objects during the design as well as the representation of as-built assets is captured in information models as well as drawings, while the non-geometrical information attached to it is stored in various types of documents.

Each Appointed Party, i.e. Design Appointed Party and Constructor Appointed Party, works internally in their own Common Data Environment and under the "Work In progress" state, where the various tasks teams develop their design models and documentation. After the deliverables of the respective stage are checked, they are placed in the CDE of the project, as defined by the Appointing Party in the IM Protocol, under the "Shared" state. At the end of the Technical Design stage and the Handover stage, and when everything is approved and verified, the final deliverables are placed under the "Published" state and the Asset Management department is informed. Finally, both the Appointed Parties and the Appointing Party store the information produced and received during the several information exchanges in another environment, not accessible to the other parties, to use it for future purposes, such as archive, and operation and maintenance purposes respectively. This concerns the "Archive" state.

### 6.1.4 Research Sub-Question 4

***"How can the organizations' digital ambitions be aligned with the process?"***

The organizations' digital ambitions can be summarized into the following: information reuse and transferring of as-built information to a digital form is desired and could be achieved by creating an Asset Information Model, which will enable the integration of information into a single model. Therefore, the end of the use of an asset could lead to the start of a new one by utilizing the already existing information and requirements. Moreover, the improvement of collaboration between the parties from the beginning of the process is also discussed, focusing on the engagement of all parties during the project stages, particularly applying to the Design Appointed Party and Constructor Appointed Party. Having access and working in the same environment will aid in detecting any deviations of the as-built asset from the designed object, earlier in the process. By implementing that, during the actual construction, the Design Appointed Party will also have the opportunity to advise on the constructed assets, thus minimizing the time lost as a result of misinterpretations of the design.

## 6.2 Answer to the Main Research Question

The answers to the aforementioned sub-questions help to address the main research question:

***"How can the workflows for information management be defined to allow digitization across the whole lifecycle"***

In order to define the workflows for information management to allow digitization across the whole lifecycle, multiple aspects need to be taken into consideration. The project stages should be clearly defined along with the sequence of activities that ought to be followed during each project stage. The different parties involved should be also identified to understand their responsibilities and interdependencies. Moreover, the type of information produced and shared with a party respectively is another aspect to be considered as this would provide a deeper understanding of the processes that need to be followed. Furthermore, in order to facilitate digitization, the various formats of information need to be also addressed, as well as the platforms and environments used for information storage. Finally, efforts should be made to improve the procedure by incorporating further digital ambitions.

It is important to understand that the topic of information management is quite complex and a number of simultaneous actions are required in order to improve the workflows. This becomes even more crucial when considering the overall goal towards digital transformation. Therefore, a variety of parties needs to be engaged and fully aware of their tasks during the entire lifecycle, starting from the initial definition of information requirements until the actual operation and maintenance of the as-built asset. As a consequence, a vast amount of information is also produced and transferred between all these different parties, using different formats and being stored in different platforms and types of storage. Furthermore, the information deliverables might need to be reviewed by several parties, depending on the project stage. This may eventually lead to confusion and misinterpretation of what task needs to be performed each time during a project stage, as there are several actions happening at once. Therefore, the outcome of this graduation research proposes an efficient way of determining the information management workflows by presenting a comprehensive, integrated approach to all the activities that occur during the whole lifecycle.

## 6.3 Theoretical & Practical Contribution

The proposed process map focuses on the integration of several aspects that are considered important in order to better define the workflows for information management and enhance digitization through the whole lifecycle. The process map is designed in a self-explanatory way, providing a clear overview of all the aspects addressed. Furthermore, it is believed that its theoretical contribution is essential since it presents a combined approach to identifying the processes, whereas previous studies only concentrate on one at a time.

Given that this graduation research follows a more practice-oriented approach, the process map is ultimately created using information from the documentation and responses from participants working in the construction industry. Therefore, as the process map can be used for several projects, regardless of their domain, it can serve as guideline for organizations who desire to improve their information management processes and implement their digital ambitions. Moreover, it can provide an overview of the information that should be produced during each project stage as well as the type of format used and collaborative platforms used, thus aiding the parties involved in better understanding the expected deliverables and corresponding information requirements.

