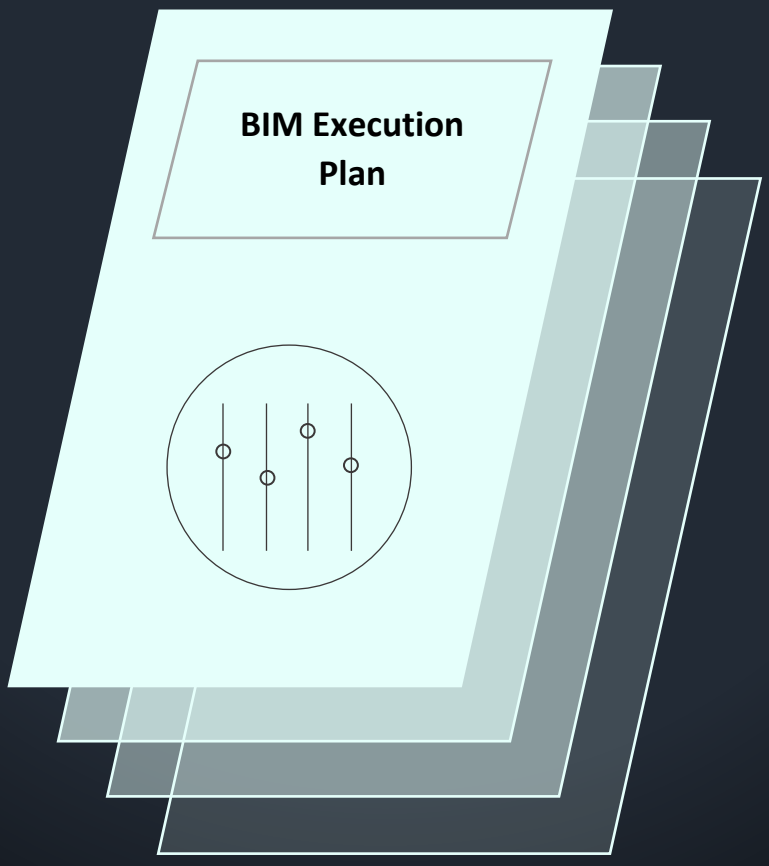
A study on the customization of the BIM Execution Plan based on project characteristics



Iason Tzanakakis | M.Sc. Thesis

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A study on the customization of the BIM Execution Plan based on project characteristics

M.Sc. Thesis for the degree of
Master of Science in Construction Management and Engineering
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Preface

This graduation thesis: “A study on the customization of the BIM Execution Plan based on project characteristics”, is the last chapter of my M.Sc. in Construction Management and Engineering at TU Delft. The research was carried out in collaboration with Sweco Netherlands and lasted seven months, from May 2021 to December 2021. One more thesis that online collaboration was the primary way of working. Living still in a pandemic era, two years now, online is the new normal; however, I hope to get back soon the energy of the physical collaboration.

This thesis has two main outputs: a) a process of customising a BIM Execution Plan (BEP) based on project characteristics and b) a decision support tool that practically captures this BEP customization process for BEP authors. These two outputs concern the theoretical contribution of the thesis (the process) and the practical end product (the tool). Striking a balance between these two outputs was quite challenging, and it would not have been balanced without the support of the graduation committee and the company supervisor. Thus, I would like to thank each one of them:

Hans Bakker, the chairman of my committee, whose feedback was precise, comprehensive, sometimes sharp, but always helpful in staying on track. His handwritten comments were so much helpful! The first supervisor, Tong Wang, whose constant feedback helped me to make crucial improvements on my research method and report. She was precise and made me better understand the scientific aspect of the thesis’ results and how to achieve this. The second supervisor, Yan Liu, who was there to help, provided critical feedback and literature sources throughout the research. The main gain from my master and my thesis, apart from the knowledge in construction management, is the fit-to-purpose approach. Thanks, people of TU Delft.

Regarding Sweco NL, first and foremost, I would like to thank Albert Roeleveld, my company supervisor, who established an amicable collaborative and supervising relationship. He supported me from the initiation until completing my thesis, always with valuable comments and discussion. Furthermore, he consistently fulfilled his supervising role by providing any resource I needed quickly and effectively. At the same time, thanks also each one of the 16 Sweco employees who provided input to the research. Special thanks to Ronnie Lauxen, an Information Manager at Sweco, who helped my thesis substantially. Sweco NL became the first engineering consultancy in the Netherlands that received an ISO 19650 certificate. Hence, I believe that I collaborated with one of the most relevant companies to the context of my thesis. Thanks for this collaboration.

First, I would like to thank my parents, Konstantinos & Stella, who have supported my education and general development for many years. They are the foundation that made the realization of any of my targets possible. Both are great paradigms for my life, and as I get older the love for them becomes more substantial. Lots of love also to my girlfriend, Eleftheria, who is always by my side, making me a better person with her love and words. She spent much time on improving my report, next to me! A hug from her gives me the energy to keep going calm and focused! Finally, I would like to thank my cousin, Dimitra, who was more than happy to help me in a critical moment for my thesis.

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Executive Summary

Introduction & The problem statement

The construction sector suffers from flat or sometimes even falling productivity rates compared to the growth of other sectors (e.g. manufacturing) and that of the global economy (EUBIM Task Group, 2016). At the same time, it is one of the least digitalized sectors. A root cause, among others, is poor information management which becomes even more difficult due to the overproduction of information. Recently, most of the ISO 19650 series have been released to offer the construction industry a guideline for the organization and digitization of information in construction assets when building information modelling (BIM) is used. An essential document of that ISO is the BIM Execution Plan (BEP) which defines how, why, when, and by whom the information modelling aspects of the contract will be carried out (Castainghristoph, 2018).

However, a uniform application of standards and guidelines in projects is not recommended as it can hamper flexibility and versatility. On the contrary, the tailor-making of a standard as per the needs and characteristics of a project is supported by different authors (Burgan & Burgan, 2014; Shenhar et al., 2002) and can yield benefits for an organization. Organizations are struggling to set up a process to customize the BEP that fit the needs of a project.

The problem that seeks an answer is the development of a process for the customization of a BEP according to the project's needs.

The purpose of the research

This research focuses on the BIM Execution Plan (BEP) and how this can be tailored to fit the needs of a project. It is examined the development of a process for customizing a BEP based on a list of project characteristics. This process is then practically captured and validated with the development of a decision support tool. This tool aims to help BEP authors and recommend the extent of development of the BEP contents as per the project's needs.

This research will focus on the preparation phase of infrastructure projects where the post-contract BIM execution plan applies. Compared to the pre-contract, a post-contract BEP is a complete document that contains all the critical project's information and applies until the project's completion. Then, after the award of the project, follows the preparation phase where the post-contract BEP is being developed.

Research questions

The main research question of this thesis is formulated below:

"How can the BIM Execution Plan (BEP) be tailored to fit the needs of a project based on predefined project characteristics?"

This main question is answered through the following four sub-questions:

- **R.SQ.1:** *"Which are the most important Project Characteristics (PCs) for the development of a BEP that fits the needs of a project?"*

- **R.SQ.2:** *"How can the most important PCs be correlated to the contents of a BEP template?"*
- **R.*SQ.3:*** *"How can the extent of development categories of the BEP contents be defined?"*
- **R.*SQ.4:*** *"How can the PCs, the BEP contents and the recommendations for their extent of development, be combined in a practical and user-friendly way?"*

Research steps

Several research methods have been deployed in order to answer the research questions described above:

- A **literature review**, to get familiarized with the context of the thesis (Information management, ISO 19650) and collect project characteristics (PCs)
- A **questionnaire survey**, to evaluate the collected literature's project characteristics
- **Semi-structured interviews**, for the collection of empirical project characteristics, the sorting of all the characteristics as per their importance, the correlation of the sorted PCs with the BEP contents and finally for the discussion about the extent of development (e.o.d) of the BEP contents
- **Structured interviews**, to make a final selection of the number, titles and descriptions of the extent of development categories of the BEP contents.

Main results

The main results of the research concerned:

- A **process** from A to Z for the **tailoring** of a **standard** that fits the need of a project
- **The decision support tool** that captures and makes operational this process. In this tool, the user assesses a project based on PCs, and the tool produces a recommendation regarding the extent of development of each BEP content.

Another finding is that practitioners' perceptions is not always aligned with the literature, as 36% of the EM.PCs presented similarity or exact match with the LI.PCs. In addition, the validation results of the decision support tool are encouraging. More specifically, the tool's results have a small deviation from what experts recommend without the tool.

Conclusion & Recommendations

The final part of the thesis, the conclusions and recommendations, answers all the research subquestions, gradually reaching the main question of this study. The conclusion is that the BEP author can tailor a BIM execution plan to fit the needs of a project based on some predefined project characteristics. The decision support tool is the practical mean for the recommendation on the extent of development of the BEP contents.

The thesis author also makes some recommendations for future research and Sweco NL. The highlighted recommendation for future research concerns the investigation of the European Norm EN 17412, which concerns the Level of Information Need (LoIN) when using BIM. This norm might present interest for exploration and relevancy to this thesis objectives. Furthermore, regarding Sweco, the internal level of knowledge about the ISO 19650 and BEP can be monitored to take relative training informative actions. Finally, further development of the decision support tool is also recommended, e.g., incorporating a RACI matrix, to improve its efficiency.

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List of Abbreviations

Abbreviation	Meaning
AEC	Architecture, Engineering and Construction
BEP	BIM Execution Plan
BIM	Building Information Modelling
DST	Decision Support Tool
e.o.d , E.o.D	Extent of Development
EIR	Exchange Information Requirements
EM.PCs	Empirical Project Characteristics
ISO	International Organization for Standardization
LI.PCs	Literature's Project Characteristics
MCA	Multi-Criteria Analysis
PCs	Project Characteristics

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1. Introduction

The construction sector is one vital pillar of the European economy, with an annual output approximately equal to 9% (1.3 trillion €) of Europe's GDP, while this sector employs over 18 million people. However, as Figure 1 presents, the sector presents flat or falling annual productivity rates (Veldhuizen et al., 2019). To compare, the productivity rate for construction has increased only by 1% over the past two decades compared to the growth of 2.8% of the world economy (Mckinsey Global Insititute, 2017).

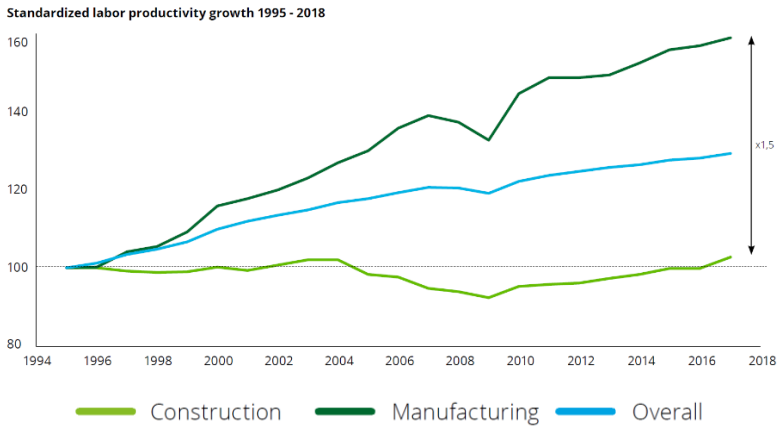


Figure 1 - Productivity growth of Manufacturing and Construction sector (Veldhuizen et al., 2019)

These statistics about moderate productivity rates have several primary causes. For example, the construction industry is one of the least digitalized sectors (Figure 2), and this issue is related, among others, to poor information management (EUBIM Task Group, 2016).

Figure 2 - Industry Digitization Index (Manyika et al., 2015)

Digitalization results in a massive influx of data and information, while organizations are often overflooded with those and need to manage them (EUBIM Task Group, 2016). This information overproduction results in information complexity and negatively influences project success (Luo, He, Xie,

et al., 2017). Therefore, information management is not meaningless. Instead, it needs to be more efficient to improve productivity and combat information complexity.

The ISO 19650 series was recently published, which defines information management concepts and requirements within a broader context of digital transformation (UK BIM Framework, 2019). Therefore, the importance of successfully implementing the ISO 19650 series in construction projects is easily understood. Hence, this ISO's role can have in project's productivity by improving information management. An essential element of this ISO is the BIM Execution Plan (BEP) which defines how, why, when, and by whom the information modelling aspects of the contract will be carried out (Castainghristoph, 2018).

In general, adopting standards into business processes promotes efficiency, facilitates compliance with regulations, reduces processing costs and errors, facilitates communication and works as a countermeasure to complexity (Beimborn et al., 2009; Canales, 2014). Furthermore, concerning the construction industry, standardized processes can result in higher quality and homogeneous construction (Aapaoja & Haapasalo, 2014).

However, there lies a risk of relying on a standard and believing that it automatically improves a project's performance. Every construction project is unique and has distinguishing characteristics that set it apart from others. This fact raises the question of whether or not a "one size fits all" approach effectively applies in all the projects (Burgan & Burgan, 2014; Shenhar et al., 2002). This approach concerns the uniform application of methods, techniques and standards without adjusting them to fit the needs of a project. A project involves parties and teams with varying knowledge and expertise and project managers with different experience levels. At the same time, some projects are predictable, others are complex and risky, and so on (Burgan & Burgan, 2014). When the project's policymakers do not realize the differentiation and variance mentioned above, it is wrongly attempted to force a project to fit a given methodology or standard (Burgan & Burgan, 2014). Companies need to tailor-make the standards according to their specifics and culture to get more from standardization (Milosevic et al., 2001). International Organization for Standardization (2018) also mentions the need for adaptation not to hamper flexibility and versatility. Canales, (2014) proposed in his paper that a corporate strategy of both being committed to a standard and focusing on flexibility yields substantial benefits. Consequently, a discussion has been initiated on tailor making methods and standards.

Striking a balance between optimum standardization and flexibility has always been challenging (Aapaoja & Haapasalo, 2014). A subsequent question is how this desired balance between standardization and flexibility can be practically achieved. The literature addresses several findings of how a project's characteristics can adjust project management methods and techniques. Several studies have investigated the classification of projects as per their characteristics (Safa et al., 2015), how that helps to adjust, for example, project management techniques as per the project's needs (Bosch-Rekveldt, 2011, pg. 42; Burgan & Burgan, 2014).

Different organizations put effort into developing BIM execution templates for their projects. (Belgian Building Research Institute, 2019; Bongers et al., n.d.; Bouw Infromatie Raad Werkgroep, 2016; Computer Integrated Construction Research Group of The Pennsylvania State University, 2010; NHS England, 2018; Rail Baltica, 2018; Richards et al., 2013; University of Cambridge, n.d.). They aim to set up a template to apply universally, and they are struggling to set up a process to customize the BEP to fit the needs of a project.

This thesis research will examine how this tailor-making principle can be applied on ISO 19650 and specifically on the BIM execution plan. That means it will focus on examining a more beneficial tailor-making of the BEP to fit the needs of a project based on project characteristics.

1.1 Problem Statement

This subchapter formulates the problem statement that justifies the relevancy of this thesis research.

The construction sector is one of the least digitalized sectors, and the management of information is poor. ISO 19650 is a standard that can be a response to poor information management. At the same time, the risk of the "one size fits all" approach concerns the uniform application of a method without first adjusting it to fit the needs of a given project. In other words, the problem that seeks an answer is how standards can be tailor-made to fit the project's needs. Nevertheless, it has not examined the leveraging of project characteristics to assist in the tailor-making of a standard (in our case of the BIM execution plan as described by the standard series ISO 19650).

1.2 Research Goal

This thesis addresses a practical challenge on how the BIM execution plan (BEP) can be tailored to fit the needs of a project. More specifically, the goal is to investigate which project characteristics are essential for tailoring a BEP, answer how to achieve this, and propose how a BEP author can practically benefit from this research. This research will result in a proposed process for customizing a BEP based on project characteristics.

The practical output of the thesis research will be a decision support tool (in MS Excel). This tool will incorporate the proposed process. Firstly, the tool user would be able first to assess a project based on predefined project characteristics (PCs). Then, based on this assessment, the tool recommends the necessary extent of development (e.g. briefly, regular, extensively) for each of the BEP's contents. "Predefined" means that the research findings will result in a fixed list of PCs applicable to construction projects. This list will be used in the decision support tool for the assessment of any project.

The research follows some steps for the development of the decision support tool. These steps are captured in a process that proposes tailoring a standard based on the principle that "one size does NOT fit all".

This research will focus on the preparation phase of infrastructure projects where the post-contract BIM execution plan applies. The main BEP is prepared and finalized in the preparation phase of a project after its award to a prospective party. Therefore, this is the most critical phase concerning BEP development.

1.3 Research questions

The main research question of this thesis is formulated below:

"How can the BIM Execution Plan (BEP) be tailored to fit the needs of a project based on predefined project characteristics?"

The practical outcome of the thesis is a decision support tool for assessing a project based on predefined characteristics and the recommendation of the necessary extent of development for the BEP contents. This outcome consolidates all the research results, which answer the main research question. Theoretical knowledge was first acquired, and empirical data were collected by answering the following research sub-questions:

- **R.SQ.1:** *"Which are the most important Project Characteristics (PCs) for the development of a BEP that fits the needs of a project?"*
- **R.SQ.2:** *"How can the most important PCs be correlated to the contents of a BEP template?"*
- **R.*SQ.3:*** *"How can the extent of development categories of the BEP contents be defined?"*
- **R.*SQ.4:*** *"How can the PCs, the BEP contents and the recommendations for their extent of development, be combined in a practical and user-friendly way?"*

1.4 Thesis Structure

The following figure presents the structure of the thesis with the main contents for each chapter.

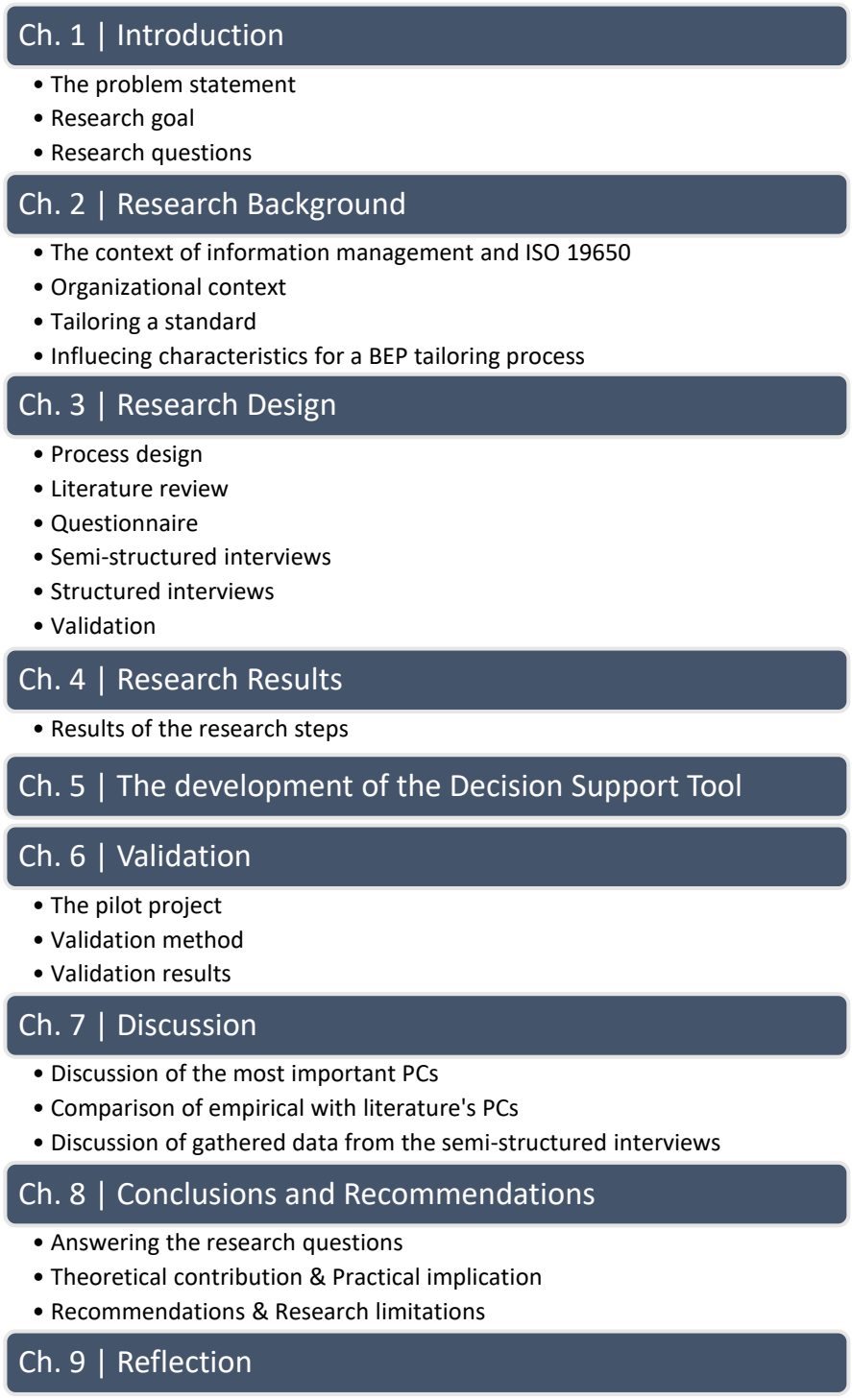


Figure 3 - The thesis structure

2. Research Background

This chapter aims to first familiarize the reader with Information Management, ISO 19650 and the BIM execution plan. Next, it provides information about the organizational context and its relevancy to that ISO and the BEP. Finally, this chapter discusses the customization of standards and the influencing factors for tailoring a BEP.