## 6.4 Recommendations

Following and based on the identified research limitations, recommendations for further research are given. Moreover, as this graduation research was conducted in collaboration with Netherlands Airport Consultants, further recommendations are provided concerning the construction industry as well as the company.

### 6.4.1 Recommendations for future research

This research was developed based on the application of ISO 19650 standards and the use of the project stages as described in the RIBA Plan of Work (2020). As other standards exist within the construction industry, also depending on the organization, it is suggested to examine how the workflows for information management may be determined according to these and if any differentiations occur. Moreover, future research could also focus on providing more details on the actual type and standardization of information needed per project stage, in order to design a more detailed version of the process map. Finally, the sample of interviewees used in this research consisted of participants within the same domain and involved in the same projects. Therefore, it is recommended that a bigger sample is used by also selecting participants from different domains within the construction industry. This would aid in providing a more accurate approach to the definition of workflows, as any bias would be avoided and the validity of results would be increased.

### 6.4.2 Recommendations for the industry & NACO

As already mentioned, not all digital ambitions can be realized within the current context of the construction industry. Some initiatives should be made in order to facilitate the implementation of some actions. These relate to the desire for extracting all the information from BIM models, thus minimizing the risk of information doubling and the use of different forms for the demonstration of the same information. Moreover, the live connection of the project and information should be also investigated as it would provide many benefits to the monitoring of development, thus also enabling the information to be registered in real time.

The recommendations for the company concern mostly the enhancement of the collaboration with the other parties involved as well as the implementation of its digital ambitions.

In order to improve the collaboration with the Appointing Party during the start of the project, it is recommended to be actively involved in the development of information requirements. This could be achieved with the use of a common platform or document during the drafting of requirements, which would enable keeping track of the changes and making remarks before their official release through the EIR. Such an engagement in the early stages of the process would minimize the confusion or misinterpretation of information requirements and subsequently save valuable time during the design stages.

Moreover, the company should seek efficient collaboration with the Constructor Appointed Party in order to avoid deviations between the as-built asset and the original design. By providing access to the CDE used even at the early stages of the design, the Constructor Appointed Party could have a clearer overview of the steps followed and could advise based on his experience. However, in order for this to happen the appropriate contract should be drafted, precisely specifying the obligations of each party and the extent to which each may interfere with the process.

# Reflection

This thesis consists my last step towards pursuing my MSc in Construction Management and Engineering, after a challenging and sometimes stressful journey of selecting a thesis topic and surpassing all the obstacles that arose during the past months. Following a more practice-oriented mindset as a person and holding also a degree in Civil Engineering, I had to overcome the challenge of balancing the theoretical contribution with the practical end result. However, with the correct guidance and with my patience and persistence, I was able to produce a result that not only can be applied in the construction industry but also notably contributes to the academic community. Therefore, I am very pleased with my work and the final outcome of this graduation and I strongly believe that it can aid several organizations in the industry in improving their efficiency and achieving their goals of digital transformation, while also providing significant input to scientific research.

Being captured by the field of digital transformation and Building Information Modelling, I found this topic extremely interesting and challenging at the same time, as I had to get acquainted with a vast amount of terms and concepts that I had little knowledge of. However, this was also the most interesting part of my journey since, in my opinion, information management is a rather complex topic that requires the integration of several components in order to be addressed properly. This is also the reason behind the selection of a process map as the most effective way of representing all these different interrelations between the different components as they occur over time. My engagement on this particular topic undoubtedly helped me to improve my managerial skills, while also broadening my horizons on the field.

The only thing that I would change during the past months is the stress that followed these challenging conditions. Certainly, it was a great journey and I hope that other people will find my work intriguing and a source of motivation for further research.

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# Appendix I:
# Semi-structured Interviews Outline

### *Appointing Party*

The purpose of this graduation research is to determine the workflows for information management to allow digitization across the whole lifecycle. Therefore, this research aims at the development of a process map to determine more efficient workflows to be followed, by linking the distributed information between the different actors involved throughout the several project stages.

The purpose of the semi-structured interviews is to gain important insight into the way that both the appointing party and delivery team produce, interpret and deliver an asset's information with regards to the type and detail of information needed as well as format, while also taking into account the organization's digital ambitions.