2.1 The context of Information Management and ISO 19650

2.1.1 Digitalization and Information Management

In the last decade, the engineering and construction industry has moved towards greater digitalization (Winfield, 2020). A significant enabler for this digital transformation in construction and the Construction 4.0 concept is the Building Information Modelling (Boton & Forgues, 2020). Sometimes, people link the term "digitalization" with advantages and progress without considering potential drawbacks that need to be handled. Digitalization in the construction sector, it could be argued, has a lot to do with how digital data, or information, is collected and managed (Winfield, 2020). The following phrase by the EU BIM Task Group, (2016) is characteristic regarding specific digitalization consequences that need to be managed:

"*Digitalisation brings an unprecedented amount of data and information. Organizations and projects alike are often overflooded with too much data and information. Over-production and over-processing of data, just because technology can and data storage has become cheap, increases waste, costs and risks significantly.*"

What the above phrase highlights is the overproduction of data and information. The paper of Winfield, (2020) examines whether information management, specifically the ISO 19650 series, can be a stepping stone to help manage this flow of information. She also adds that without properly standardized implementation, methods, and understanding, Construction 4.0 will be impossible to achieve. Due to its neutral and comprehensive format, the ISO 19650 series could supply the necessary standardized key to this puzzle (Winfield, 2020).

The published guidance of the UK BIM Framework explains the fundamental principles of BIM according to ISO 19650. According to it (UK BIM Framework, 2019), the ISO 19650 series define information management concepts and requirements within a broader context of digital transformation.

2.1.2 What is ISO 19650?

The necessity for the ISO 19650 series to be implemented as the standard for information management using BIM stems from the industry's need to improve procedures and productivity while also moving toward digital transformation. The ISO 19650 series is a set of international best practices standards. It specifies information management principles and requirements in the context of digital transformation in the built environment (including construction and asset management industries) (UK BIM Framework, 2019).

The ISO 19650 series aims to guarantee that parties explicitly define what information and deliverables are expected by the client and the processes and tools to be utilized by the various parties in the project, from the start until its completion (Winfield, 2020). Winfield, (2020) did a critical analysis of the ISO 19650 series regarding the digitization of information management. She mentions that although ISO 19650 facilitates and promotes the growth of digitization by providing greater precision in the management of digital information, it should not be viewed as a panacea for all problems.

The ISO 19650 series are published by the International Organization for Standardization (ISO), with the title:

"Organization and digitization of information about buildings and civil engineering works, including building information modelling (BIM) — Information management using building information modelling" and consists of:

- 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

This research focuses on ISO 19650 parts 1 and 2, where the BEP is prescribed as well.

What is discussed in "ISO 19650 - 1:2018 Concept and principles"?

ISO 19650-1 set out the recommended concepts and principles for business processes across the built environment sector to enable the management and production of information (namely "information management") during the life cycle of built assets when BIM is used (ISO 19650-1, 2018). This document can be adapted to assets or projects of any scale and complexity and applies to their whole life cycle, including strategic planning, initial design, engineering, development, documentation and construction, and end-of-life (ISO 19650-1, 2018).

Additionally, this standard defines various information requirements and the resulting (i.e., responses to the requirements) models. The requirements are drawn by the client (named as "Appointing party" in the ISO 19650) and concern the information that they need for their asset(s) or project(s) to support the organizational or project objectives (ISO 19650-1, 2018). More specifically, all the requirements are stated in the Exchange Information Requirements (EIR), which integrates the Organizational (OIR), the Asset (AIR) and the Project (PIR) Information Requirements. The different types of information requirements are shown in Figure 4.

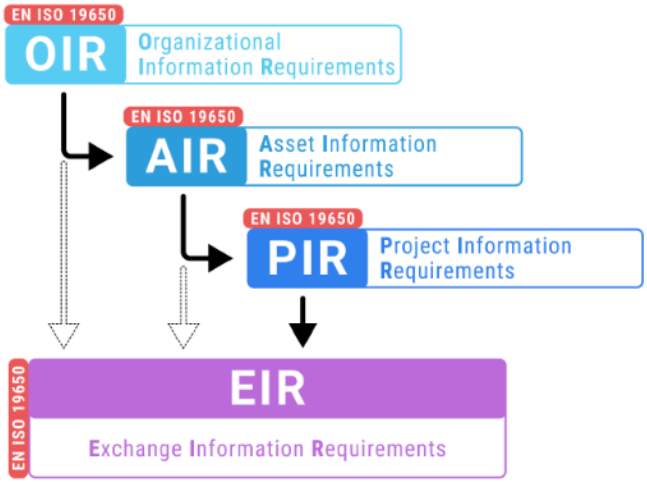


Figure 4 - The different information requirements (Henttinen, 2020)

What is discussed in "ISO 19650 - 2:2018 Delivery phase of assets"?

This document contains the information requirements for the production and management of information using BIM, during the delivery phase of built assets. In addition, it describes the process for reviewing and revising the information regularly until the best practice is established. It also aims to provide the right collaborative environment within which different project parties (e.g., consultant(s), designer(s), contractor(s), and subcontractor(s)) can produce and exchange information in an effective manner (ISO 19650-2, 2018).

This document applies to all types of built assets and construction projects, regardless of their size, complexity, or procurement approach. Large estates, infrastructure networks, individual buildings and pieces of infrastructure, as well as the projects or programs that provide them, fall under this category (ISO 19650-2, 2018).

ISO 19650 uses a specific nomenclature for the project parties. Figure 5 shows this nomenclature for different project parties and provides an example for each.

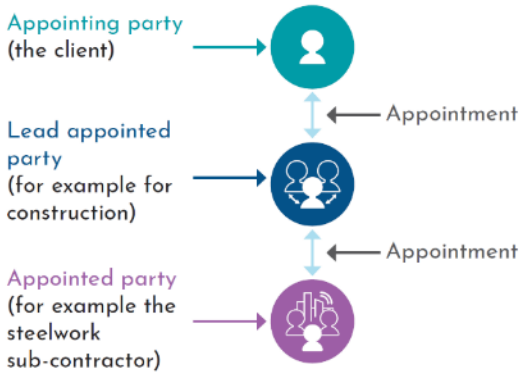


Figure 5 - The primary project parties (UK BIM Framework, 2020)

The client (appointing party) can have several appointments, for example, for architecture, engineering, project management, and construction. In the same way, a lead appointed party (e.g., a contractor) can have several appointments with appointed parties.

In a bigger and more complex project, it is likely the appointing party (the client) to have several appointments (assigned parts of the scope) with lead appointed parties (for example, for architecture, engineering, project management and construction). Similarly, a lead appointed party (e.g., main contractor) is likely to have several appointments with appointed parties (e.g., a subcontractor) (UK BIM Framework, 2020). The following schema (Figure 6) illustrates a paradigm with multiple parties in a project.

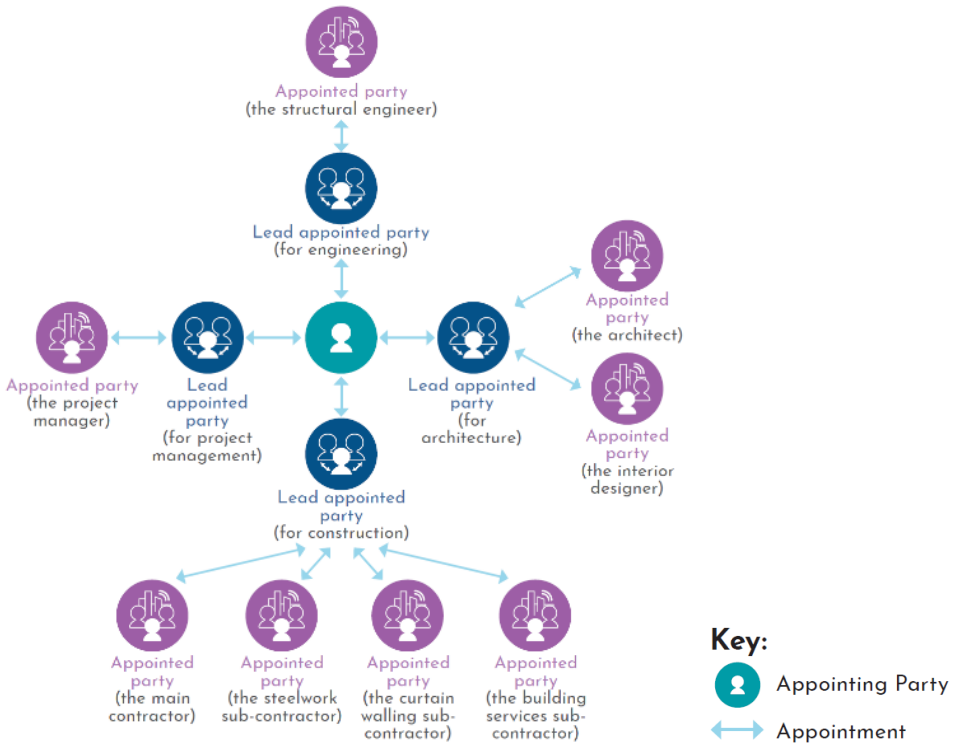


Figure 6 - A project schema where there are multiple lead appointed parties and appointed parties (UK BIM Framework, 2020)

2.1.3 What is a BIM Execution Plan?

An essential element of the ISO 19650 is the BIM Execution Plan (BEP) which defines how, why, when, and by whom the information modelling aspects of the contract will be carried out (Castainghristoph, 2018). The BIM execution plan is defined in ISO 19650-2, clauses 3.1.3.1 and 5.3.2.

To better understand when, why and by whom a BEP is developed, a reference is made to the relevant steps that are followed in a project's tender. At first, the client (appointing party) sets its information requirements for the development of the project and the operation of the completed built asset. Those requirements, as already mentioned, are included in the Exchange Information Requirements (EIR) (Hrdina & Matějka, 2016). Then, during the tender process, each prospective lead appointed party (for

example, a consultant or a contractor) responds to the EIR with a (pre-appointment) BIM execution plan that includes declarations of capability and capacity to apply the ISO 19650 series and their approach on how to manage information (ISO 19650-2, 2018). The provision of the (pre-appointment) BIM execution plan is a requirement of ISO 19650-2 (UK BIM Framework, 2020).

When the appointment is made, meaning the award of the contract in the lead appointed party, the selected team creates the post-appointment BEP.

Each appointed party, including those known to the lead appointed party and those appointed at a future time, shall concur with the created BIM execution plan. This is to verify that their activities, use of ICT tools, and capability to work following the delivery team's requirements are appropriately reflected (UK BIM Framework, 2020).

The contents of the BEP template that Sweco NL uses for all its projects can be found in Appendix E.

2.2 Organizational context

This thesis is executed in collaboration with Sweco Netherlands. Sweco NL is an architectural and engineering consultancy firm that provides services for building and urban areas, water, energy and industry, mobility, and infrastructure. It is an international company with experience from large, multidisciplinary, and complex to small and specialist projects. Sweco NL aims to use a BIM Execution Plan in every project that incorporates BIM. To achieve that is working on adopting ISO 19650 by all its departments. In 2019, Sweco NL became the first engineering consultancy in the Netherlands that received an ISO 19650 certificate from the British Standards Institution (BSI). This certification effort helped the company master the processes for producing and exchanging digital information throughout the entire delivery and operational phase of an asset according to the ISO 19650 requirements.

When it comes to the BIM execution plan, a devoted task team in Sweco NL works to improve its BEP template and make it more content-wise. At the development phase of the thesis topic, some BEP authors explained that a BEP should not always be the same for all the projects. On the contrary, the size of the BEP should change from project to project. This perception was the stepping stone for the thesis author to start searching the literature on how a standard can be flexible.

2.3 Tailoring a standard

Does “one size fits all” or not? This question triggers a discussion on whether all projects should be treated similarly with the same standards and project management approaches or every standard and project management approach should be adjusted to fit the needs of a project.

One of the common misconceptions is that all projects are the same, and the same methods can be used for all of them (Shenhar et al., 2002). Every project is unique, adds the paper of Burgan & Burgan categorically. Construction projects involve people with varying degrees of knowledge and expertise, project managers with different levels of sophistication; some projects are predictable, others are complex and risky, and so on (Burgan & Burgan, 2014). This paper discusses the adjustment of the project management approach as per the needs of each project. They believe that the nature and characteristics of the project should determine the sort of project management approach (Burgan & Burgan, 2014). They

also present a project evaluation method that should be considered while selecting the most suitable project management approach.

It is a fault attempting to force a project to fit a given methodology that does not fit its needs, for example, the experience level of the project's parties (Burgan & Burgan, 2014). One of the project's management risks is when project managers stick and rely on the same management methodology and do not consider different approaches that might fit more to the project (Cobb, 2011, pg. 11). In contrast, it should be tried to tailor the methods to fit the risks, the complexity and the characteristics of the given project (Burgan & Burgan, 2014).

In the past, the idea that "one size fits all" was more common practice in projects. However, this changes into a more fit-for-purpose approach (Burgan & Burgan, 2014). They conclude in their paper that the approach "one size fits all" is not working effectively, and the characteristic of a project are the drivers to adjust the methods to be used in the project. Techniques, standards, and methods proposed by international guides, such as the PMBOK Guide by the Project Management Institute, should not be used uniformly on every project (Burgan & Burgan, 2014).

The terms "tailoring", "tailor-made", "adjusting", "adapting" and others are frequently met in this thesis research. Thus, it is helpful to define "tailoring" by giving a definition using an example for project management processes.

The PMBOK Guide (Project Management Institute, 2017) describes some basic project management processes, tools, and techniques that are advised to implement in projects. Nevertheless, the manner of their application must be adapted to the conditions. Therefore, a project manager in collaboration with the project management team is always responsible for determining a) which processes are suitable and b) the appropriate level of rigor for each process for any given project. "Tailoring" is the term that describes this method (Burgan & Burgan, 2014).

2.4 Influencing characteristics for a BEP tailoring process

The paper of Burgan & Burgan (2014) categorically discusses that the nature and characteristics of a project should be the drivers for tailoring a method, standard, technique, or management approach to fit the project's needs. This paper is the first evidence that the project characteristics can have a crucial role in adjusting a standard method as per the project's needs.

Besides, Safa et al., (2015) highlight the usefulness of a construction projects' classification system to simplify complexity and facilitate construction management. According to them (Safa et al., 2015), the proper classification of construction projects can provide many advantages, such as improving project effectiveness, utilizing best practices, etc. Burgan & Burgan, (2014) are also in favor of a project classification system to aid the adjustment of management methods as per the project's needs. Furthermore, classification of projects is possible due to recognising first and grouping next of project characteristics.

In the Ph.D. dissertation of Bosch-Rekveldt, (2011, pg. 42), the authors discuss the outcome of several studies which focused on the adaption of project management to project characteristics. Numerous studies have examined the relationship between project characteristics and project management styles, project execution and planning, and so on, in various sectors (construction, product development, etc.).

The literature also discusses the influence of project characteristics on, for example, the success and performance of projects, the use of ICT systems in projects, information management, communication among project parties, the complexity in projects. A BEP aims, among others, to master information complexity, achieve effective implementation of ICT tools in the project, define clearly the communication between project's parties, and contribute to the success of a project.

The existence of these studies is one more evidence that project characteristics can help in tailoring management techniques, methods, processes and standards. However, the literature also discusses other terms, apart from characteristics, that influence several project aspects. Therefore, the following paragraphs discuss first what a characteristic is and then present the interrelation between project characteristics, complexity factors and success factors.

Characteristics are those elements that give a project its identity. Since every project is unique, it is not possible to capture and define all those elements. However, some common characteristics of projects are, for example, the "number of contractors in the project", the "organizational complexity", the "budget" of the project, its "goal, objectives and scope" and so on.

Followingly it is presented the interrelation between project characteristics, complexity factors and success factors. These interrelations justify using the term "project characteristic" as an umbrella term for complexity and success factors aiming to include these in the research findings.

The interrelationship between project characteristics & complexity factors

When searching for "project characteristics" in the literature, many findings concern "complexity factors". Thus, at first, the relation between "characteristics" and "complexity factors" must be clarified. Remington et al., (2009) argue that complexity factors may be defined in dimensions or characteristics. Complexity is considered a multi-attribute characteristic of a project (Marle & Vidal, 2016; Safa et al., 2015). Besides, Bosch-Rekveldt, (2011) considers complexity a project characteristic that differs from other project characteristics such as the size of a project (Baccarini, 1996). Following those arguments, there is a robust semantic correlation between those two terms, "complexity factors" and "characteristics". Therefore, the literature review for the discussion around project characteristics also concerns the research about complexity factors.

The interrelationship between project characteristics & success factors

Another term included in the literature research and the findings is "success factors". Therefore, the interrelationship between this term and project characteristics needs to be established. Some characteristics are linked to and drive project success (Wohlin et al., 2003). This is the first evidence that project characteristics that are drivers for success are, in other words, project success factors. Therefore, it is easier to predict whether or not a project will succeed by estimating the values of those success-related characteristics (Wohlin et al., 2003). A success factor is defined as any characteristic distinguishing good from excellent performance when performing a task or fulfilling a role (Nguyen et al., 2004).

Although there is a relation between project characteristics and success factors, it does not stand the same interrelation with success criteria. This is because success criteria are the benchmarks against which a project's success or failure will be measured (Nguyen et al., 2004). Therefore, the thesis research concerned success factors and not criteria.

3. Research Design

This chapter discusses the research strategy used for this project and its rationale. The research strategy is given to demonstrate the relationship between the steps and the research questions as defined in subchapter 1.3.

3.1 Process design

As discussed in subchapters 2.3 and 2.4, a standard yields more benefits if tailoring it based on the characteristics of a project. This is why this research gathers data about ISO 19650, BEP, and project characteristics that could be important in the BEP's tailor-making. The research gathers mainly qualitative data. Some of those are existing knowledge from the literature, and others are new empirical knowledge. Figure 7 presents the thesis' designed process that investigates how a BEP can be customized based on literature's and practitioner's project characteristics. The results of the designed process are discussed in Chapters 4 and 5.

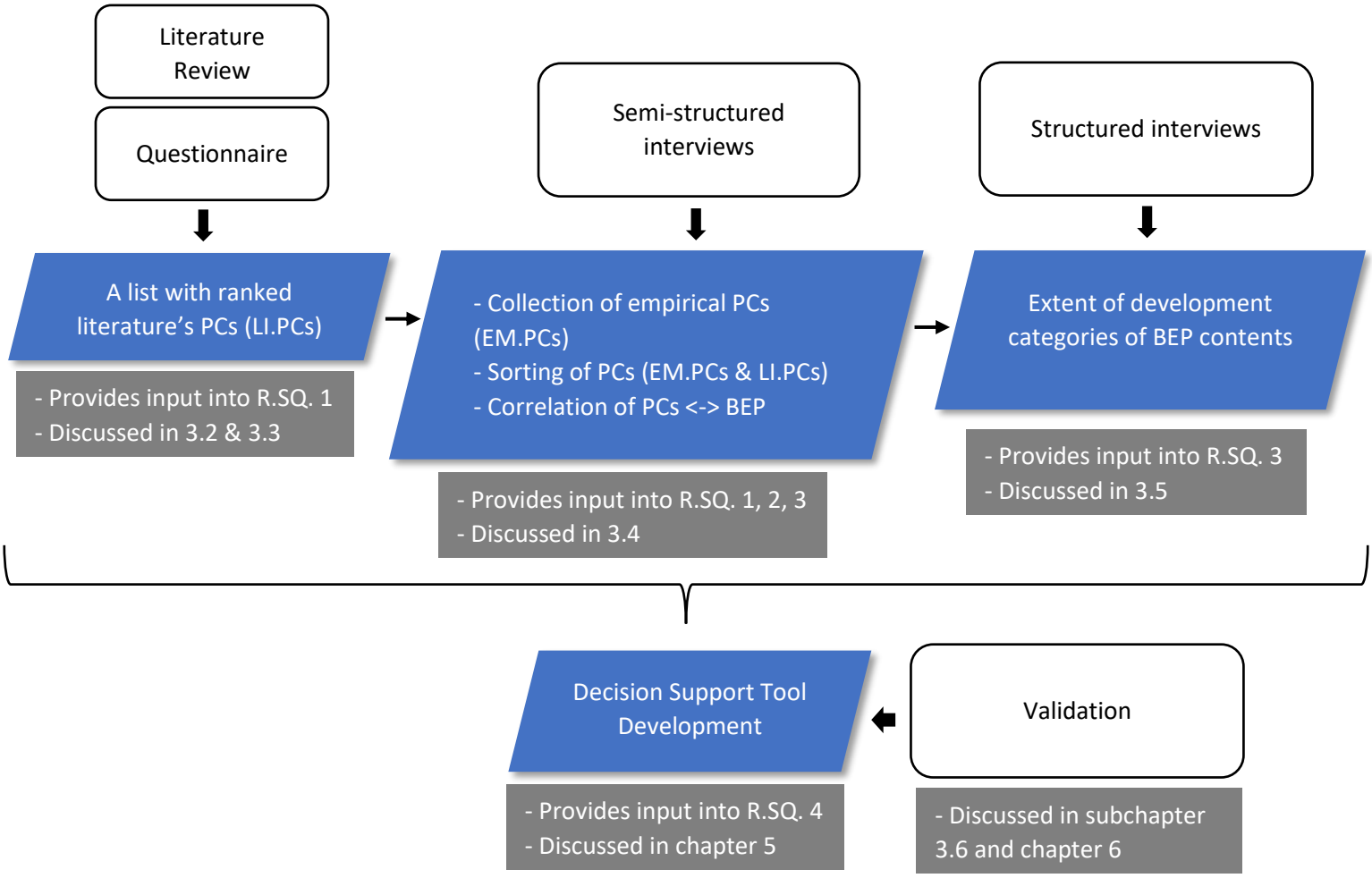


Figure 7 - Flow chart of the designed process

3.2 Literature review

A literature study has been conducted to acquire knowledge in the context of information management, standardization and flexibility, ISO 19650 and BEP, and to get in-depth knowledge and recommendations regarding the project characteristics (PCs) of construction projects. This literature review partly contributes to answering the first sub-question: *"Which are the most important Project Characteristics (PCs) for the development of a BEP that fits the needs of a project?"*

Apart from the development of theoretical background and the PCs collection, the literature review reveals the relevance of the research and indicates the problem statement.

The first step for initiating the literature review was to decide on a few keywords that will be used in the research. Two sets of keywords were mainly used:

- the first concerned a breakdown structure of the project types ["project, "construction project", "infrastructure project" and "water construction project"] AND ["characteristics"],
- the second set concerned the words ["BIM", "communication", "collaboration", "information sharing, exchange, management", "standardization"] AND ["characteristics"]

Next, it has been decided the research databases and journals that will be examined. The literature research was executed in the academic databases: Elsevier Scopus, ASCE (American Society of Civil Engineers) library and Emerald. The found literature sources concern mainly journal papers from journals about construction, engineering, project management, and information systems.

The following figure presents the steps to conduct the literature review.

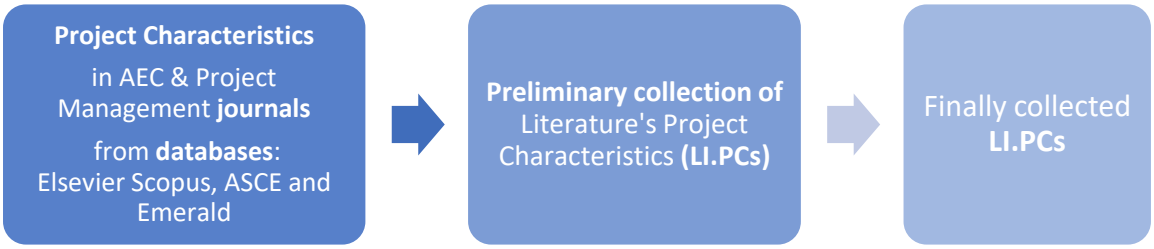


Figure 8 - Literature review steps for the collection of LI.PCs

Several literature sources were examined for the collection of project characteristics. The literature exploration resulted in preliminary literature's project characteristics. These LI.PCs were filtered by using criteria about their clarity, relevancy to the thesis context, and uniqueness. The results are presented in subchapters 4.1.1 and 0.

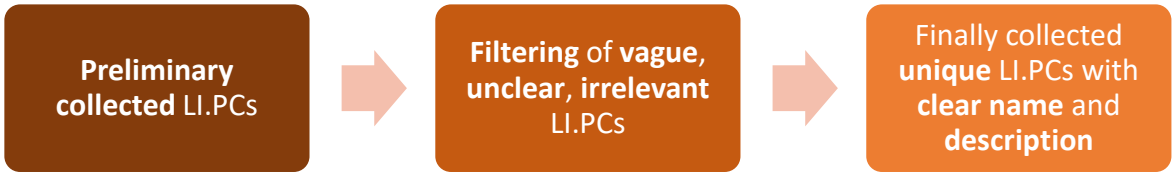


Figure 9 - The filtering of the LI.PCs starting from preliminary collected LI.PCs and ending to unique and clear LI.PCs

3.3 Questionnaire

After collecting project characteristics from the literature (LI.PCs), the next step is to rank them, through a questionnaire, according to their importance for developing a BIM execution plan (BEP). The ranked LI.PCs are then analyzed using a RIDIT analysis method to distinguish the 15 most important LI.PCs.

The questionnaire was sent to 18 Sweco employees who have used or developed a BEP at least once. The sample demographics are discussed in the results part and are also presented in Appendix B. The questionnaire consisted of 51 questions about the profile of the respondent and the ranking of the LI.PCs. The structure of the questionnaire can be found in Appendix B. To rank the importance of the LI.PCs and measure people's perception, a five-point Likert scale was used as suggested by (Vagias, 2006). Figure 10 shows an evaluation question for a LI.PC based on a 1-5 Likert scale. Then, the responses were analyzed using a RIDIT analysis method. This method is appropriate to order Likert scale items (Wu, 2007) in ascending or descending order based on importance (Bhattacharya & Kumar, 2016).

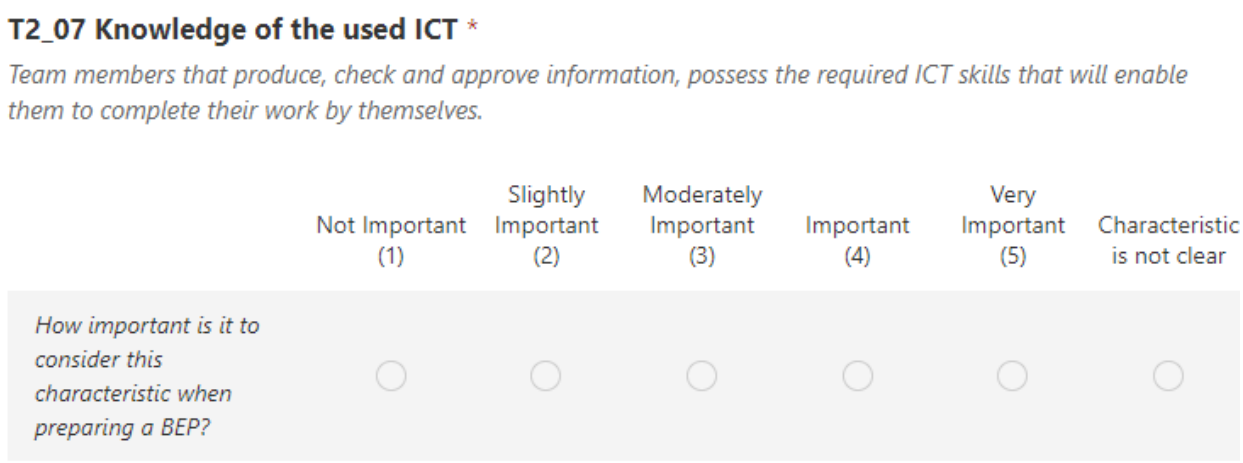


Figure 10 - An example evaluation question for a LI.PC from the questionnaire

In a few characteristics, some terms were adjusted to the ISO 19650 terminology to provide a clear description to the respondents about each project characteristic and how it could potentially influence the preparation of a BEP. The adjustment of a few terms to the terms of the ISO 19650 helps avoid potential misunderstanding of a characteristic, meaning the probability a respondent will understand a different interpretation for it. For example, the term "client" is met in the questionnaire as "Lead appointing party" which is the word that ISO 19650 uses for the client. Another example is about the characteristic "key-staff capability/experience", where the key roles in a BIM-relevant organizational structure (e.g. Information manager, BIM director) were added in parenthesis in the description of this LI.PC.

3.4 Semi-structured Interviews

Interviews are a valuable research method when it is critical to examine perspectives, experiences and validate research findings. Therefore, the next step after the conducted literature review and the collection of the questionnaire responses was the execution of semi-structured interviews with Sweco employees to collect empirical data. First, it aimed to collect empirical project characteristics and sort

them with the LI.PCs as per their importance. Next, the goal was to correlate the sorted PCs with the BEP contents and discuss the extent of development of the BEP contents.

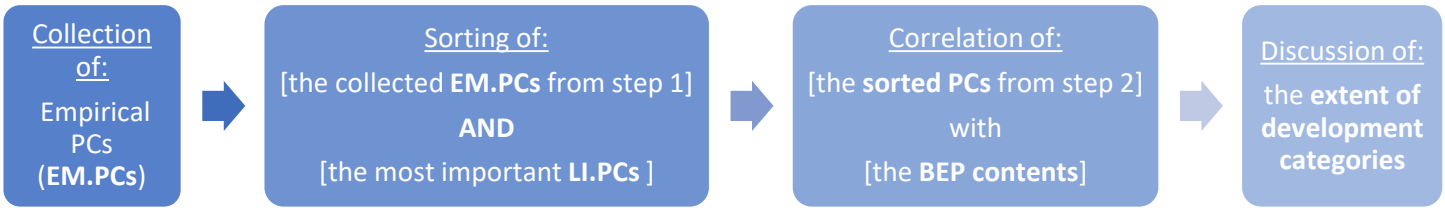


Figure 11 - Literature review steps for the collection of LI.PCs

Before the interviews, the interviewees received information about the thesis project, its topic, and its goal by email. In addition, a one-minute introductory video was attached to the email, which explained the thesis goal, the method for collecting data, and the way of contribution of the interviewees. *(Click **here** to watch the introductory video that was sent to the interviewees)*

First, a discussion about the interviewee and his/her involvement in projects and BEPs initiated the interviews. Next, the interviewees indicated the main challenges when preparing or using a BEP. After the general discussion, the interviews were structured in four main steps, as is discussed followingly. In Appendix C, Table 19 presents all the interview steps (major and minor), and every step is provided with an explanation about its aim, result, and mean.

1st Step: Collection of empirical project characteristics

The first step of the semi-structured interviews aims to collect empirical project characteristics by the interviewees. They all have at least a minimum of experience with ISO 19650 and BEP. The collection of EM.PCs facilitated through a discussion, which aimed to put the interviewee "in the shoes" of a BEP author assigned with the BEP preparation and can know in advance any information and characteristic of the project that can help him/her prepare a practical BEP. In that way, the interviewee brainstorms several empirical project characteristics that might be good to know for developing a BEP.

2nd Step: Sorting of project characteristics (EM.PCs & LI.PCs)

The following interactive step in each interview concerns using an online concept board where the interviewee is asked to sort the questionnaire's top-rated LI.PCs and the collected EM.PCs. For the sorting of both the LI.PCs and the EM.PCs, a sorting matrix was provided with a seven-point Likert scale (Vagias, 2006) from [-3: Not at all important] to [+3: Extremely important].

This step combines for the first time:

- the most important LI.PCs, according to the analysis of the questionnaire responses, AND
- the collected EM.PCs that the interviewee provided in the first step

The sorting matrix (Figure 12) has been arranged so that 23 characteristics can be sorted in total. This means that apart from the 15 LI.PCs, 8 more EM.PCs can be sorted in this matrix. However, if an

interviewee provides more than 12 EM.PCs then additional ranking cells will be added to the scores (-1), (0) and (+1).

For each score in the sorting matrix, a limited number of ranking cells exist so that a specific number of characteristics can have the same score. In that way, the interviewee has a limited number of scoring options for every characteristic and is motivated to distinguish the most important project characteristics.

Figure 12 - The sorting matrix for the sorting of both LI.PCs and EM.PCs

3rd Step: Correlation of project characteristics with BEP contents

An additional interactive step of the semi-structured interviews concerned the correlation of the sorted project characteristics to the contents of the BIM execution plan template. This process was also performed on an online concept board, where the interviewee was asked to correlate each project characteristic (were placed on the horizontal axis) with the BEP contents (vertical axis) (Figure 13 and Figure 14).

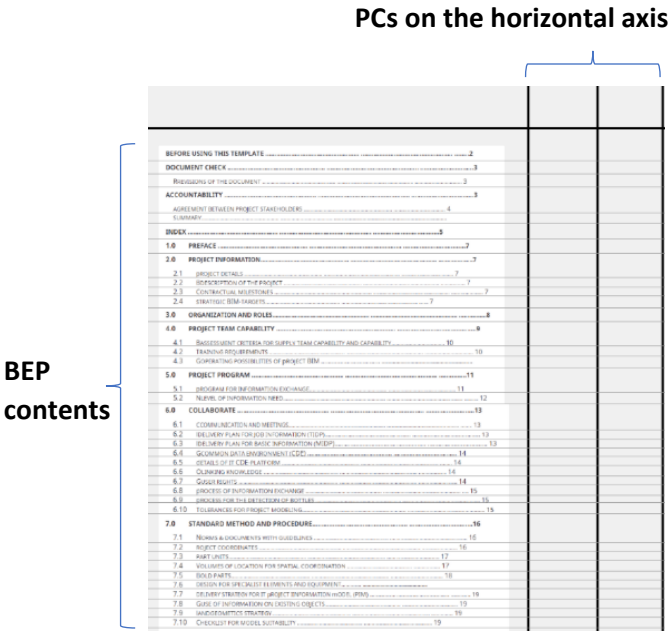


Figure 13 – The correlation matrix, empty and not filled by any interviewee

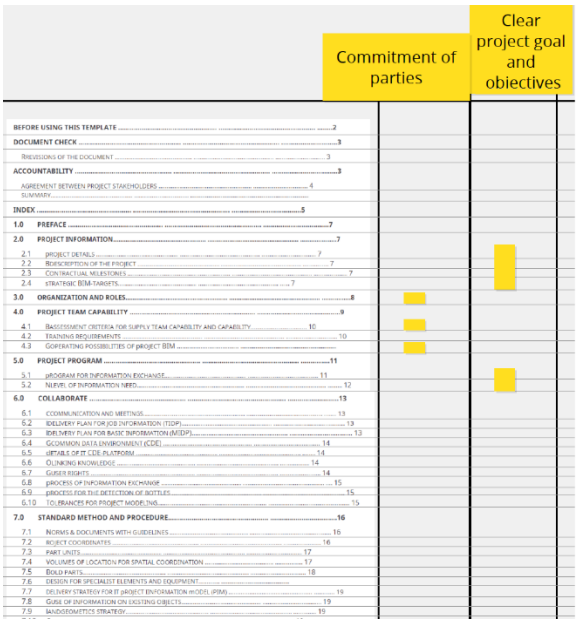


Figure 14 - Example of a correlation matrix, filled by one interviewee

Sweco Netherlands uses one BEP template for all its projects. The contents from this template have been used for the correlation process. The contents of this template may be found in Appendix E, **Error! R eference source not found.**.

4th Step: Discussion on the extent of development categories (number, categories names, definitions)

The last step of the semi-structured interviews initiated a discussion on the extent of development (e.o.d) categories of the BEP contents. More specifically, interviewees should propose the number, titles for these categories and phrases that should be included in the description of each e.o.d category. Lastly, they recommended where the additional explanation should be placed (e.g., main BEP or Appendices) due to the more extensive e.o.d categories.

A Multi-Criteria Analysis (MCA) method was employed to select the 15 most important project characteristics and decide their correlation to the BEP contents.

3.5 Structured Interviews

The last data collection method was the execution of structured interviews to make a final selection about the number, titles, and descriptions of the extent of development categories of the BEP contents. The interviewees were three Sweco employees, all BEP authors, and very familiar with the ISO 19650 series. It was important to include BEP authors in this process rather than the users, as the authors will need to understand the meaning of those categories and consult them in the future.

The interviewees were provided with options regarding:

a) the titles, number, and description of the extent of development categories,
b) the location in the document (e.g., main BEP document or Appendices), that should be placed the additional and more extensive explanation for a chapter,
c) the criteria to decide when the more extensive explanation needs to go to each document location, and
d) which extent of development category prevails in case of multiple recommendations about the extent of development of the same chapter.

The decision on the above four questions was made based on the majority's selections. In addition, phrases selected by the interviewees as "Should be in the description" were kept to describe the extent of development categories.

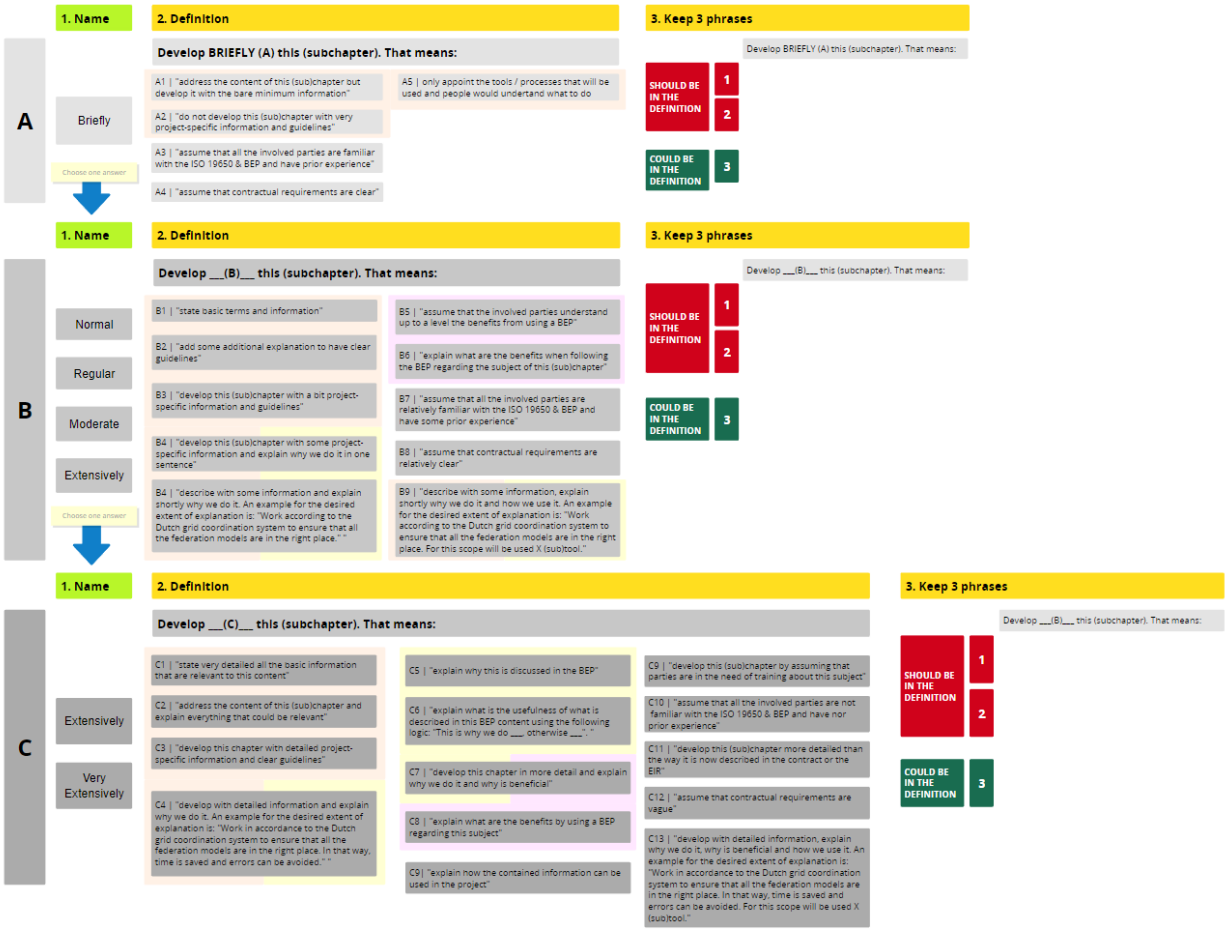


Figure 15 - The decision board on the phrases that should be in the definition of each extent of development category

3.6 Validation of the process with the Decision Support Tool

The designed process was validated through the decision support tool. This tool incorporates as inputs all the research results. The goal of validation is to check the applicability and functionality of the tool from the perspective of practitioners, gather their feedback and suggestions. Three experts with proven experience on ISO 19650 and BEP were selected for the validation, and a pilot project was employed to test the tool. However, none of the experts had previous knowledge or involvement in the project that was used as a pilot.

The validation had both a quantitative and a qualitative form. The quantitative form concerned the interpretation, using numbers and charts, of the convergence between the expert's perceptions regarding the BEP of the pilot project and the output of the decision support tool. The qualitative form concerned specific questions that were asked to the experts to raise comments and suggestions regarding the tool and understand the impact of the present research on the BIM and ISO 19650 process of the company.

The validation process, the pilot project, and the outcome are described in detail in Chapter 6.

4. Research results

This chapter first presents the demographics of the respondent groups, both for the questionnaire and the semi-structured interviews. Then, summarizes the findings of the thesis research about:

- the most important project characteristics, their description and scoring scale,
- the correlation of the project characteristics with the BEP contents, and
- the extent of development categories of the BEP contents

The presentation of the results follows the same order with the discussion of the research method in Chapter 3. Hence, the reader can correspond each result with the corresponding research method.