In order to avoid misunderstandings and to avoid confusion, the RIBA Plan of Work (2020) Project Stages have been used:

**Project Stages: RIBA Plan of Work (2020)**

0. Strategic Definition
1. Preparation & Briefing
2. Concept Design
3. Spatial Coordination
4. Technical Design
5. Manufacturing & Construction
6. Handover
7. Use

❑ **Background**

a. Company
b. Job Title
c. Professional experience

❑ **Information requirements**

d. What is your opinion on defining the information requirements prior to the start of a project?
e. How do you see the Exchange Information Requirements supporting the information needed for each stage?
f. What type of information do you consider necessary to be established?
g. What difficulties do you encounter when defining the information requirements?
h. What in your opinion, would be the best approach to improve this procedure?

❑ **BIM use & Project stages**

i. How are the responsibilities and tasks divided in the organization?
j. What type of information and documents do you expect to be delivered at the end of the Manufacturing & Construction stage?
k. What type of information and documents do you expect to be delivered at the end of the Handover stage?

❑ **Information & Documentation**

l. What is the organization's approach to information management?
m. What difficulties do you encounter when receiving the information produced by the delivery team at the end of each stage and when sharing with the contractor?
n. What in your opinion, would be the best approach to improve this procedure?
o. What is the more convenient format of information to be delivered at the Handover stage?
p. How is the information stored at the end of each project stage?

### *Design Appointed Party*

The purpose of this graduation research is to determine the workflows for information management to allow digitization across the whole lifecycle. Therefore, this research aims at the development of a process map to determine more efficient workflows to be followed, by linking the distributed information between the different actors involved throughout the several project stages.

The purpose of the semi-structured interviews is to gain important insight into the way that both the appointing party and delivery team produce, interpret and deliver an asset's information with regards to the type and detail of information needed as well as format, while also taking into account the organization's digital ambitions.

In order to avoid misunderstandings and to avoid confusion, the RIBA Plan of Work (2020) Project Stages have been used:

**Project Stages: RIBA Plan of Work (2020)**

0. Strategic Definition
1. Preparation & Briefing
2. Concept Design
3. Spatial Coordination
4. Technical Design
5. Manufacturing & Construction
6. Handover
7. Use

- **Background**
  a. Company
  b. Job Title
  c. Professional experience

- **Information requirements**
  d. What is your opinion on defining the information requirements prior to the start of a project?
  e. How do you see the Exchange Information Requirements supporting the information needed for each stage?
  f. What type of information do you consider necessary to be established?
  g. How would you interpret what is to be delivered if the information requirements are not established in a document?
  h. What difficulties do you encounter when receiving and interpreting the information requirements?
  i. What in your opinion, would be the best approach to improve this procedure?

- **Information & Documentation**
  j. What difficulties do you encounter when producing the deliverables?
  k. What in your opinion, would be the best approach to avoid these problems?
  l. What difficulties do you encounter when sharing the information produced at the end of each project stage back to the client?
  m. What in your opinion, would be the best approach to avoid these problems?

- **BIM use & Project stages**
  n. How are the responsibilities and tasks divided between the delivery team at the three design stages (Concept Design, Spatial Coordination, Technical Design)?
  o. How is the information stored during each project stage?

### *Constructor Appointed Party*

The purpose of this graduation research is to determine the workflows for information management to allow digitization across the whole lifecycle. Therefore, this research aims at the development of a process map to determine more efficient workflows to be followed, by linking the distributed information between the different actors involved throughout the several project stages.

The purpose of the semi-structured interviews is to gain important insight into the way that both the appointing party and delivery team produce, interpret and deliver an asset's information with regards to the type and detail of information needed as well as format, while also taking into account the organization's digital ambitions.

In order to avoid misunderstandings and to avoid confusion, the RIBA Plan of Work (2020) Project Stages have been used:

**<u>Project Stages: RIBA Plan of Work (2020)</u>**

0. Strategic Definition
1. Preparation & Briefing
2. Concept Design
3. Spatial Coordination
4. Technical Design
5. Manufacturing & Construction
6. Handover
7. Use

- **Background**
  a. Company
  b. Job Title
  c. Professional experience

- **Information requirements**
  d. What is your opinion on defining the information requirements prior to the start of a project?
  e. How do you see the Exchange Information Requirements supporting the information needed for the actual construction?
  f. What type of information do you consider necessary to be established?
  g. How does it align with the information that is provided to you?