4.1 Literature's Project Characteristics

This subchapter discusses the project characteristics proposed by the literature as influencing factors of project success, the use of ICT systems in projects, digitalization, information management, and communication among project parties.

First, the collection process to filter the findings and arrive at the list with the LI.PCs is described.

4.1.1 The filtered LI.PCs

Several literature sources were examined for the collection of project characteristics. Two hundred and three prospective LI.PCs were preliminarily collected from 23 sources. These LI.PCs were possibly relevant to the context of the thesis research. The list of LI.PCs was methodically and more carefully reviewed (Figure 16) to end up with the finally collected LI.PCs.

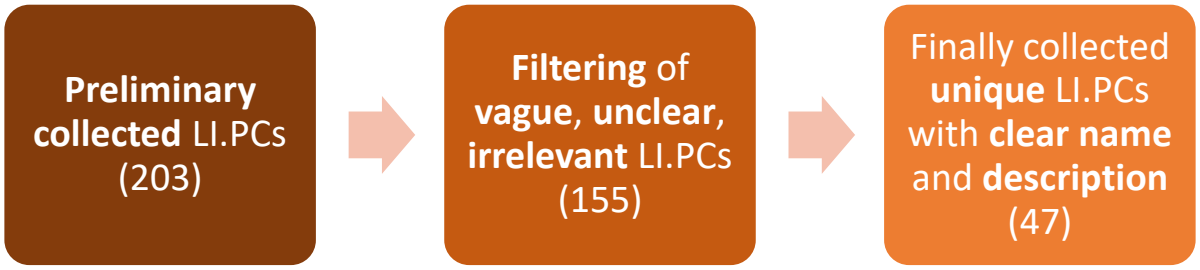


Figure 16 - The filtering process of the LI.PCs starting from 203 preliminary collected LI.PCs and ending to 47

They were initially categorized in 4 categories to avoid characteristics with vague debatable meaning. Table 1 describes each category, the criteria that a LI.PC should meet in order to be categorized and an example of LI.PCs that were included in each category.

Table 1 - Initial categorization of collected PCs

#	Category & Criterion	Examples of LI.PCs that were included in each category
01	LI.PCs that have a clear meaning and description. ***Criteria**: LI.PC should have clear meaning and description*	**Use of electronic data exchange system:** *The use of one electronic data (information) exchange system/platform in the project, in which all of the involved and relevant parties and members have access.*
02	LI.PCs whose name is general, while more specific, well-defined subcategories of that PC have been collected and included in Category #01. ***Criteria:*** *1. LI.PC doesn't meet the criterion for #01 category* *2. LI.PC is general* *3. Other more specific LI.PCs are in #01 category*	The PC **"Number of involved parties"** *has a general meaning as there are many different involved parties in a project, while, more specifically PCs were collected and included in category #01, such as:* **"Number of designers involved in the project"** and "**Number of contractors involved in the project"**
03	LI.PCs that have a vague meaning, without any description and it is easy to give different interpretations. ***Criteria:** LI.PC's meaning is vague and doesn't have a description*	**"Level of automation"** has been found in the literature as a project characteristic without further description. However, it is not mentioned what automation refers to. For example, it can refer to the IT systems' level of automation, or the level of automation of the construction process, etc. Because it is doubtable and subjective to different interpretations, it was characterized as a PC with vague meaning.
04	LI.PCs that are finally not relevant to the research and the BIM Execution Plan (BEP) contents. ***Criteria:** LI.PC is not relevant to the context of the research*	**"Project confidentiality"** is a characteristic that is not relevant to any of the contents of the BEP, and consequently does not influence its content.

The categorization of the found project characteristics provided an overview of the literature findings while indicating whether or not a project characteristic was adequately clear to be further used in the research. The categories were carefully reviewed to minimize the probabilities of using the research characteristics that have doubtable meaning. As a result, the project characteristics with a clear meaning and description were kept to continue the research. Figure 17 visualizes the categorization mentioned above of the literature findings regarding the project characteristics. In total, seventy-six per cent (76%) of the literature findings had a clear meaning, could be clearly described and could provide clear input to the research. The rest twenty-four per cent (24%) of the findings were doubtable concerning their meaning and were not further considered in the research.

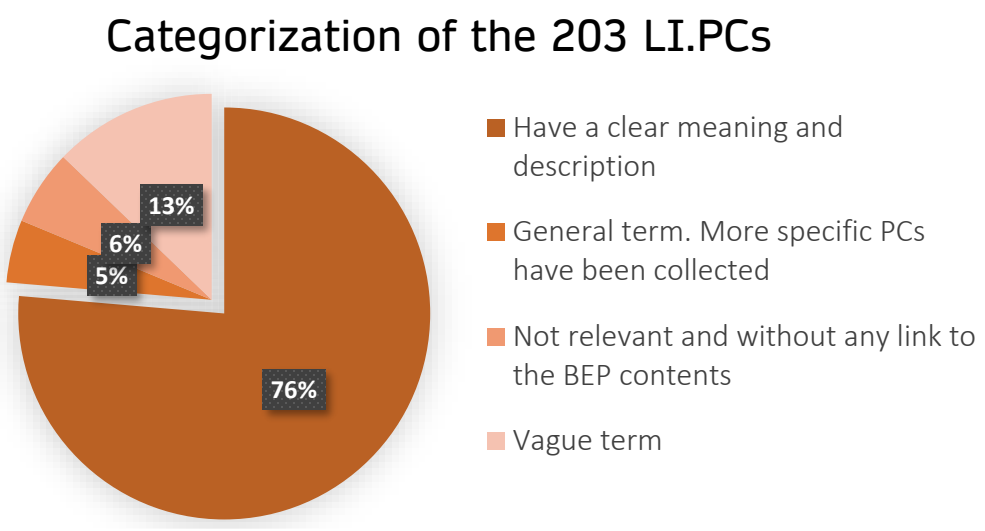


Figure 17 - Categorization of the literature's project characteristics

The next step was to consider the uniqueness of the kept 155 (76%) project characteristics. Many project characteristics were found more than once in the literature and had the same meaning as others. Therefore, two new distinct categories were created to avoid duplication and repetitiveness, as listed in Table 2.

Table 2 - Further categorization of the collected and clearly defined project characteristics

#	Category & Criteria	Examples of LI.PCs that were included in each category
05	Unique LI.PCs that have a clear meaning and description. ***Criteria:*** *1.* LI.PC has clear meaning and description *2.* *No similar LI.PC is already in this category*	**Use of electronic data exchange system:** *The use of one electronic data (information) exchange system/platform in the project, in which all of the involved and relevant parties and members have access.*
06	LI.PCs that have been already collected with the same meaning as per the provided description in the literature, and were grouped under a common project characteristic included in category #05 as a unique LI.PC. ***Criteria:*** *Similar LI.PC is already included in #05 category*	**"Number of contractor organizations"** AND "**Number of trade contractors"** *were grouped as "***Number of contractors***" *since both project characteristics refer to the number of involved contractors in the project.* **"Contractor's experience of similar projects"** AND **"Contractor's experience with similar types of projects"** *were grouped as* **"Experience in past projects of the contractor"** *since both refer to the experience of the involved contractor(s).*

Figure 18 visualizes the result after the additional categorization mentioned above of the project characteristics. The categorization concerned:

- 47 unique LI.PCs that have a clear meaning and description (30%)
- 108 LI.PCs that have been already collected, with the same meaning, as per the provided description in the literature, and were grouped under a common project characteristic which was included in category #05 as a unique LI.PC (70%)

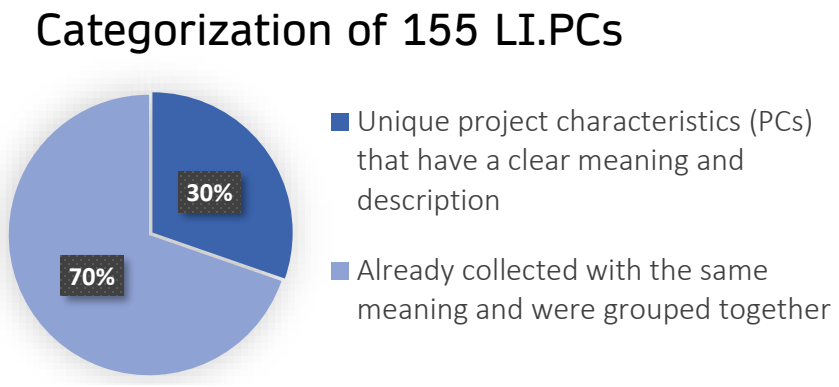


Figure 18 - Categorization of 155 literature's project characteristics (LI.PCs) that had a clear meaning

4.1.2 Influencing Project Characteristics for tailoring a BEP

A filtering process described in section 4.1.1 was applied to end up with 47 unique project characteristics with a clear name and description. The majority of the LI.PCs were clustered in themes based on their meaning and common keywords contained in their names and descriptions. Four themes can capture most of these project characteristics: (1) Experience and Capability related characteristics, (2) ICT-related, (3) Communication-related and (4) Project's information-related characteristics. However, a few characteristics could not be grouped under one common theme.

All these themes and the included project characteristics are presented below. In addition, Appendix A provides a list of the 47 PCs, their description.

Theme 1: The experience and capability of the involved parties

The project characteristics that are discussed in this theme are:

- T1_01 Experience in past projects of the Design team
- T1_02 Experience in past projects of the Consultant's team
- T1_03 Experience in past projects of the Contractor(s) and Subcontractor(s)
- T1_04 Experience in past projects of the Client
- T1_05 Key (BIM) staff capability/experience

The reviewed literature sources have extensively examined the expertise of the parties involved in previous projects and the availability of experienced / capable key personnel. Both are mentioned as distinct project characteristics. In addition, several researchers have investigated the influence of the experience of project participants in project execution, project performance and success. Some of the literature sources highlight the importance of having onboard experienced parties without indicating which party they refer to (designer, consultant, or contractor). In contrast, other sources make a particular reference to specific project participants.

Ospina-Alvarado et al., (2016) research about critical success factors for achieving technological project integration underlined the importance of having teams and individuals with experience in similar types of projects. Luo et al., (2017) investigated how project characteristics affect project success in their paper. More specifically, they included the "experience of participants" as a characteristic that mitigates information complexity and positively influences the project's success.

Ling & Liu, (2004) explored key clients' and contractors' characteristics that affect project performance. In their paper, they identified 65 characteristics relevant to projects' performance and quality, including the: "Consultant's experience with similar projects" (T1_02), "Owner's experience with similar projects" (T1_04), "Contractor's experience with similar size of projects" (T1_03) and "Subcontractors' experience and capability" (T1_03).

Alzahrani & Emsley (2013) explored, using a questionnaire survey, the contractors' characteristics that impact construction projects' success. The contractor's experience (T1_03) was a project success factor regarding their involvement in construction projects.

Liu et al., (2016) executed literature research and case study review to identify contractor's characteristics that affect the decision making for a project delivery system (PDS). A project delivery

system defines the parties' roles and responsibilities for the design, procurement, and construction phase. Their findings reported that contractor's and subcontractor's experience (T1_03) are among the project characteristics that influence the selection of a PDS for a project (Liu et al., 2016).

In 2015, a similar team of researchers, focusing on the owner's perspective, examined the key characteristics that affect the decision-making for a project delivery system. Among their findings, the owner's previous experience with a similar project (T1_04), was included as an influencing characteristic for selecting a project delivery system (Liu et al., 2015).

Cho et al., (2009) also examined the relationship between project performance and project characteristics in their paper and drew similar conclusions with Ling & Liu, (2004). The level of experience of the owners with similar projects (T1_04) is a characteristic that affects project performance from a cost and time aspect (Cho et al., 2009). Chen et al., (2012) included the "experience/ability in past projects" of the client (T1_04) and the contractor (T1_03) in the critical success factors for construction projects.

Chan et al., (2004) developed a conceptual framework on critical success characteristics for a construction project. Their framework considered characteristics like the design team's experience (T1_01). The design team plays a major role from the inception phase to the completion of a project. Therefore, an experienced and capable design team strongly contributes to the project's success (Chan et al., 2004). Furthermore, following the results of their research, the skills and experience of key project staff (e.g. team leader) (T1_05) is also considered as an attribute of success in a project (Chan et al., 2004).

Chua et al., (1999) researched the project characteristics that are critical success factors in projects for budget, schedule, and quality objectives. The "key staff's capability" was identified as the most important characteristic in the category of participants-related characteristics. The key staff roles concerning a BIM-related organizational structure are the Information manager, BIM leader, BIM director, and BIM coordinator (Kassem et al., 2018).

All the above findings underline the importance of having experienced and capable parties with past experience in a project. This characteristic is important for project success, the achievement of technological integration (Ospina-Alvarado et al., 2016), the mitigation of information complexity (Luo et al., 2017) and deciding of roles and responsibilities (Liu et al., 2016). A BIM execution plan aims, among others, to master information complexity, achieve effective implementation of ICT tools in the project, define clearly the roles and responsibilities of parties, and contribute to the success of a project. Thus, characteristics which influence those project's aspects are important also to relate them with the development of a BEP.

Theme 2: The existence and use of ICT systems in the project

The project characteristics that are going to be discussed in this theme are:

- T2_01 Clarity of the ICT system operation
- T2_02 Different versions of software adopted by different parties
- T2_03 Effective IT department
- T2_04 ICT use mandated in the contract
- T2_05 Information production and exchange conditions are clarified sufficiently
- T2_06 ICT system's capacity for information exchange
- T2_07 Knowledge of used ICT
- T2_08 Minimum capabilities of ICT systems
- T2_09 Use of customized ICT systems
- T2_10 Perceived ease of use of a system
- T2_11 Perceived usefulness of a system
- T2_12 Remote accessibility of ICT systems
- T2_13 Shared BIM model
- T2_14 Use of electronic data exchange system

The construction industry is interdisciplinarily relying largely on fast information exchange between owners, project managers, design consultants, contractors, subcontractors and suppliers. Project teams increasingly communicate information online to increase productivity, thanks to advances in information and communication technology (ICT) (Lam et al., 2010). The use of information and communication technology (ICT) systems in construction projects can provide numerous advantages in terms of enhancing inter-organizational communication, cooperation, and coordination (Adriaanse et al., 2010). ICT systems are a core part of the BIM execution plan, and their effective implementation is one of the goals for the BEP.

A thorough discussion has been made in the literature about the influence of Information and Communications Technology (ICT) systems in coordination, project success and efficiency.

Starting with the first literature source in chronological order, Georgy & Chang, (2005) studied the project characteristics that influence engineering performance. Engineering performance refers to the effectiveness, efficiency and quality of any engineering derivable that is produced in a project. The use of “electronic data interchange” which relates to the intercompany data exchange system (T2_14), influences the engineering performance.

Adriaanse et al., (2010) discussed the barriers and drivers for using ICT tools in the construction industry. They followed an ethnographic research method to focus on the human factor and study how people use the ICT systems in a construction project. One of the drivers they identified was the clarity of ICT system operation (T2_01), which refers to parties’ awareness of the project's ICT systems. The clarity is determined in two ways: first, by the availability of user support, and second, by the system's user-friendliness (Adriaanse et al., 2010). They believe that clarity regarding how ICT tools work can contribute to the successful inter-organizational use of ICT systems. Adding to that, Adriaanse et al., (2010) recognized as important drivers for the use of ICT systems, the “perceived usefulness” (T2_11) and the “perceived ease of use” (T2_10) of an ICT system. The degree to which an individual believes that implementing a certain system would enhance his or her job performance is referred to as usefulness.

The degree to which an individual believes that utilizing a certain system would be easy is referred to as ease of use.

In addition, contractual arrangements about the ICT use serve as an external motivator for project participants, regardless of whether ICT use is mandated by the contract (T2_04) (Adriaanse et al., 2010).

Adriaanse et al., (2010) also found that customized ICT systems (T2_09) can be a barrier to using ICT systems in a project. That happens, for example, when a client or the engineering firm employs customized ICT applications, in which the contractor's internal working processes have not been incorporated (Adriaanse et al., 2010). This might result in the use of different applications for the same scope and double work.

Another factor that impedes the effective use of ICT systems in a project is different software versions adopted by different parties (T2_02). This can cause incompatibility issues (Lam et al., 2010). Another aspect to examine is the remote accessibility of the ICT systems (T2_12), for example, for a remote worksite. If this is not ensured can be a barrier to the use of ICT tools in the project (Lam et al., 2010). A third characteristic mentioned by Lam et al., (2010) is technical and refers to the adequate capacity of the used ICT systems for information transferring (T2_06).

Many authors highlight the "knowledge of the used ICT tools" (T2_07) as a highly influencing factor that enables digitalization in projects. More precisely, several authors have addressed the necessity for the project's parties to know the ICT systems they employ because they can impact the project's success. Alzahrani & Emsley, (2013) include this characteristic as a critical success factor that significantly impacts the success of a project. When the knowledge of used technology is not adequate, it can increase complexity and harm project success (Luo, He, Xie, et al., 2017). Lu et al., (2015) captured the value of knowing the technology that is employed in a project: The required technological competence and knowledge will allow participating actors to perform their tasks independently, eliminating the need for rework and reducing coordinating effort (Lu et al., 2015).

Ospina-Alvarado et al., (2016) identified a set of critical success characteristics for achieving technology-oriented project integration in their research. A medium-important characteristic concerning project integration is the use of a shared BIM model (T2_13) that has the input of all team members and can be used by them.

Jarkas, (2017) studied characteristics that contribute to project complexity and ranked those as per their importance. The efficiency of information production and exchange was placed fourth (4th) in his study among twenty-six (24) contributors to project complexity. An efficient and clear information production and exchange system (T2_05) is critical in a construction project, especially when many stakeholders are involved. On the other hand, inefficiency may result in problematic decision-making and increase project complexity (Jarkas, 2017).

Jahanger et al. (2021) identified influencing characteristics related to the successful implementation of digital construction-phase information management (DCIM) systems in construction projects. The relative importance of potential influencing characteristics was analyzed in their study. For example, the minimum capabilities of the used software (T2_08) were an extremely important influencing characteristic for implementing digitized information management in projects. Another very important characteristic, according to them, is the existence of an effective IT department (T2_03).

Theme 3: Communication among the involved parties

The project characteristics that are going to be discussed in this theme are:

- T3_01 Change in the communication system
- T3_02 Communication effectiveness within clients
- T3_03 Communication effectiveness within contractors
- T3_04 Communication effectiveness within designers
- T3_05 Communication among project's participants
- T3_06 Information updating frequency
- T3_07 Degree of matrixing (way of exchanging information)

The adequacy of formal and informal communication channels and their effectiveness in providing sufficient information on project objectives, status, changes, client needs, and current problems, to the appropriate project members is referred to as communication (Chua et al., 1999). Certainly, ISO 19650 and the BIM execution plan set up communication, information management, and information exchange conditions.

To begin with, Chan et al., (2001) collected empirical project success factors from people involved in public design and build projects through a questionnaire. A factor analysis of the responses showed that establishing an adequate communication channel within the project's participants and teams (T3_05) is considered a critical success factor.

Potential changes in the communication system (T3_01) need to be considered as they influence the engineering performance in projects as per the paper of Georgy & Chang, (2005).

There is a need to update information regularly (T3_06) to facilitate tracking changes in any kind of information. Lam et al., (2010) identified this characteristic for effective information exchange among teams. The need for self-discipline regarding the information update frequency was top-ranked among the total of characteristics.

Safapour & Kermanshachi, (2019) aimed to determine essential rework indicators in construction projects by executing statistical tests to questionnaire responses. They found several characteristics that lead to rework, and among them, the communication effectiveness within owners (T3_02), designers (T3_04) and contractors (T3_03). Bad communication within those parties affects the possibility of having reworks, creating conflicts among project participants (Safapour & Kermanshachi, 2019).

The last project characteristic for discussion in this theme is the degree of matrixing (T3_07), which influences the complexity of a project (Lu et al., 2015). It concerns the way that the information is exchanged within a project. In a project organization with a high degree of matrixing, members tend to adopt informal methods of information exchange. Conversely, in a project organization with a low degree of matrixing, members often adopt official methods of information exchange (Lu et al., 2015).

Theme 4: Project's information and documents

The project characteristics that are going to be discussed in this theme are:

- T4_01 Clarity of requirements
- T4_02 Clear project goal and objectives
- T4_03 Clear project scope
- T4_04 Extent to which tender documents allow additions to the scope
- T4_05 Design complete before tendering
- T4_06 Design complete at construction start
- T4_07 Information completeness
- T4_08 Delays/mistakes in design
- T4_09 Design changes

Implementing a project is fundamentally a process of information collection, processing, and application from the standpoint of information theory (Lu et al., 2015). For ISO 19650 and BIM execution plan, which concern the organization and digitalization of information in construction, information is the essence. Furthermore, the Exchange Information Requirement (EIR) is a primary input for developing a BEP. A clear EIR increases the chances for a well prepared BEP. The EIR captures the client's requirements, the project's goal, objectives and scope. Thus, it is important to examine these aspects' characteristics and the project's information and documents.

At first, a construction project is initiated mainly by the client's needs. Hence, one of the project success factors is the clarity of the client's requirements (T4_01) (Lam et al., 2008). Similar findings were obtained in the research of Chan et al., (2001), who tried to identify a set of project success characteristics for construction projects and examine their relevance on the project's outcome. A thorough understanding of the client's clearly stated requirements is considered a project success factor (Chan et al., 2001). The finding of Chan et al., (2001) about the importance of having clear requirements by the client is also supported and included in the research of Liu et al., (2015), who focused on the owner's characteristics that facilitate the decision making on project delivery system.

In addition, setting clear goals and objectives (T4_02) is very important to achieve alignment between the participants in a project. Clarity on that facilitates the fulfilment of milestones, Safapour & Kermanshachi, (2019) add. Other authors also highlight the importance of having clear project goals and objectives. More specifically, having clearly defined goals and objectives in a project is considered a critical success factor. It allows team members to understand and agree on them, avoiding unexpected outcomes (Ospina-Alvarado et al., 2016). The study of Lu et al., (2015) explored goal uncertainty, its underlying causes, and how it complicates a project's task. As a result, the more unclear the project goal and objectives are, the more complexity brings to project tasks (Lu et al., 2015). Following that, one more study about project complexity by Luo et al., (2017) investigates the relationship between project success factors and project complexity. The level of goal uncertainty and clarity is related to the complexity of a project. The lower that level is, the more increased the goal complexity is (Luo, He, Xie, et al., 2017). Chua et al., (1999) mention that clear objectives are important for a successful project and shall be considered in contractual arrangements. Apart from setting clear goals and objectives, defining clearly the scope (T4_03) is also important as its clarity and completeness level impacts the engineering performance

(Georgy & Chang, 2005). The extent to which tender documents allow additions to scope (T4_04) is a characteristic to consider as it can influence the project's performance (Ling & Liu, 2004).

Another set of characteristics concerns the design documents, including substantial information about the project. A characteristic that has been broadly discussed in the literature and is relevant to the design documents and information, is the completion ratio of design before tendering and construction. Chen et al., (2012) identify critical success factors for construction projects in their paper. According to them, these factors reflect the characteristics of a project, and their results include the completion ratio of design before tendering and construction, respectively. Other authors also suggest those two characteristics. More specifically, the "design completion before tendering" (T4_05) has been suggested by Ling & Liu (2004) as a characteristic that influences project performance. Safapour & Kermanshachi, (2019) and Chua et al., (1999) consider as project characteristic the completion ratio of design at the start of construction (T4_06). The first author's advice is to consider it as it can be the reason for incomplete design information, while the latter mention it as a critical success factor. For Lu et al., (2015), it is important to ensure the completeness of the information (T4_07) in the project. The more complete it is, the more the task complexity decreases.

Continuing the discussion around the design documents, delays or mistakes in design (T4_08) constitute a characteristic that affects the success of a construction project (Chan et al., 2004). At the same time, potential changes in the design (T4_09) are also a characteristic that can cause rework of tasks in the project, and when changes occur, the possibility of late decision making in a project increases (Safapour & Kermanshachi, 2019).

Non-grouped (no theme) project characteristics

A list of 12 literature's project characteristics that are not classified under a common theme is presented below.

- NT_01 Appropriate organization structure
- NT_02 Availability of dedicated (client's) staff
- NT_03 Availability of resources (in terms of technology and information)
- NT_04 Client's involvement during design and construction
- NT_05 Commitment of parties
- NT_06 Complexity of faith: Uniqueness of the solution
- NT_07 Need for training
- NT_08 Number of contractors involved in the project
- NT_09 Number of designers involved in the project
- NT_10 Organizing skills of high staff (e.g. BIM Director, Information Manager)
- NT_11 Understanding of roles and duties
- NT_12 Use of facilitator

First of all, in terms of communication, information management and collaboration is critical to evaluate the number of involved parties in a project. More precisely, the number of contractors (NT_08) and designers (NT_09) involved in a project are two characteristics that can result in reworks if not properly considered and coordinated (Safapour & Kermanshachi, 2019).

Lam et al., (2008) first investigated the determinants of success for D&B projects and then developed a project success index for these projects. The importance of ensuring the commitment of the project's parties (designer, consultant, and contractor) is discussed in their research (NT_05).

Some other authors focus on the project's environment and organizational structure. Chan et al., (2004) developed a conceptual framework of critical success factors for construction projects. The appropriate organizational structure (NT_01) is a characteristic of a stable environment that contributes to successful projects (Chan et al., 2004). Taking a closer look at the people who constitute the organizational structure in a project, key stakeholders from a coordination standpoint are those with managerial roles referred to as high staff: teams' leaders and directors, project managers, etc. Therefore, the organization skills of high staff (NT_10) is a critical characteristic as it influences project planning, scheduling and communication (Chan et al., 2004). The term "high staff" refers to project's people that hold critical organizational roles. In a BIM organizational structure, critical organizational roles are, for example, the BIM Director, Information Manager, BIM leader (Kassem et al., 2018).

After setting the project's organizational structure, it is equally important to ensure that people understand their roles and responsibilities. The understanding of roles and responsibilities (NT_11) is a vital characteristic for project success, according to Chan et al., (2001).

In their research, Ospina-Alvarado et al. (2016) included an interesting characteristic that concerns the facilitation of communication among project participants. That is the use of a facilitator (NT_12), which entails positioning someone with leadership skills who can assist in the development of communication skills, foster respect, and trust. Furthermore, the same person guides the project team through the integration process, aligns individual goals with project goals, eliminates conflict fear, gain commitment from various stakeholders, and holds each party accountable for their responsibilities (Ospina-Alvarado et al., 2016).

Client involvement during design and construction (NT_04) is a desired characteristic to achieve project technology integration, according to Ospina-Alvarado et al., (2016). Because, regular feedback between the client and the other parties is provided when the client is actively involved in those phases.

What is also critical regarding the client of a project is the availability of adequate owner staffing (NT_02). This is one of the primary characteristics for successful project completion that were found in the research of Songer & Molenaar, (1997), who tried to identify critical project characteristics for the public sector in the design and build projects. Furthermore, besides the necessary availability of people, it is also vital to ensure resources (NT_03) regarding technology and information, for instance (Ospina-Alvarado et al., 2016).

Luo, He, Jaselskis, et al., (2017) conducted a literature review for project characteristics that influence project complexity. The complexity of faith (NT_06) is one of their discoveries, which Geraldi, (2008) also introduced. This characteristic refers to the difficulty of introducing something new in the project or tackling new challenges. It can be, for example, a unique solution that has not been dealt with in the past and requires further attention.

The last project characteristic that was identified in the literature concerns the need for training (NT_07) of project participants (e.g. design team, consultant's team members). More specifically, Lam et al., (2010) researched the effectiveness of ICT tools for construction information exchange among

multidisciplinary teams. They highlighted the need for training, as an important characteristic, to avoid hindrances when employing ICT for internal information exchange.

Many of the above-discussed project characteristics are directly (e.g., project goal and objectives, need for training, etc.) or indirectly (e.g. the use of a facilitator, the complexity of faith) addressed in the contents of a BEP. In addition, those project characteristics influence aspects that are important also for the BIM execution plan, such as the clarity and alignment of project goals and objectives and the technology project integration (Ospina-Alvarado et al., 2016). Thus, it can be stated that potentially there is a link between those PCs and the BIM execution plan.

To conclude, It is essential to state that none of the examined papers in the literature discusses project characteristics linked to standardization, or ISO 19650 or the BIM Execution Plan. Therefore, a wider variety of literature sources was examined. The filtered findings that are discussed in the themes above concern the relation/influence of project characteristics to the success and performance of projects, the use of ICT systems in projects, the digitalization, the management and exchange of information, communication among project parties, the complexity in projects and the project parties. These characteristics that influence the aforementioned aspects are also relevant to the context of a BEP. The BEP aims, among others, to master information complexity, achieve effective implementation of ICT tools in the project, define clearly the communication between project's parties, and contribute to the success of a project.

4.2 The questionnaire results

The questionnaire was distributed to 18 employees of Sweco. They were selected with the criterion to have used or developed a BEP for a project at least once. Finally, 13 employees answered the questionnaire. Most of them (9 out of 13) are BEP authors, and the rest (4 out of 13) are BEP users. Moreover, 54% of respondents are "Familiar" or "Very familiar" with ISO 19650 and have used or developed a BEP at least three times. It was noticed that the BEP authors are more experienced and familiar with the ISO 19650 series. Precisely, 56% of the BEP authors replied "Very familiar " and 67% at least "Familiar" with ISO 19650.

The questionnaire responses provided 47 evaluated LI.PCs, with a score from one to five. The analysis of the responses aims to select the top-rated LI.PCs in order to use them in the next research steps: the semi-structured interviews. Taking into consideration that:

1. the main purpose of the questionnaire step is to distinguish the most important LI.PCs, according to the practitioners' perspective,
2. during the interviews, there is a need to have a manageable number of project characteristics for correlation to the BEP contents, and
3. the final product of the thesis, the decision support tool, has to be practical and not too time-consuming,

it was decided in consultation with the company supervisor that a logical number for the predefined project characteristics is 15.

The RIDIT analysis method was used to select the 15 LI.PCs with the highest score. This method ranks the evaluated project characteristics as per their mean ridit value (ρ). The ρ value is based on the response frequency of the ordered items, meaning the PCs, from the Liker survey, meaning the questionnaire (Wu, 2007). Table 3, presents the 15 LI.PCs with the highest ρ values as a result of the questionnaire evaluation. It is important not to confuse this list of literature's project characteristics (LI.PCs) with the 15 most important PCs resulting from the semi-structured interviews.

Table 3 - The 15 LI.PCs with the highest mean ridit value (ρ) as a result of their evaluation in the questionnaire

#	Project Characteristic	Description	Mean ridit ρ value	RIDIT Analysis Ranking
T2_05	Information production and exchange conditions are clarified sufficiently	It is sufficiently and clearly described how the information is produced and exchanged among team members.	0.161	1
T3_05	Communication in team	Maintaining open and direct lines of communication between all project participants at all times, with no restrictions.	0.288	2
T2_14	Use of electronic data exchange system	The use of one electronic data (information) exchange system/platform in the project, in which all of the involved and relevant parties and members have access.	0.294	3
T2_01	Clarity of the ICT system operation	The clarity of the ICT systems operation that will be used for all the involved parties (lead appointing party, (lead) appointed party(ies)) and task team members.	0.321	4
T1_05	Key staff (e.g. BIM Director) capability / experience	The capability and experience of key staff of the appointed party. As key staff is meant the Information Manager, BIM Director and BIM Coordinator.	0.332	5
T4_01	Clarity of requirements	Appointing party's requirements and specifications, the EIR is clear and sufficient for the development of the BEP.	0.337	6
T4_02	Clear project goal and objectives	Project goal and objectives are clearly defined in the tender documents, can be easily stated in the BEP, and the stakeholders (e.g. appointed parties, team members) are informed about.	0.350	7
T4_07	Information completeness	Design data and documents are clear, complete, provide sufficient information and are adequate for the preparation of the BEP.	0.355	8
T4_09	Design changes	Design changes that usually occur due to changes in requirements.	0.382	9
T2_13	Shared BIM model	The use of one BIM model that has the input of all team members is clearly understood for the involved parties and members.	0.395	10
T4_03	Clear project scope	Project scope is clearly defined in the tender documents, can be easily stated in the BEP, and the stakeholders (e.g. appointed parties, team members) are informed about it.	0.401	11
T2_06	IT system's capacity for information exchange	Capacity in terms of files' size and speed of the ICT systems for information exchange	0.404	12
NT_08	Commitment of parties	The commitment of involved parties (lead appointing party, (lead) appointed party, task team members) and of the top management to follow processes, roles and undertake duties as described in the contract, ISO 19650 and/or BEP.	0.408	13
T3_04	Communication effectiveness within designers	Existence of an effective communication relationship between designers, without unresolved conflicts. (*In case that there are more than one designing firm*)	0.412	14
T3_06	Information updating frequency	The way and the frequency that the information will be updated, is clarified and planned.	0.436	15

4.3 The semi-structured interviews results

In total 15 semi-structured interviews were completed. This sample consisted of interviewees with different BEP roles, experiences, and familiarity with ISO 19650 series and the BIM execution plans. Most of them (9 out of 15) are BEP authors, and the rest (6 out of 15) are BEP users. Moreover, 40% of respondents are "Familiar" or "Very familiar" with ISO 19650. Finally, 46% of the interviewees have used or developed a BEP at least three times.

The semi-structured interviews and the analysis of the collected empirical data resulted first in the 15 most important project characteristics. Next, the correlation of these PCs with the BEP contents was established. Lastly, the recommendation about the extent of development categories of the BEP contents was discussed.

The outcome of the semi-structured interviews in combination with the literature review findings and the questionnaire responses, answer the first two research sub-questions:

- "*Which are the most important Project Characteristics (PCs) for the development of a BEP that fits the needs of a project?"*
- "*How can the most important PCs be correlated to the contents of a BEP template?*".

4.3.1 The 15 most important project characteristics for tailoring a BEP

The analysis of semi-structured interviews resulted in a list with the most important project characteristics found in the literature and provided by the practitioners. The Multi-Criteria Analysis was used to identify the 15 most critical project characteristics, with the underlying criteria and weighted scores outlined in Section 3.3.2.

After completing the interviews were finally sorted 30 project characteristics as "very" and "extremely" important. As it is described in section 4.2, it was decided that a rational number of predefined PCs is 15.

The next step was to decide the criteria and their weight. The criteria were a) the level of familiarity of each interviewee and b) the times he/she had used or developed a BEP. The MCA criteria should have the same scale. Thus, the second criterion was adjusted on a scale from 1 to 5, as follows:

Table 4 – The adjustment of the second criteria on a scale from 1 to 5

Times used or developed a BEP in different projects (n)	**Scale (1-5)**
$n \leq 2$	1
$3 \leq n \leq 4$	2
$5 \leq n \leq 6$	3
$7 \leq n \leq 8$	4
$n > 8$	5

During the semi-structured interviews, it was met the case, some interviews to state familiar with ISO 19650, because they had followed for example a seminar. However, they lacked the "learning by doing" experience, meaning the experience that someone acquires by using or developing a BEP. For that reason,

a more significant weight factor (0.6) is attributed to the criteria “times used/developed a BEP”. Table 5 shows the criteria and the corresponding weights.

Table 5 - Criteria and Weights used in the MCA

Criteria	Weight
Interviewee’s level of familiarity with ISO 19650 (1-5)	0.4
Times used or developed a BEP in different projects (1-5)	0.6

Each interviewee gets a weighted score based on his/her level of familiarity and the number of different BEPs that he/she has used or developed.

The scores for each PC are 2 or 3 and correspond to the ranking scores in the sorting matrix of the semi-structured interviews (Figure 12). More precisely, scores 2 and 3 correspond to the “Very Important” and “Extremely Important” options, respectively.

The final total weighted score for each PC is the sum of the products of [interviewee’s weighted score] by [the score of each PC].

			Interviewees													
Criteria		**w**	**INT_01**	**INT_02**	**INT_03**	**INT_04**	**INT_05**	**INT_07**	**INT_08**	**INT_09**	**INT_10**	**INT_11**	**INT_12**	**INT_13**	**INT_14**	**INT_15**
Level of familiarity *(1-5)*			2	5	1	5	5	2	5	2	3	2	4	5	2	2
Level of familiarity *(weighted)*		0.40	0.8	2.0	0.4	2.0	2.0	0.8	2.0	0.8	1.2	0.8	1.6	2.0	0.8	0.8
BEPs used / developed *(1-5)*			1	5	1	5	4	1	3	1	1	1	2	3	1	1
BEPs used / developed *(weighted)*		0.60	0.6	3.0	0.6	3.0	2.4	0.6	1.8	0.6	0.6	0.6	1.2	1.8	0.6	0.6
Interviewees' weighted score			**1.4**	**5**	**1**	**5**	**4.4**	**1.4**	**3.8**	**1.4**	**1.8**	**1.4**	**2.8**	**3.8**	**1.4**	**1.4**
#	**PCs**		**PC score per each interviewee** *(2=Very important, 3=Extremely important)*													**Tot. Weighted Score**
NT_05	Clear project goal and objectives		3	3	3		2	3	3					3	3	3	66.4
NT_06	Clear project scope			3	2	2	2	2			3			2	3	3	60
NT_08	Commitment of parties					2	3	2	3		2					2	43.8
NT_04	Clarity of requirements					2	3		2		3						36.2
T2_05	Information production and exchange conditions are clarified sufficiently		2		3			3			2	2	2				22
EPC_09	Roles and Responsibilities			2										2	2		20.4
T1_05	Key staff (e.g. BIM Director) capability / experience								2			3	3				20.2
T2_01	Clarity of the ICT system operation				2					2		2		2			15.2
EPC_25	Experience/knowledge in working with ISO, BEP					3											15
EPC_30	No. involved parties in the project (designers, consult., contr.)					3											15
EPC_70	Centralized communication													3			11.4
T2_13	Shared BIM model							2	2								10.4
EPC_11	Information Risk-based Management			2													10
EPC_13	Incompatibility between softwares and their inputs-outputs			2													10
EPC_45	Know which parties are involved in the project									3			2				9.8

Figure 19 - The applied MCA for the 15 most important PCs

Followingly, the total weighted score for each PC is the sum of the products of the interviewees' experience and the scores that each PC has.

Table 6 - The list with the 15 most important PCs

#	Project Characteristic
1	Clarity of project goal and objectives
2	Clarity of project scope
3	The commitment of project's parties
4	Clarity of requirements
5	Project's key staff capability and experience
6	Roles, Responsibilities and Ownership of data
7	Clarity of information production and exchange conditions
8	Experience, Capability and knowledge of project's parties about ISO 19650 and BIM Execution Plan (BEP)
9	The number of external project's parties
10	Clarity of the ICT systems' operation
11	Centralized communication system
12	Information risk-based management
13	Incompatibility between software inputs-outputs
14	Shared BIM model
15	Knowledge of who are the project's parties

The literature findings and the recommendation of the interviewees composed the description for each one of the characteristics. When it comes to their scoring scale, it measures whether or not the under-assessment project matches the description of the characteristic. That means the scores do not have numeral values but are descriptive. An exemption applies only to one characteristic: "The number of external project's parties", which has a numeral scoring scale, as provided by the interviewee. The scale is divided into two extremes that correlate to the degree to which the project matches or does not fit the characteristic's description and one intermediate category. The higher the score, the more closely the project matches the PC description.

Table 7 provides a detailed list of the 15 most important project characteristics with their description and scoring scale.