- **Information & Documentation**
  h. What difficulties do you encounter when receiving and interpreting the design documents?
  i. What in your opinion, would be the best approach to improve this procedure?
  j. What difficulties do you encounter when sharing the information produced at the Handover stage back to the client?
  k. What in your opinion, would be the best approach to avoid these problems?

- **BIM use & Project stages**
  l. What type of deliverables do you produce during the Construction and Handover stage?
  m. How is the information stored during the Construction and Handover stage?
  n. What is the more convenient format of information to be delivered at the Handover stage?
  o. What difficulties do you encounter during the Construction and Handover stage with regard to the as-built asset?
  p. How do you deal with the as-built asset deviating from the original design?
  q. What in your opinion, would be the best approach to avoid these problems?

# Appendix II:
# List of Interviewees

| Appointing Party | | |
|---|---|---|
| **Name** | **Organization** | **Role** |
| Sjoerd van Kampen (Interviewee no. 3) | Amsterdam Airport Schiphol | Asset owner of automatic (closing) installations in the Asset Management department |
| Milan Seegers (Interviewee no. 2) | Amsterdam Airport Schiphol | BIM advisor in the Asset Management department |

| Design Appointed Party | | |
|---|---|---|
| **Name** | **Organization** | **Role** |
| Mike dos Santos Freitas (Interviewee no. 6) | NACO | BIM Manager Aviation |
| Rutger Heeren (Interviewee no. 4) | Royal HaskoningDHV | Project Manager |
| Bart Polman (Interviewee no. 1) | NACO | Lead Engineer Airport Building Design |

| Constructor Appointed Party | | |
|---|---|---|
| **Name** | **Organization** | **Role** |
| Rolph Baggen (Interviewee no. 5) | SPIE Nederland | Information - BIM Manager |
| Yamoh Rasa (Interviewee no. 7) | Heijmans N.V. | BIM Coordinator |

# Appendix III:
# Information Deliverables (for a door)

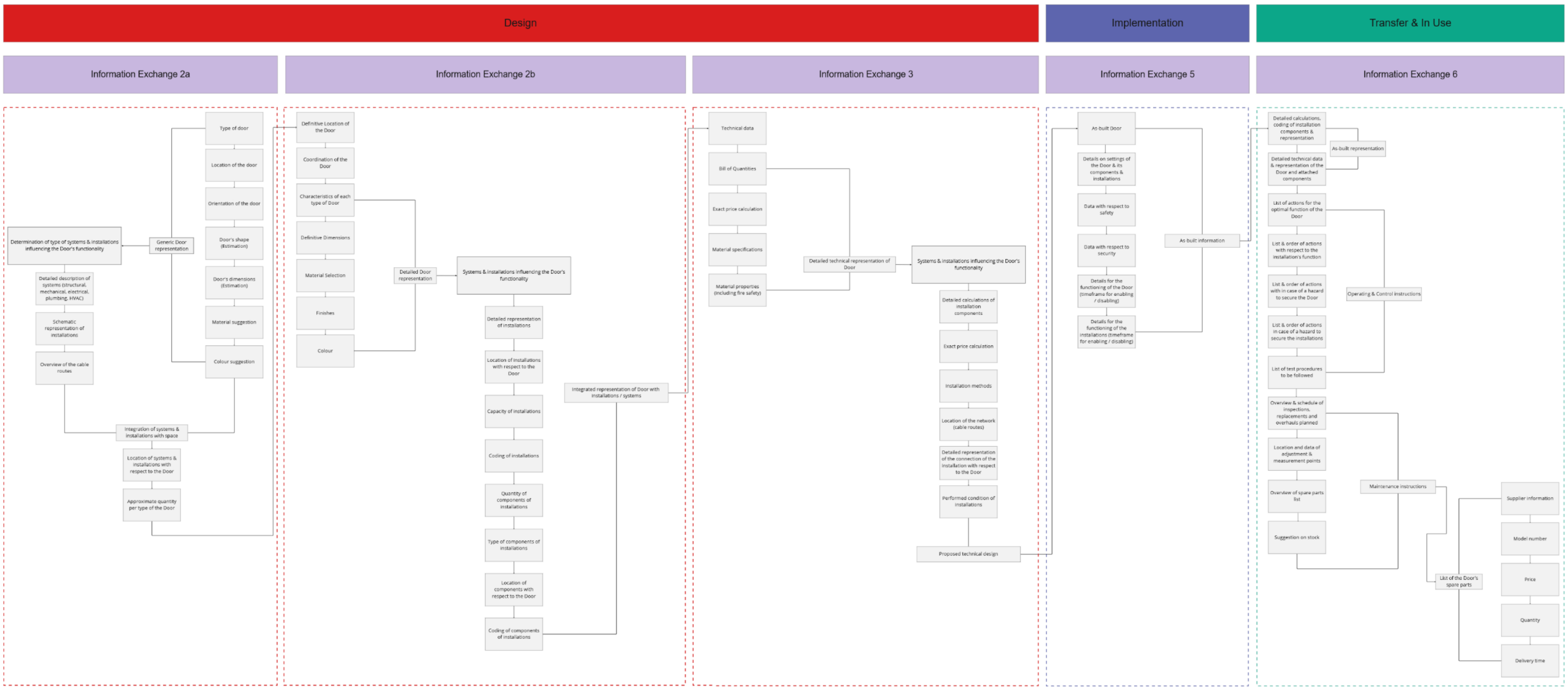
## *Overview of Information Deliverables*