Table 7 - The 15 most important PCs, their description and scoring scale (1/3)

#	Name	Definition	Scoring scale		
			1	2	3
1	Clarity of project goal and objectives	The degree to which project goal and objectives: • are clearly defined in the tender documents, • can be easily transferred and captured in the BEP, and • are understood and agreed upon by the project's parties. *As project's parties are meant: the lead appointing party, the (lead) appointed parties (i.e. client, consultants, designers, contractors, subcontractors).*	• **Not clearly** defined goal and objectives, and/or • **not easy to capture** in the BEP, and/or • **most** of the **project's parties do not understand and agree** on them	• **Relatively clearly** defined goal and objectives, and/or • **moderately easy to capture** in the BEP, and/or • **some project's parties understand and agree** on them	• **Clearly** defined goal and objectives, and/or • **easy to capture** in the BEP, and/or • **most** of the **project's parties understand and agree** on them
2	Clarity of project scope	The degree to which project scope: • is clearly defined in the tender documents, • can be easily transferred and captured in the BEP, and • is shared and understood by the project's parties. *As project's parties are meant: the lead appointing party, the (lead) appointed parties (i.e.client, consultants, designers, contractors, subcontractors)*.	• **Not clearly** defined scope and/or • **not easy to capture** in the BEP and/or • **not shared and understood** by most of the project's parties	• **Relatively clearly** defined scope and/or • **moderately easy to capture** in the BEP and/or • **shared and understood** by **some** project's parties	• **Clearly** defined scope and/or • **easy to capture** in the BEP and/or • **shared and understood** by **most** of the project's parties
3	Commitment of project's parties	The degree to which the project's parties and the top management are committed to follow processes, roles and undertake duties as described in the contract, ISO 19650 and/or BEP. *As project's parties are meant: the lead appointing party, the (lead) appointed parties (i.e. client, consultants, designers, contractors, subcontractors).* *As top management is meant, for example, team managers, project managers, etc.*	**Not committed** parties and top management	**Relatively committed** parties and top management	**Fully committed** parties and top management
4	Clarity of requirements	The degree to which the appointing party's (client) requirements and specifically the EIR (Exchange Information Requirements) are clear and sufficient enough for the development of the BEP.	**Not clear** requirements	**Relatively clear** requirements	**Clear** requirements
5	Project's key staff capability and experience	With this characteristic is measured the capability and experience of the project's key staff regarding the ISO 19650 and BEP (BIM Execution Plan). *As key staff is meant the Information Manager, BIM Director and BIM Coordinator.*	**Not capable** key staff or **without prior experience**	**Relatively capable** key staff **with some prior experience**	**Capable** key staff **with prior experience**

Table 7 - The 15 most important PCs, their description and scoring scale (2/3)

#	Name	Definition	Scoring scale		
			1	2	3
6	Roles, Responsibilities and Ownership of data	The degree to which: a) the roles and responsibilities and b) the ownership of data and models are known and clear to all the project's parties. Ownership is related to the roles and responsibilities of parties and refers to the production of data, models and documents.	**Not known and not clear** to most of the project's parties	**Relatively known and clear** to some of the project's parties	**Known and clear** to most of the project's parties
7	Clarity of information production and exchange conditions	With this characteristic is assessed whether or not it is sufficiently and clearly defined how the information is produced and exchanged among project's parties and team members.	**Not clearly** defined	**Relatively clearly** defined	**Clearly** defined
8	Experience, Capability and knowledge of project's parties about ISO 19650 and BIM Execution Plan (BEP)	With this characteristic is assessed the project's parties: • past experience and knowledge about ISO 19650 and the BEP, • capability to deliver their work in accordance with the BEP	**Not capable** project's parties or **without prior experience & knowledge**	**Relatively capable** project's parties **with some prior experience & knowledge**	**Capable** project's parties **with prior experience & knowledge**
9	The number of external project's parties	With this characteristic is measured the number of externals (apart from Sweco) project's parties. The bigger the number is, the higher the chance for complexity it is. *As project's parties are meant for example: designers, consultants, contractors and subcontractors.*	The number of the external project's parties is: **n ≤ 3**	The number of the external project's parties is: **4 ≤ n ≤ 6**	The number of the external project's parties is: **n > 6**
10	Clarity of the ICT systems' operation	The degree to which the operation of the project's ICT systems is clear to all of the project's parties and task team members. *As project's parties are meant: the lead appointing party, the (lead) appointed parties (i.e. client, consultants, designers, contractors, subcontractors).* *Task team members are the internal teams of the different parties that work on the project's tasks.*	The operation of the ICT systems is **not clear**	The operation of the ICT systems is **relatively clear**	The operation of the ICT systems is **clear**
11	Centralized communication system	With this characteristic is assessed whether or not is used in the project a centralized communication system (CCS). That means the communication (emails, phone calls, online meetings, etc.) happens in one place: a centralized communication platform system.	Communication is **not centralized**	Communication is **partly centralized**	Communication is **completely centralized**

Table 7 - The 15 most important PCs, their description and scoring scale (3/3)

#	Name	Definition	Scoring scale		
			1	2	3
12	Information risk-based management	This characteristic assesses whether or not the information management is risk-based. That means, whether or not the information management-related risks are assessed and monitored frequently. For example, risks can be related to people's knowledge level about the use of a project's ICT systems, or the existence of many different stakeholders, etc.	Information management is **not risk-based**	Information management is **partly risk-based** but risks are not assessed and monitored frequently	Information management is **risk-based** and the risks are frequently assessed and monitored
13	Incompatibility between software inputs-outputs	This characteristic assesses the degree to which are used in the project different software that lurks the risk of incompatibility between their inputs and outputs.	In the project are being used different software that lurks a **high risk of incompatibility**	In the project are being used different software that lurks a **medium-low risk of incompatibility**	In the project are being used different software that **does not lurk any risk of incompatibility**
14	Shared BIM model	With this characteristic is assessed whether or not is used a shared BIM model type in the project for the same purpose, in which have access, use and provide input to all the task team members. *As BIM model types are meant the models that serve different purposes, for example, the Architectural BIM model, the Structural BIM model, etc.* *Task team members are the internal teams of the different parties that work on the project's tasks.*	It is **not used only one** shared BIM model **for most** of the different model types (purposes)	It is **used only one** shared BIM model **for the majority** of the different model types (purposes)	It is **used only one** shared BIM model **for all** of the different model types (purposes)
15	Knowledge of who are the project's parties	The degree to which is known: • who are the project's parties, their departments and teams, and • with which parts of the scope, they are working on. Having this knowledge facilitates the coordination of the parties.	**Not known**	**Partly known**	**Known**

4.3.2 The correlation of the 15 Project Characteristics with the BEP contents

Another analysis concerned the analysis and selection of the correlation between the 15 most important PCs and the BEP contents. Each interviewee had correlated each PC to different BEP contents, and in some cases, there was no convergence on the correlation for each PC. Therefore, a combination of Multi-Criteria Analysis and some correlation acceptance criteria were employed to decide on the correlations.

As criteria for the MCA have used the two variables of the interviewees, namely their level of familiarity and the times that they had used/developed a BEP in different projects. The exact weight factors that were used in the previous analysis were also set for this analysis. The justification of why those factors were selected is also the same as with the previous analysis.

Table 8 - Criteria and Weights used in the MCA

Criteria	**Weight**
Interviewee's level of familiarity with ISO 19650 (1-5)	0.4
Times used or developed a BEP in different projects (1-5)	0.6

The MCA was applied separately for each one of the 15 PCs. Thus, the MCA resulted in total weighted scores for each correlation of a PC with a BEP content. Due to the many different proposed correlations for each project characteristic were needed to set some minimum acceptance criteria for a correlation, as shown in Table 9.

Table 9 - Minimum acceptance criteria for a correlation

Criteria	**Min. Value**
Minimum total weighted score	10
Minimum % of opinion convergence	50%

The minimum acceptance criteria for the total weighted score of a BEP chapter correlated to a PC was chosen by the author's best judgment to be 10. Thus, a correlation is only accepted when proposed either a) by many different interviewees or b) by a few who are familiar with ISO 19650 and have developed/used a BEP at least some times. Thus, for example, a total weighted score of 10 can be reached either by:

a) [Four "Slightly familiar" interviewees who have developed only once a BEP] AND [one "Familiar" interviewee who have developed 5 BEPs], OR
b) [two interviewees that are "Very familiar who have developed 5 BEPs]

The semi-structured interviews, the applied MCA, and the set minimum acceptance criteria for a correlation resulted in the established correlation of BEP chapters to each project characteristic. Table 10 presents these correlations according to the view of the interviewees. The colours correspond to the different BEP chapters and help the reader observe which PCs correlate to each chapter.

Table 10 - The decided correlation of project characteristics to BEP contents (1/2)

1	2	3	4	5	6	7	8
Clear project goal and objectives	**Clear project scope**	**Commitment of parties**	**Clarity of requirements**	**Key staff (e.g. BIM Director) capability / experience**	**Roles and Responsibilities**	**Information production and exchange conditions are clarified sufficiently**	**Experience/knowledge in working with ISO, BEP**
2.1 Project Details	2.1 Project Details	3 Roles, Responsibilities and Authorities	5.1 Information Exchange Programme	3 Roles, Responsibilities and Authorities	3 Roles, Responsibilities and Authorities	5.1 Information Exchange Programme	SUM Summary
2.2 Project Description	2.2 Project Description		5.2 Level of Information Need (LoIN)	4.1 Delivery Team Capability & Capacity Assessment Criteria	6.7 User Privileges	6.8 Information Exchange Process	2.1 Project Details
2.3 Contactual Milestones	2.3 Contactual Milestones		6.2 Task Information Delivery Plan	4.2 Training Requirements			3 Roles, Responsibilities and Authorities
2.4 Strategic BIM objectives	2.4 Strategic BIM objectives		6.3 Master Information Delivery Plan	4.3 Project BIM uses			6.2 Task Information Delivery Plan
5.2 Level of Information Need (LoIN)			6.4 Common Data Environment (CDE)				6.3 Master Information Delivery Plan
			6.8 Information Exchange Process				
			6.10 Project Modeling Tolerances				
			7.2 Project Coordinates				
			7.3 Model Units				
			7.4 Placeholder Volumes for Spatial Coordination				
			7.5 Bold Parts				
			7.6 Design for Specialist Fixtures & Equipment				
			7.7 Project Information Model (PIM) Delivery Strategy				

Explanation of colours

Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6	Chapter 7	Chapter 8

Table 10 - The decided correlation of project characteristics to BEP contents (2/2)

9	10	11	12	13	14	15
No. involved parties in the project (designers, consult., contr.)	**Clarity of the ICT system operation**	**Centralized communication**	**Information Risk-based Management**	**Incompatibility between software and their inputs-outputs**	**Shared BIM model**	**Know which parties are involved in the project**
3 Roles, Responsibilities and Authorities	6.4 Common Data Environment (CDE)	6.1 Communication and Meetings	2.4 Strategic BIM objectives	6.4 Common Data Environment (CDE)	6.1 Communication and Meetings	2.2 Project Description
5.1 Information Exchange Programme	6.5 CDE platform details	6.8 Information Exchange Process	6.1 Communication and Meetings	6.5 CDE platform details	6.2 Task Information Delivery Plan	
6.1 Communication and Meetings		6.9 Detection of bottles process	6.2 Task Information Delivery Plan	7.11 Document name	6.3 Master Information Delivery Plan	
6.2 Task Information Delivery Plan		7.11 Document name	6.3 Master Information Delivery Plan	7.12 Revisions	6.4 Common Data Environment (CDE)	
6.3 Master Information Delivery Plan			6.4 Common Data Environment (CDE)	7.13 Status Codes	6.8 Information Exchange Process	
6.4 Common Data Environment (CDE)			6.5 CDE platform details	7.14 Explanation of further Information Characteristics	6.9 Detection of bottles process	
6.5 CDE platform details			6.6 Linking Knowledge	8.1 Approved Software	7.2 Project Coordinates	
6.6 Linking Knowledge			6.7 User Privileges	A Appendix A Naming Conventions	7.4 Placeholder Volumes for Spatial Coordination	
6.7 User Privileges			6.8 Information Exchange Process		7.1 Model Suitability Checklist	
6.8 Information Exchange Process	8.1 Approved Software		6.9 Detection of bottles process		8.1 Approved Software	
6.9 Detection of bottles process	8.2 Project Specific Shared Resources		6.10 Project Modeling Tolerances		8.2 Project Specific Shared Resources	
			7.1 Standards & Guidance Documents		8.3 Security Requirements	

Explanation of colours

Chapter 2	Chapter 3	Chapter 4	Chapter 5	Chapter 6	Chapter 7	Chapter 8

4.4 Structured Interviews Results

The structured interviews were conducted with a small sample of people. More specifically, 3 BEP authors who are "Very Familiar" with ISO 19650 series and the BEP were interviewed. They also have developed more than five different BEPs each.

The semi-structured interviews provided data to realize the structured interviews. The last provided an answer to several questions which concerned the extent of development categories of the BEP contents. More specifically, this research step resulted in:

a) The decision on the number, names and description of the extent of development categories,
b) A decision on where the additional and more extensive explanation for a chapter should be located in the BEP document,
c) Criteria to decide when and where is placed this more extensive explanation, and
d) The criteria to decide which extent of development category prevails in case of different recommendations for the same chapter.

The outcome of this step provides an answer to the third research subquestion: "*How can the extent of development categories of the BEP contents be defined?".*

The data collection process regarding the above topics is analysed in section 3.5. The results on the topics mentioned above are presented below in the same order as stated above.

4.4.1 The number, names and description of the extent of development categories

At first, all the interviewees agreed (100% opinion's convergence) that the extent of development categories (e.o.d) should be three.

Regarding the **titles** of the e.o.d categories, all the interviewees agreed on the name:

a) "Briefly" for the extreme category in which the project matches the PC description
b) "Extensively" for the extreme category in which the project does not match the PC description

2/3rd (67%) of the interviewees agreed on the name "Regular" for the intermediate category.

For the **description** of each e.o.d category, the phrases that were highlighted by the interviewees as "Should be in the description", were kept and incorporated in the description of each e.o.d category. Table 11 presents those three e.o.d categories.

Table 11 – Descriptions of the extent of development categories of the BEP contents

Category	Definition
Briefly	Develop BRIEFLY this (sub)chapter. That means: 1. address the content of this (sub)chapter but also develop it with the bare minimum information, 2. appoint only the tools/processes that will be used in the project, assuming that readers would understand what to do, 3. assume that the contractual requirements are clear, and 4. assume that all the involved parties are familiar and have prior experience with the ISO 19650 & BEP.
Regular	Develop REGULAR this (sub)chapter. That means: 1. develop this (sub)chapter with some project-specific information and guidelines, 2. explain shortly why we do it (e.g. following a process/or using a tool) and how we use it (e.g. process or tool). An example for the desired extent of explanation is: "Work according to the Dutch grid coordination system to ensure that all the federation models are in the right place. For this scope will be used X (sub)tool, 3. add some additional explanation to have clear guidelines, and 4. assume that all the involved parties are relatively familiar and have some prior experience with the ISO 19650 & BEP.
Extensively	Develop EXTENSIVELY this (sub)chapter. That means: 1. develop this chapter with detailed project-specific information and clear guidelines, 2. explain why we do it (e.g. following a process/or using a tool), why is beneficial and how we use it (e.g. process or tool). An example for the desired extent of explanation is: "Work according to the Dutch grid coordination system to ensure that all the federation models are in the right place. In that way, time is saved, and errors can be avoided. For this scope will be used X (sub)tool.", and 3. assume that all the involved parties are not familiar have no prior experience with the ISO 19650 & BEP.

4.4.2 The location of the more extensive explanations in BEP

Asa direct extension, the last two e.o.d categories, namely the “Regular” and “Extensively”, provide an additional explanation for the proposed BEP contents. Therefore, the 2/3rd (67%) of the interviewees were in favour of the option:

“*For the Regular and Extensively categories: depending on the times that a chapter is recommended to be regular or extensively developed, place the additional explanation in the main BEP document or the Appendices*.”

The next step was to decide when this additional explanation should be placed in the main BEP document or the Appendices. All the interviewees agreed that the following criteria should apply:

- *“If the category Regular constitutes more than 50% of the total recommendations for a chapter, then the additional explanation stays in the main BEP document.”*
- *“If the category Extensively constitutes more than 50% of the total recommendations for a chapter, then the additional explanation stays in the main BEP document.”*

All the interviewees proposed a value of 50% to decide the location of the additional explanations.

4.4.3 The prevailing category for a BEP chapter

The last decision that had to be made by the interviewees was to propose when an e.o.d category prevails in case of multiple recommendations for the same chapter. All the interviewees (100% convergence) proposed that a more extreme category prevails when it constitutes at least 25% of the total number of recommendations for the same chapter. That means:

- *"If the category Regular constitutes more than 25% of the total recommendations for a chapter, then is the dominant category."*
- *"If the category Extensively constitutes more than 25% of the total recommendations for a chapter, then prevails over every other category."*

All the interviewees proposed a value of 25% for an e.o.d category to prevail.

5. The development of the Decision Support Tool

Each research step contributed to the development of one main research objective: the decision-support tool for developing a BIM execution plan that fits the project's needs. The present subchapter describes the input, the operation, the settings, and the output of the tool. Figure 20 visualizes the different components of the tool that are going to be decomposed and presented. It is important to mention that the term "input" can have two different interpretations: a) the input that the research provided to develop the tool, and b) the input required by the tool's user in order for the tool to produce a result. Therefore, for the better understanding of the reader, the term "input" will be accompanied by the terms "research's" or "user's".

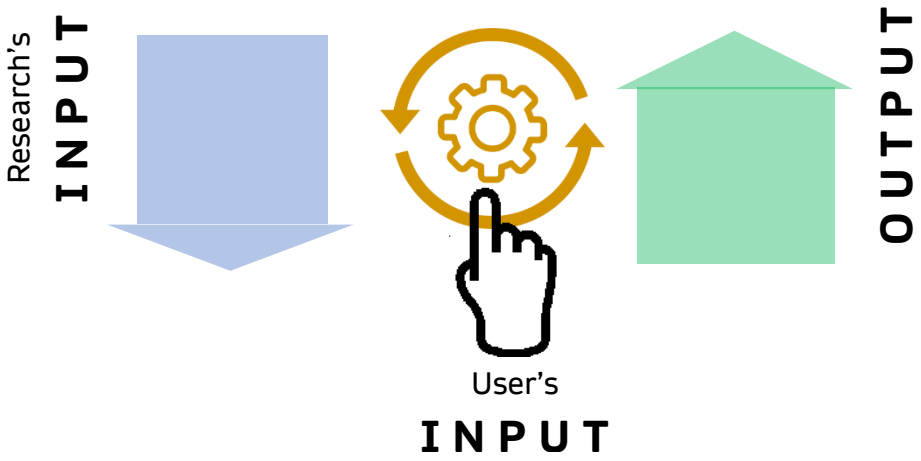


Figure 20 - The tool's major components

The development of the tool provides a complete answer to the fourth research subquestion:

"How can the PCs, the BEP contents and the recommendations for their extent of development, be combined in a practical and user-friendly way?"

5.1.1 The research's input for the tool

As already mentioned, all the research steps provide the necessary input for developing the decision support tool. More specifically, the following research's elements were used for the tool development:

The research's elements that provided input to the development of the tool:	**This element is a result of the:**
1. The 15 most important project characteristics, including their description and scoring scale	• Literature review • Semi-structured interviews
2. The correlation of the 15 most important characteristics with the BEP contents	• Semi-structured interviews
3. The extent of development categories of the BEP contents	• Semi-structured interviews • Structured interviews
4. The decision on when and where the additional explanation of the more extensive categories should be placed, including the criteria to decide that	• Semi-structured interviews • Structured interviews
5. The decision on which extent of development category prevails in case of multiple recommendations	• Structured interviews

Research's
INPUT

Apart from the abovementioned elements, there are two additional inputs for developing the tool. At first, the BEP template that is used by Sweco NL and was used to extract the BEP contents that were correlated with the project characteristics.

5.1.2 The user's input

The tool's user is required to provide input only once. This input concerns the assessment of a project based on the predefined 15 project characteristics. The assessment is possible by attributing a score from 1 to 3 to each project characteristic. The score is set based on how closely the project matches the description of the characteristic. As expected, there might be a case that not all of the predefined project characteristics will always apply to the project being evaluated at the time. Thus, the user chooses whether or not this PC is applicable for each project. Figure 21 is the page where the user needs to assess a project as described above.

User's
INPUT

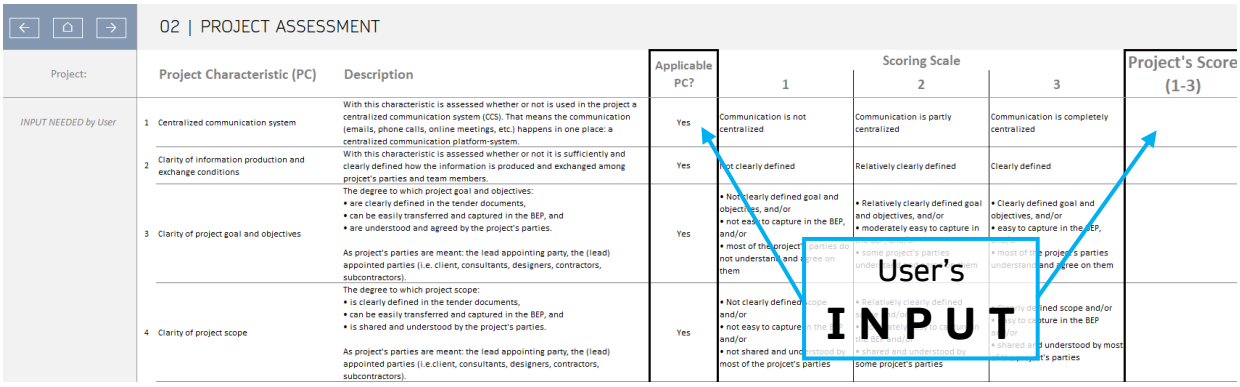


Figure 21 - The field where is required the input by the user

The user also provides some informative data to the tool, such as the project name, notes about the tool, etc. However, those data are not considered an input because they do not influence the operation of the tool and, consequently, the output produced.

5.1.3 Process followed by the user

The user is navigated in the tool through a logical process. The tool directs the user through the necessary steps and notifies him/her when additional input is required. The steps are described below (Table 12) and are illustrated in the flow chart of the next page (Figure 22).

Table 12 - The steps of the tool that follows the user

Name of the step	**Description**	**Requires / Produces**
00 | Home Screen	This is the starting page of the tool, the "Home Screen", in which the user can start using the tool, or access the settings or read the instructions for use.	-
01 | Project's Data	The user provides data about the project's name, the client and the names of the BIM-related key staff.	Requires data by the user
02 | Project Assessment	The user assesses the project based on predefined characteristics. First needs to select whether or not each PC applies to the under assessment project.	Requires input by the user
03 | Correlation Matrix	The user (if desires) can have an overview and be informed about the chapters that are correlated to each. ! This is not the final output of the tool!	-
04 | E.o.D Recommendation	This is the final output of the tool, which is provided for every BEP content: • The e.o.d category • The proposed location to place the additional explanation	Produces output
05 | User's Notes & Recommendations	The last (optional) step is the page where the user can make notes/recommendations about the project, and indicate if any of the PCs need to be further considered. Lastly, can provide feedback about the tool, the PCs and their correlation to BEP contents.	Requires data by the user

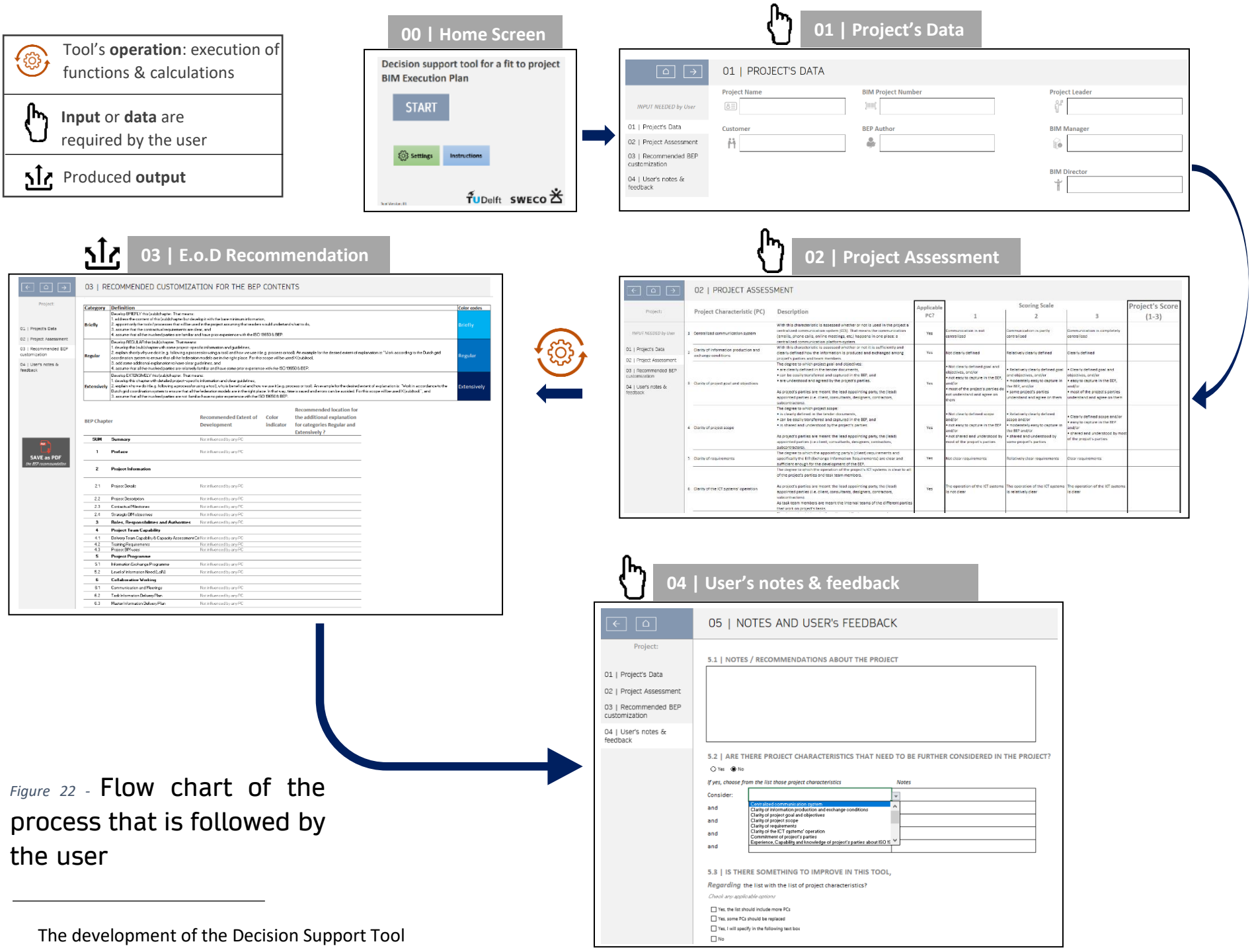


Figure 22 - Flow chart of the process that is followed by the user

5.1.4 The operation of the tool

The tool executes some functions and does some calculations to produce the output. This process between the user's input and the tool's output is named the tool's operation. In a few words, the following describes the operational processes that produce an output after providing the user's input.

The tool utilizes the user's input of step "02 | Project Assessment" and all the research's inputs as described in section 5.1.1.

Based on the score of each PC, the tool attributes the corresponding e.o.d category (Table 13) for the correlated BEP contents.

Table 13 - The matching between the project's score and the e.o.d category

Project's Score	Extent of Development category
1	Extensively
2	Regular
3	Briefly

The tool then counts the number of times each e.o.d category was proposed for each BEP content. Based on this calculation (detailed in subchapter 4.4.3), the tool indicates which e.o.d category prevails and is ultimately recommended. Furthermore, it proposes where any additional explanation (as described in section 4.4.2) should be inserted: in the main BEP or Appendices.

5.1.5 The output of the tool

The output of the tool concerns a recommendation for each chapter about:

- The extent of development category (both in text form and with a color indicator).
- The location (Main BEP document or Appendices) where the additional explanation for categories Regular and Extensively should be placed.

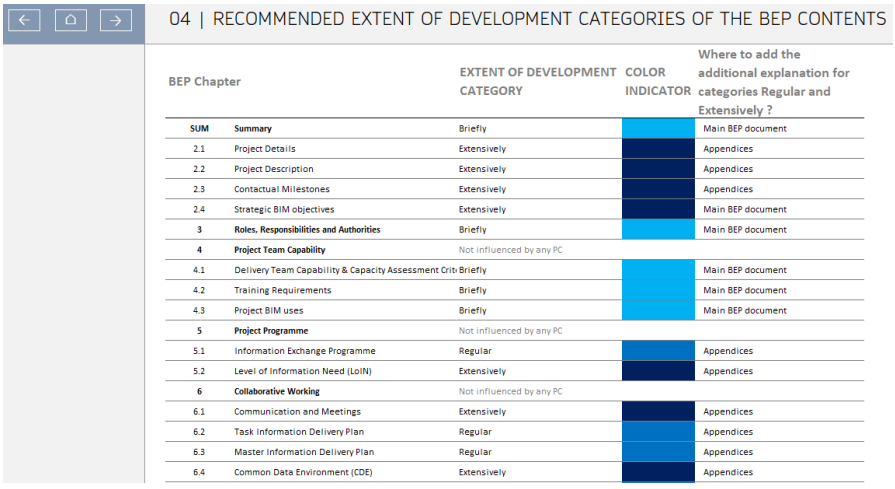


Figure 23 - An example of the recommendations in the output page of the tool

5.1.6 The tool's settings

One of the goals for the decision support tool was to deliver a product that can be easily maintained and adjusted in the future. Therefore, the tool's settings page has a primary role for that goal. Every data that the tool's user see are connected and extracted trom the seetings page. Therefore, any change in the settings will automatically adjust the user's environment. Certainly, the thesis author suggests that one or a few BEP experts should have access to the tool's settings and make changes. The company can assign this role to someone in the future.

The settings adjust any information in the tool, such as the list with the project characteristics and scoring scale. Moreover, the correlation of the PCs to the BEP contents can be modified. The BEP contents can be also updated in the future. Furthermore, any message that appears to the user can be modified in the settings. Lastly, everything related to the extent of development categories (e.g., their names, description and location in the BEP document) can be set on this page.

5.1.7 The user's notes and feedback

The last step that the user follows in the decision support tool concerns potential notes and recommendations. At first, the user can keep some notes and make recommendations for the project and the process he/she followed to assess it based on the PCs.

In addition, the tool asks the user if any PC should be considered further for the project in general and not only for the BEP. This question is because some PCs might relate to the project's overall success or complexity. Next, the user can provide feedback regarding the decision support tool and suggest ways for further improvement.

A tool for the better application of the ISO 19650 is currently under development by Sweco NL. Therefore, a meeting with the developers of this tool was held, and it was discussed that this future tool could be linked and possibly incorporate the thesis' decision support tool. More specifically, the assessment of a project based on the PCs and the user's recommendation can provide input in this future tool. Therefore, the page with the user's recommendations and notes can contain information that later can be linked with the under-development tool.

5.1.8 Summary of tool's essential components

Figure 24 is a replica of Figure 20, but with all of the tool's input and output information filled in.

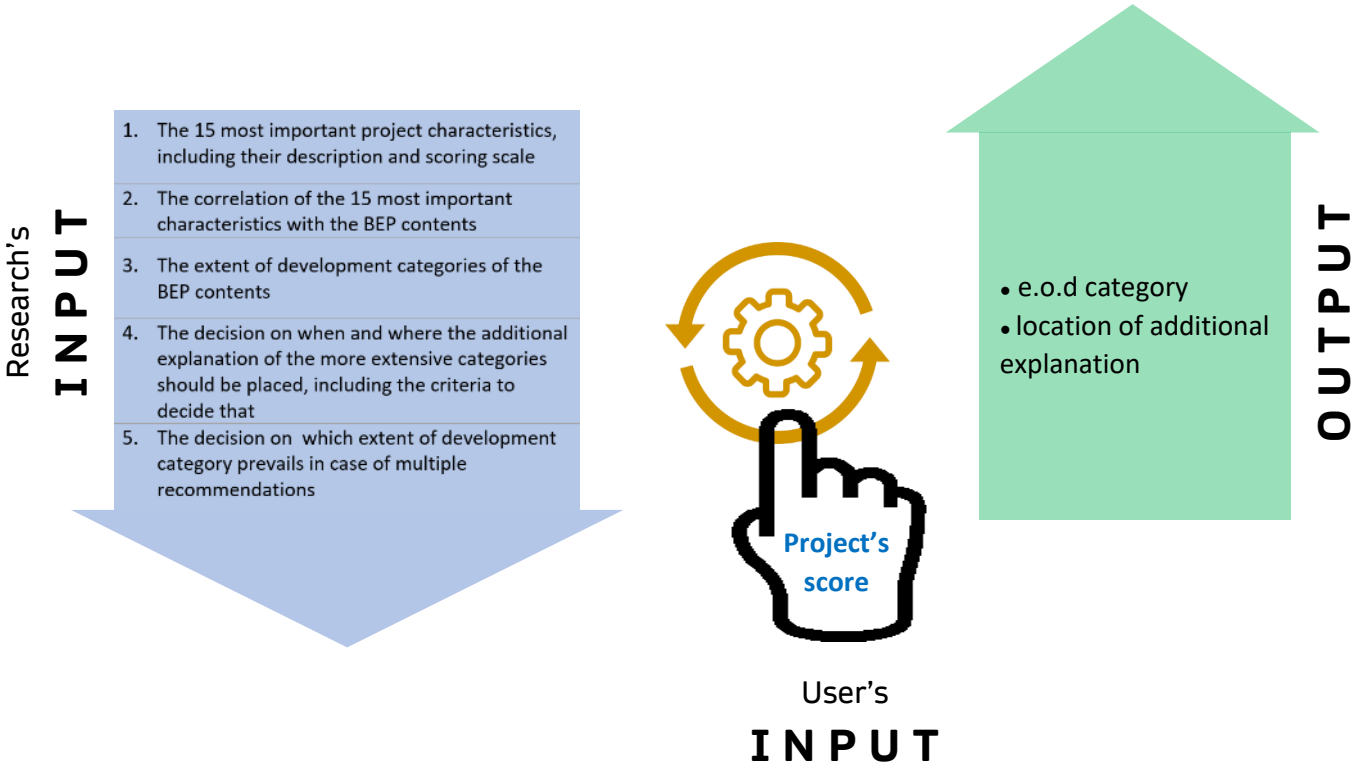


Figure 24 - The tool's major components (filled)

Appendix F presents all the main windows of the decision support tool.

6. Validation

Validation aims to ascertain the practicality and viability of research results from practitioners' perspectives and gather their feedback. The validation of the decision support tool aims to confirm all of the research's preliminary findings, including the validity of the finally selected PCs, their correlation to the BEP contents, and the extent of development categories of the BEP contents. For the validation, a meeting was organized into two rounds with three experts who have proven experience in ISO 19650 and in developing BIM execution plans. A pilot project was selected for the validation of the decision support tool.

6.1 The validation experts

Two experts were provided by Sweco Netherlands, while Sweco Belgium provided the third. The reason for selecting an expert outside the Sweco Netherlands is to explore whether the tool can be more generally used. In addition, the BEP template and the adaption to the ISO 19650 standards differ between Sweco NL and Sweco BE. Thus, it was possible to evaluate the tool's validity and functionality by individuals who use different BEP templates in two distinct companies. This validation can provide an early conclusion on the tool's applicability by the AEC industry and not only by Sweco NL.

6.2 The pilot project: Bedrijvenstrook Zeeburgereiland

The project is entitled Bedrijvenstrook Zeeburgereiland, and it involves the urban development of an approximately 7-hectare business area in Amsterdam. Optimal use of space and a clear separation between business and public space was desired to assign an urban character to the area.

The BIM-related objective of the scope is to capture the existing, temporary and future situation of the project, concerning the public space, the buildings, the plumbing installations, utility companies and installations and the area's soil system.

Figure 25 - Visualization of the area of the project

6.3 Validation Method

A pilot project was used for the validation. The main criterion for selecting the pilot project was that none of the experts should have been involved in any way in the project. The idea was to provide the experts the data from the pilot project, which are necessary for developing a BEP. The validation session was divided into two rounds, A and B, on two different days.

6.3.1 Validation Round A

The first day of validation concerned an introduction to the thesis goal, the validation method and the pilot project.

Next were provided with:

- all the relevant data of the pilot project that are necessary for the preparation of a BEP, and
- a recommendation form for the extent of development of the contents of the BEP template that Sweco NL uses.

First, they were asked to examine the pilot project's data individually. Further, based on the project's data, they made recommendations (again individually) on the extent of development of each BEP chapter. Their recommendations are referred to, from this point on, as "Expert's recommendation."

Next, they were introduced to the decision support tool and were instructed on how it operates. Finally, the last task for this round was to use the DST tool individually and assess the project based on the predefined project characteristics. After assessing the project, the DST recommended the e.o.d of each of the BEP chapters. As a result, it was created and then compared three distinct "Expert's recommendations" and three distinct "Tool's recommendations" regarding the extent of development for the BEP contents of the pilot project.

The pilot project's data

The pilot project's data concerned the Exchange Information Requirement (EIR) document and some supplementary information, mainly regarding the competencies of the project's parties. Those data are usually provided to a BEP author when asked to prepare a BEP for a project.

The recommendation form for the e.o.d of the BEP template's contents

They were asked to recommend the e.o.d of each chapter of the BEP template by choosing one of the following recommendation options for each chapter:

Table 14 - The recommendation options for the e.o.d of the BEP contents

Recommendation Option	Description
0	This content provides information, which is not directly affected by the characteristics of this project
BRIEFLY (BR)	*The description of each option is the same as the description of the e.o.d categories given in Table 11.*
REGULAR (RE)	
EXTENSIVELY (EX)	

6.3.2 Validation Round B

On the second day of validation, experts were supplied with specific comparison data and statistics from round A. Those statistics facilitated the analysis of the validation outcome and fueled a discussion. Afterwards, a discussion was initiated based on specific questions about their suggestions, the pros/cons, the tool's applicability, future recommendations, etc.

6.4 Validation results

The validation results first present some comparison statistics between the expert's and tool's recommendation regarding the e.o.d of the BEP contents. Next is presented the feedback that the experts provided.

6.4.1 Comparison results and statistics

Result 1: Convergence between the expert's and tool's recommendation

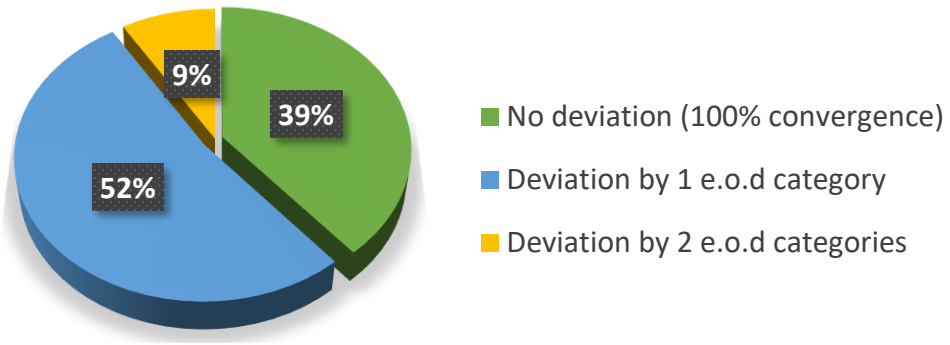
The first comparison concerned the deviation between the Expert's and Tool's recommendation regarding the e.o.d of the BEP contents. Table 15 and Figure 26 show the deviation percentages for each expert and, on average, for each deviation case. No deviation between the recommendation of the Experts and the Tool concerned on average 39% of the BEP contents. Extreme deviation, meaning the deviation by 2 e.o.d categories, occurred only for 9% of the BEP contents.

A very encouraging result regarding the tool's efficiency is that for 91% of the contents, a maximum deviation by 1 e.o.d category was observed.

Table 15 - Percentages of deviation between Expert's and Tool's recommendation regarding the extent of development of the BEP contents

The deviation between Expert's and Tool's recommendations	**Example of deviation** (**E**=Expert, **T**=Tool)	**EXP_01**	**EXP_02**	**EXP_03**	**Average** (%)
No deviation (100% convergence)	**E**: RE , **T**: RE	36%	39%	41%	**39%**
Deviation by 1 e.o.d category	**E**: BR , **T**: RE	55%	56%	47%	**52%**
Deviation by 2 e.o.d categories	**E**: BR , **T**: EX	9%	6%	12%	**9%**
Deviation by max. 1 category	**E**: BR , **T**: RE **E**: RE , **T**: EX	91%	94%	88%	**91%**

Figure 26 - The deviation between Expert's and Tool's recommendations



Result 2: "What was the recommendation of the tool when a deviation was noticed?"

Another statistic element was the behaviour of the tool when deviation occurred:

- For a deviation by 1 or 2 e.o.d categories, the tool recommended a more extreme category for 59% of the cases
- For a deviation by 2 e.o.d categories, the tool recommended a more extreme category for 78% of the cases

It was discussed with the experts whether or not it means that the tool is mainly on the "safe side". All three commented that it is better to propose a more extreme category and ensure that all the project's parties clearly understand BEP content. In this way, the author gets a more conservative recommendation, and by his/her judgment, he/she can decide which is the appropriate e.o.d category.

Result 3: "How did the experts score the PCs in the tool?"

This result presents how experts assessed the pilot project based on the predefined project characteristics.

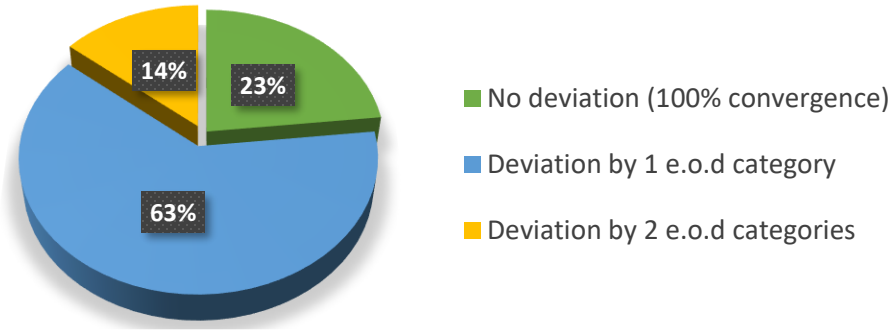
- 5 PCs out of the 15 scored similarly by all
- 9 PCs out of the 15 scored similarly by the 2/3rd
- 1 PC out of the 15 scored differently by everyone

Those data show that most experts scored the majority (9/15) of the PCs similarly. This fact can be related and possibly linked to the deviation percentages of the e.o.d categories. For example, the % of PCs with the same score (33%) and the % of BEP contents with the same e.o.d recommendation (39%) is very similar. Respectively, the same applies to the % of PCs scored differently by all the experts: 7% and the % of BEP contents with deviation by 2 e.o.d category: 9%.

Result 4: "What was the convergence of the experts' recommendations?"

The last statistic discussed concerns the deviation observed between the three different recommendations of the experts about the e.o.d of the BEP contents.

Figure 27 - The deviation between Experts' recommendations



This statistic checks whether the deviation observed in the tool's recommendation was also observed in experts' recommendations without the tool. As it can be seen, experts had, either way, different opinions on the extent of development for 77% of the BEP contents.

6.4.2 Validation feedback

The last step of the second validation round concerned the gather of feedback by the experts. The first remark is that this tool should support the BEP author in the BEP preparation process, and the tool's recommendation should not be considered absolute. A threat of using that kind of tool is that the user stops thinking and follows the outcome as absolute. Thus, if the tool is used to assist its user, then it yields many benefits.

At first, starting from the main principle of the tool, getting a recommendation on how much effort to spend on each BEP content is better than just filling a universal BEP template. Moreover, when a BEP author uses the tool, he/she needs to think about the project before acting, which helps to understand the project better. All three experts agreed that the DST tool could immediately be used at Sweco NL for the BEP preparation process. The tool's recommendations can save time for the BEP authors, spark conversation about the project, and help by indicating which additional information is required to understand the project. One expert adds that using the tool for the assessment of the project at the same time with all the project's parties can produce even better results.

Apart from the tool's primary goal, which is the recommendation about the extent of development of the BEP contents, it can also be used as an educational tool for people who want to understand better what a BEP is, why it is important and how it is related to the project. For example, a new BEP author can use the tool to overview the deviation between his/her perceptions and the tool's recommendations and focus on them. However, it can also be helpful for experienced people, for the same reason, as they can check where their perceptions deviate from the tool's recommendations and analyze why. One expert adds that it is good that the tool's recommendations are mainly on the safe side (see result 2, pg. 70).