| | Information Exchange 1 | Information Exchange 2a | Information Exchange 2b | Information Exchange 3 | Information Exchange 4 | Information Exchange 5 | Information Exchange 6 |
|---|---|---|---|---|---|---|---|
| **A Applications, permits, assignments** | A-33, A-61 | | | | | A-33 | A-61 |
| **B Calculations** | B-24 | | | B-24 | B-24 | | B-24 |
| **C Certificates of approval/defectiveness** | C-42, C-54 | | C-14 | C-14 | | | C-42, C-54 |
| **D Dates, Lists** | D-55, D-62 | | | | | | D-55, D-62 |
| **E Material and supplier information** | E-01, E-02, E-03, E-04, E-05, E-32, E-47, E-60 | | | E-01, E-02, E-11 | E-01, E-02, E-11 | E-01, E-32 | E-01, E-02, E-03, E-04, E-05, E-47, E-60 |
| **H Plans** | | | | | H-19 | | |
| **J Reports of inspections, measurements and controls** | J-29, J-31, J-34, J-37, J-38, J-48, J-64 | | | | J-12 | J-29, J-31, J-34, J-37, J-38, J-64 | J-37, J-38, J-48, J-64 |
| **K Technical diagrams** | K-01, K-02, K-03, K-05, K-06, K-07, K-12, K-13, K-22 | K-01, K-02, K-03, K-05, K-06, K-12, K-13, K-22 | K-01, K-02, K-03, K-05, K-06, K-07, K-10, K-12, K-13, K-22 | K-01, K-02, K-03, K-05, K-06, K-07, K-12, K-13, K-22 | K-01, K-02, K-03, K-05, K-06, K-07, K-12, K-13, K-22 | | K-01, K-02, K-03, K-05, K-06, K-07, K-12, K-13, K-22 |
| **L Technical drawings** | L-01, L-03, L-04, L-05, L-26 | L-01, L-03, L-04, L-05, L-26 | L-01, L-03, L-04, L-05, L-26 | L-01, L-03, L-04, L-05, L-26 | L-01, L-03, L-04, L-05, L-26 | | L-01, L-03, L-04, L-05, L-26 |

## *Content & Format of Information Deliverables*

| LABEL | NAME | CONTENT | FORMAT |
|---|---|---|---|
| A-33 | Document Switching Order | Document confirming that the installation/object may be enabled or disabled | PDF |
| A-61 | Functional clearance | i) Declaration given to the contractor indicating that a certain area is free of function<br>ii) Statement given to ASM indicating that a particular installation is free of function | PDF |
| B-24 | Cable Calculation | Document with the calculation of cables to be used per cable type | PDF |
| C-14 | Approval document constructor | A document in which the constructor indicates that he agrees with the proposed design | PDF |
| C-42 | Inspection report Lift Institute | Inspection report | PDF |
| C-54 | Overview of CE markings/Certificate of CE standard | CE markings for all installations and installation components (including composite installations) | PDF |
| D-55 | Overview of Used ST Connections | An overview of all connections | PDF |
| D-62 | Cable Coding | These codes must also be shown on (installation) drawings | PDF, EXCEL |
| E-01 | Complete specifications (material/asset/space) | Including fire properties of applied materials | PDF |
| E-02 | Maintenance instructions | The maintenance instructions should contain a complete program in which all inspections, replacements and overhauls are planned | |
| E-03 | Spare parts list | Complete list of all parts of all assets, of parts that can fail and are replaceable | PDF |
| E-04 | Operating and control instructions | Manuals/guides and instructions for use must describe at least the following topics | PDF |
| E-05 | Supplier information | If the supplier is already known, then only state the article number and type designation | PDF |
| E-11 | Selection list | A selection list is a list that is filled in during the preparation of the PoR of a project to specifically indicate which requirements the asset must meet | PDF |
| E-32 | Documentation Adjustment/set-up data | Settings of all installation components, as they should be set up in a properly working situation | PDF |
| E-47 | Hanging and Closure statement | Document with an overview of all applied hinges and locks, including roof hatches and floor hatches | PDF |
| E-60 | Warranty certificates | The original warranty certificates of all objects Including | PDF |
| H-19 | Demolition Plan | Architectural drawing of the current situation, indicating the demarcation of the project, and which objects will be demolished / temporarily removed | PDF, DWG, IFC |
| J-12 | Zero inspection report | Report of performed condition determination of installations and constructional situation | PDF |
| J-29 | FAT report | FAT reporting | PDF |
| J-31 | Commissioning Report | Changes and/or comments related to the relevant object that ASM in will be taken under management | PDF |
| J-34 | SAT Report | SAT reporting | PDF |
| J-37 | TOAT Report Fire Safety Facilities | TOAT Report Fire Safety Facilities | PDF |
| J-38 | TOAT Report Emergency Power Facilities | TOAT report Emergency power supplies | PDF |
| J-48 | Commissioning Report | Commissioning Report | PDF |
| J-64 | Certificate/inspection report installation | Document demonstrating that the new installation and its components meet the legal requirements, by means of certification or inspection of the objects | PDF |
| K-01 | Block diagram | Schematics are needed for the various principles that describe the objects/installations | DWG, PDF |
| K-02 | Low voltage diagram | Schematic representation of entire low voltage installation | DWG, PDF |
| K-03 | Bulb diagram | Diagram that indicates in which positions the switches in the installation should be by means of dots | DWG, PDF |
| K-05 | Circuit diagram | Schematic diagram of the circuit of the entire installation | DWG, PDF |
| K-06 | Electrical diagram | Schematic representation of the electrical installation | DWG, PDF |
| K-07 | Single line diagram | Diagram showing the entire installation in relation to one central line | DWG, PDF |
| K-10 | Process diagram | i) Mechanical assets<br>ii) Fire Safety Assets | DWG, PDF |
| K-12 | Wiring diagram | Overview of all connections of an asset | DWG, PDF |
| K-13 | Control diagram | Schematic of all control components and their interconnections | DWG, PDF |
| K-22 | Installation diagrams | Installation diagrams | DWG, PDF |
| L-01 | Floor plan | The drawing package includes all necessary installation layouts and floor plans | PDF, DWG, IFC |
| L-03 | Detail drawings | Detail level 1:1<br>Of all (components of) assets | PDF, DWG, IFC |
| L-04 | View drawings | View | PDF, DWG, IFC |
| L-05 | Sections | i) In the case of architectural and civil assets: i) All architectural and civil assets<br>ii) For installations: Structural situation | PDF, DWG, IFC |
| L-26 | Fixture drawings | Layout Drawings | PDF, DWG, IFC |

# Appendix IV:
# Diagram of Information per Information Exchange (for a door)



# Appendix V:
# Overview of the Designed Process Map