The small number of scoring scales (3 scales) increases the chance of having deviation between the tool's recommendation and the author's perception. However, they do not suggest having more scoring scales because assessing the project will become more complex. Therefore, the discussion of whether the deviation percentages between experts' and tool's recommendations are acceptable or not is less

important. More significant is that the DST tool can support the BEP author and save time. All the experts agree with that statement.

To improve the tool further, they suggested validating it with more people, both experienced and inexperienced BEP authors. In addition, it will be helpful, especially for new BEP authors, to add more concrete examples in the PCs' descriptions and the scoring scale.

They also made some more technical recommendations for the further development of the tool. At first, they proposed automatically saving all the data to a database to make possible historical backwards engineering possible in the future and see how good the BEP was. This can also produce data for lessons learnt. Another suggestion was to transform the current DST tool into a tool that walks you through it, by first giving the project's information (e.g. the EIR) and asking to assess the project based on the PCs. This suggestion could help the user to control the flow of the information and measure how much time it takes to assess the project.

7. Discussion

This chapter discusses the research results after collecting and analyzing the collected data by the questionnaire responses, the semi-structured and structured interviews.

7.1 Discussion of the most important project characteristics

This subchapter initiates the discussion on the 15 most important PCs that were finally used as input in the tool. The justification for selecting 15 PCs, is provided in section 4.2. Table 16 lists the most important project characteristics, their score as per the applied MCA, the percentage of the "Very Familiar" interviewees who ranked each PC. Most of the PCs are grouped in three categories, as seen in the table. Therefore, the discussion on the research results concerning the most important PCs will be done based on data that are provided by this table.

Table 16 - The list of the 15 most important PCs with their MCA scores

#	Project Characteristic	MCA Score	% of "Very Familiar" people who ranked this PC	% of evaluations made by at least "Moderately Familiar" interviewees	PCs related to the **"Clarity of the project and the client's needs"**	PCs related to the **"Existence and Use of ICT systems"**	PCs related to the **"Experience / Capability of project's parties"**
1	Clarity of project goal and objectives	80.8	80%	44%	●		
2	Clarity of project scope	72.8	80%	56%	●		
3	Commitment of project's parties	58.2	60%	67%			
4	Clarity of requirements	50	60%	100%	●		
5	Project's key staff capability and experience	29.2	20%	67%			●
6	Roles, Responsibilities and Ownership of data	26.4	40%	67%			
7	Clarity of information production and exchange conditions	23.8	0%	33%		●	
8	Experience, Capability and knowledge of project's parties about ISO 19650 and BIM Execution Plan (BEP)	22.2	20%	100%			●
9	The number of external project's parties	22.2	20%	100%			
10	Clarity of the ICT systems' operation	17.6	20%	25%		●	
11	Centralized communication system	15	20%	100%		●	
12	Information risk-based management	14.8	20%	100%			
13	Incompatibility between software inputs-outputs	14.8	20%	100%		●	
14	Shared BIM model	14	20%	50%		●	
15	Knowledge on who are the project's parties	12.2	0%	50%			
			Cumulative MCA score per Theme:		203.6	85.2	51.4

Ten out of the fifteen project characteristics are grouped in categories, while the rest 5 PCs do not have commonalities and thus were not grouped. Those categories are, as shown in Table 16:

- The clarity of the project and the client's needs
- The existence and use of ICT systems in the project
- The experience/capability of the project's parties

Each category was assigned a cumulative MCA score, meaning the sum of the MCA scores of the PCs belonging to each. The higher the MCA score assigned to a PC, and consequently to a category, the more critical it is to examine while preparing a BEP for a project

The discussion starts with the more important PCs (higher MCA score) and progresses to those with the lower MCA scores. First, based on the categorization of PCs in categories and on their cumulative scores, the category "**Clarity of the project and client's needs**" is by far the most influencing category regarding the development of a BEP for a project. This category has a score of 203, which is more than double compared to the other categories' scores. That means having a clear project goal and objectives, clear project scope and clear requirements by the client, is a stepping stone in developing a clear BIM execution plan. Another fact to mention is that a high percentage of "Very Familiar" interviewees who have also developed or used at least 5 times a BEP for different projects have highly ranked the PCs of this category.

The interviewees also placed a premium on project qualities that are associated with the presence and utilization of ICT technologies in the project. Those ICT systems refer to the common data environment systems (document management software) and the software used to execute a project's tasks (e.g. BIM software). These project characteristics examine different aspects regarding the use of those ICT systems, such as the clarity of their operation, the compatibility between their inputs and outputs, how information is produced and exchanged and the access and use of shared BIM models. This category has a relatively high MCA score (85) and its contents PCs were mainly proposed by the 20% of the "Very Familiar" people, and an average of 62% of the evaluations was made by at least "Moderately Familiar" interviewees. This category highlighted the value of selecting the appropriate ICT tools in advance, based on the project's requirements and providing clear guidelines regarding their operation.

The third category concerns the **experience and capability of the project's parties** and got a score of 51. What is indicated is that a BEP author shall examine the capability and expertise of the project's key staff and teams concerning ISO 19650 and BEP, since this determines the content of several BEP chapters. As key staff is meant the Information Manager, BIM Director and BIM Coordinator of a project. The rate of 20% of the "Very familiar" interviewees favour this category, and 84% of the evaluations was made by at least "Moderately Familiar" interviewees.

The "commitment of project's parties" to follow processes, their roles and to undertake duties as described in the contract and in the BEP is ranked with a higher score than the previously mentioned category. It is ranked as an important PC by 60% of the "Very Familiar" interviewees, while 67% of the evaluations were made by at least "Moderately Familiar" interviewees.

In addition, the degree to which are known and clear to all the project's parties:

a) the "roles and responsibilities" and

b) the "ownership of data and models,

is also an important PC to consider when preparing a BEP. In other words, it is important to clarify who will produce what information in a project. This is the opinion of 40% of the “Very Familiar” interviewees, and 67% of the evaluations were made by at least “Moderately Familiar” interviewees.

Some interviewees also proposed the importance of knowing the external parties involved in the project. Since the number of the involved parties can be related to the project's complexity, at least all the “Moderately Familiar” interviewees suggest that is important to know this number. Furthermore, half of them indicate that it is equally important to know whom those external parties are, meaning to know which departments and teams are and which parts of the scope they work.

Lastly, information risk-based management is proposed as very important by one of the most familiar interviewees with the ISO 19650 series. The assessment and monitoring of information-related risks is also an element of the ISO 19650-2. For example, risks can be related to individuals’ knowledge level about the use of a project's ICT systems, or the existence of many different stakeholders, etc.

7.2 Comparison of empirical project characteristics with literature’s project characteristics

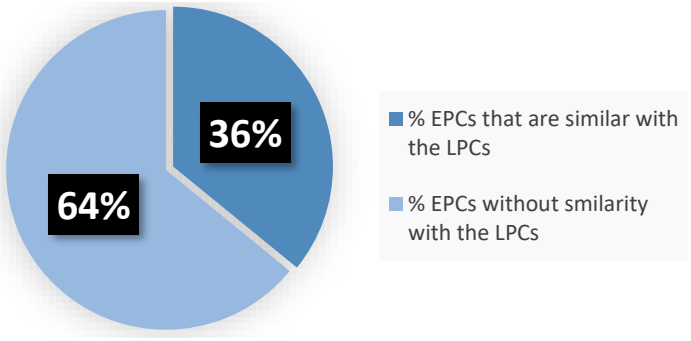
This subchapter summarizes several data discovered throughout the thesis research progress and provides information to compare the literature and empirical project characteristics.

At first, the clarity of the LI.PCs, as the interviewees perceived it, is examined. More precisely, the questionnaire respondents had the option to choose “Not clear” in case a project characteristic was not clear. Only 4% of the total responses concerned the option “Not clear”. This indicates that the majority of the project characteristics in the literature have a clear name and description. In the semi-structured interviews which succeeded the questionnaire, the “Not clear” indications were discussed with the interviewees.

Concerning the project characteristics, it is interesting to mention that during the first part of the semi-structured interviews, several practitioners proposed empirical project characteristics found in the literature and included in the questionnaire. To avoid bias, the brainstorming session for collecting empirical project characteristics was conducted without providing the characteristics found in the literature. To be more specific, 78 EM.PCs were collected in total, 28 of which presented similarity and sometimes exact match with the literature’s project characteristics. The practitioners’ perceptions were not always aligned with the literature, as a 36% of the EM.PCs presented similarity or exact match with the LI.PCs. In other words, one in three EM.PCs were already found in the literature. That is a positive indicator for the validity of the literature findings. The rest of EM.PCs (64%) did not present any similarity with the literature’s project characteristics.

Figure 28 -

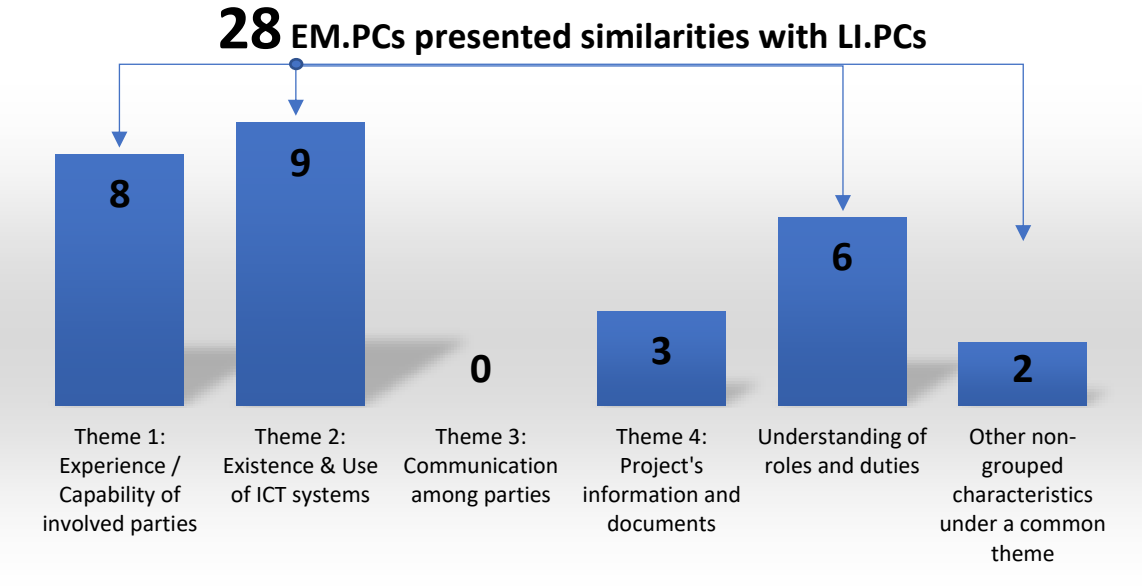
Similarity % between EM.PCs & LI.PCs



This 36% agreement between EM.PCs and LI.PCs was further investigated to determine which characteristics had a higher convergence between empirical recommendation and literature findings. The following Figure 29 illustrates the number of similarities of EM.PCs per each LI.PC theme.

Figure 29 -

Number of EM.PCs similar to LI.PCs per theme



As it can be observed, most of the EM.PCs that were similar to LI.PCs, and specifically 17 out of the 28, were similar to LI.PCs which belong to the "Theme 1: Experience / Capability of involved parties" and "Theme 2: Existence and use of ICT systems". Apart from that, 6 EM.PCs were the same as the LI.PC: "NT_16: Understanding of roles and duties". The number of similarities for each theme is equal to the number of interviewees who proposed this EM.PCs, among others. That means 9 out of the 15 interviewees believe that it is important to consider project characteristics relevant to the use of ICT systems when preparing a BEP. Similarly, 8 out of the 15, proposed EM.PCs are relevant to the experience and capabilities of the project's parties. 6 EM.PCs from 6 different interviewees concerned the importance of clearly understanding roles and duties, a characteristic that was also found in the literature.

Some interviewees mentioned the importance of having clear project goals, objectives and scope. These characteristics are also proposed in the literature and are included in Theme 4: Project's information and documents. In the same theme, the clarity of the client's requirements is a characteristic proposed both by the literature and the interviewee.

Other EM.PCs that were also found in the literature are included in the theme: "Other non-grouped characteristics under a common theme". For example, the "Number of project's parties".

To conclude, the themes mentioned above present a concurrence between the interviewee's views and the literature. However, as it is shown in Figure 28, many of the proposed EM.PCs are not similar to any of the LI.PCs. None of the interviewees proposed EM.PCs related to the communication among project's parties or relevant to the project's information and documents. Unlike, in the literature, 11 LI.PCs related to those themes of communication and project information were reported.

7.3 Discussion of interesting gathered data from the semi-structured interviews

Due to their structure, the semi-structured interviews facilitated the dialogue and the brainstorming. During this process, a few data points were collected that are worth mentioning since they provide insight into the BIM and ISO 19650-related processes that are followed in projects.

In some cases, the client does not have experience with BIM and more often with the ISO 19650 and BEP. Thus, sometimes a client describes many requirements but without clearly understanding them and how BIM works. Apart from that, even if they are conscious about their BIM-related requirements, they do not usually understand how to make a clear Exchange Information Requirements document, which is the fundamental input for developing a BEP. Occasionally, particularly when no EIR exists, it can be difficult to identify the client's requirements within the numerous tender documents. Additionally, when the customer does not provide an EIR, the company may construct the project's EIR to develop the BEP later, even though this is not a contractual agreement. One of the most experienced interviewees highlighted that a prevalent issue is the clients' unawareness about what a BEP is and how it can help a project.

The ISO 19650 series were quite recently introduced (first standard released in 2018) in the construction world. Therefore many people are not trained on how to use a BIM execution plan. One very experienced interviewee stated the importance and need to train people on how to use BEPs. According to one interviewee, it is necessary to raise BEP awareness among all project stakeholders, both internal and external, to align them with the process. At this point, it is interesting to add the perspective of an older interviewee who is not very much familiar with the latest technologies but needs to use the BEP in his projects. He advises that each project should always have someone assigned to support the BEP users with its implementation. Moreover, he adds that it is helpful to justify why we need a BEP, how it benefits us, and its added value. "We need to follow a new process, only because we need it, and not because it is new", adds the same person.

A new user of BEP mentions that he sees possibilities of using a BEP and that it can be helpful; however, in the project that he is involved the BEP exists, but they do not use it. This is because of the lack of familiarity and training of individuals regarding the ISO 19650, adds the author. Another interviewee also says that is sometimes difficult to follow a BEP. This can also be a result of unusable or impractical BEPs in projects. Potentially, this is a problem linked to the fact that much information about various project aspects needs to be considered at the beginning of the project, which makes the preparation of a practical

BEP more difficult. There is also the case that decisions need to be made at the beginning of the project, although there is no available very project-specific information, adds another interviewee.

However, most interviewees agree that a BEP needs to be simple and as short as possible. On the contrary, when the project characteristics indicate the need to provide some “Whys” in the BEP, the documents become extensive. This contradiction was observed and might be solved by adding an explanation in the Appendices.

Another point raised by an interviewee is that it may not be worthwhile to spend time producing a BEP for a small project or that even when a BEP is necessary, there is insufficient time to prepare it.

To summarize, in addition to collecting detailed data for the thesis research, a diversity of opinions, recommendations, and concerns were collected during discussions with employees who served in a variety of project roles and had different levels of experience with the ISO 19650 series. Those opinions somehow capture the current state of the implementation of the BIM execution plans. Therefore, they can be used to find remedies to some issues and communicate the ISO 19650 process to the various project parties.

8. Conclusions and Recommendations

The conclusion chapters' purpose is to consolidate critical information about the research and its results. To achieve this, the thesis objective and the answers to the research questions are reminded to the reader. Then follows a description of the theoretical and practical contribution of this thesis as the author perceives it.

This thesis addresses a practical challenge on how an ISO standard document, namely the BIM execution plan (BEP) can be tailored to fit the requirements of a project. Having a "one size fits all" approach (Burgan & Burgan, 2014) can hamper the application of standards in projects and give the illusion that when a standard is applied then is automatically easier to achieve the project's goals. The main principle of this thesis research is to find a practical way to achieve a better application of the BEP in a project by tailor-making it to fit each time the needs of each project. Therefore, the thesis research targeted that direction: to find which PCs are the most important for the tailor-making of a BEP, how this can be achieved and finally, how a BEP author can practically benefit from this research.

8.1 Answering the research questions

One main research question and four sub-questions guided the research of this thesis. This section provides the answer to each, starting with the first research sub-question and ending with the main one.

"Which are the most important Project Characteristics (PCs) for the development of a BEP that fits the needs of a project?"
(R.SQ.1)

The research results which are presented in section 4.4.1 and were discussed in subchapter 7.1, concerned fifteen (15) project characteristics for tailoring a BEP. More specifically, these 15 PCs are the most important to consider when a BEP authors develops a BEP that fits the needs of a project.

Project characteristics related to the "clarity of the project and the client's needs", "the existence and use of ICT systems" and the "experience/capabilities of project's parties" emerged as the most important ones. The following table (Table 17) sums up again the list with the 15 most important PCs. A detailed list can be found in Table 7.

Table 17 - The 15 most important PCs for the development of BEP tailored to fit the project's needs

#	Project Characteristic
1	Clarity of project goal and objectives
2	Clarity of project scope
3	Commitment of project's parties
4	Clarity of requirements

5	Project's key staff capability and experience
6	Roles, Responsibilities and Ownership of data
7	Clarity of information production and exchange conditions
8	Experience, Capability and knowledge of project's parties about ISO 19650 and BIM Execution Plan (BEP)
9	The number of external project's parties
10	Clarity of the ICT systems' operation
11	Centralized communication system
12	Information risk-based management
13	Incompatibility between software inputs-outputs
14	Shared BIM model
15	Knowledge of who are the project's parties

"How can the most important PCs be correlated to the contents of the company's BEP template?"
(R.SQ.2)

Since it was found which project characteristics could be important for tailoring a BEP, the next question was how these PCs could be correlated to the contents of a BEP. For that reason, semi-structured interviews and practitioners were employed to help find this correlation. In other words, which each project characteristic influences BEP contents. The research results are presented in section 4.3.2, and the collection method is described in subchapter 3.4.

Table 10 on page 55 presents all the correlations between project characteristics and BEP contents.

"How can the extent of development categories of the BEP contents be defined?"
(R.SQ.3)

Until now, the previous two research sub-questions discussed the project characteristics that play a role in adjusting a BEP to fit the project's needs and their correlation with the BEP contents. Those findings made clear that the PCs affect the BEP chapters by influencing their extent of development, in other words, whether these should be more or less extensively written. Thus, there is a need to establish categories for the extent of development (e.o.d) of the BEP contents. In that way, the BEP author can have a more standardized indication on the e.o.d of the BEP chapters based on the characteristics of the project. Therefore, through structured interviews with interviewees experienced with the ISO 19650, the following extent of development categories for the BEP contents were defined.

Table 18 - The extent of development categories of the BEP contents

Category	Definition
Briefly	Develop BRIEFLY this (sub)chapter. That means: 1. address the content of this (sub)chapter but develop it with the bare minimum information, 2. appoint only the tools/processes that will be used in the project, assuming that readers would understand what to do, 3. assume that the contractual requirements are clear, and 4. assume that all the involved parties are familiar and have prior experience with the ISO 19650 & BEP.
Regular	Develop REGULAR this (sub)chapter. That means: 1. develop this (sub)chapter with some project-specific information and guidelines, 2. explain shortly why we do it (e.g. following a process/or using a tool) and how we use it (e.g. process or tool). An example for the desired extent of explanation is: "Work according to the Dutch grid coordination system to ensure that all the federation models are in the right place. For this scope will be used X (sub)tool, 3. add some additional explanation to have clear guidelines, and 4. assume that all the involved parties are relatively familiar and have some prior experience with the ISO 19650 & BEP.
Extensively	Develop EXTENSIVELY this (sub)chapter. That means: 1. develop this chapter with detailed project-specific information and clear guidelines, 2. explain why we do it (e.g. following a process/or using a tool), why is beneficial and how we use it (e.g. process or tool). An example for the desired extent of explanation is: "Work according to the Dutch grid coordination system to ensure that all the federation models are in the right place. In that way, time is saved, and errors can be avoided. For this scope will be used X (sub)tool.", and 3. assume that all the involved parties are not familiar have no prior experience with the ISO 19650 & BEP.

Section 4.4 presents the research results, which are the outcome of the method described in Section 3.5.

"How can the PCs, the BEP contents and the recommendations for their extent of development, be combined in a practical and user-friendly way?"

(R.SQ.4)

So far, up to the third research sub-question, valuable information has been collected for the BEP author. First, It was found which PCs are important for the tailor-making of a BEP. Next, how those PCs are correlated to the BEP contents, and lastly, this correlation was translated into the extent of development categories for the BEP contents. The subsequent question is how all this information package can be transferred to the BEP author to benefit practically. The answer was the decision support tool (DST), which utilizes the research's outcome. The DST user, namely the BEP author, can assess a project every time,

based on the 15 most important PCs, and receive a recommendation from the DST regarding the extent of development category of every BEP content.

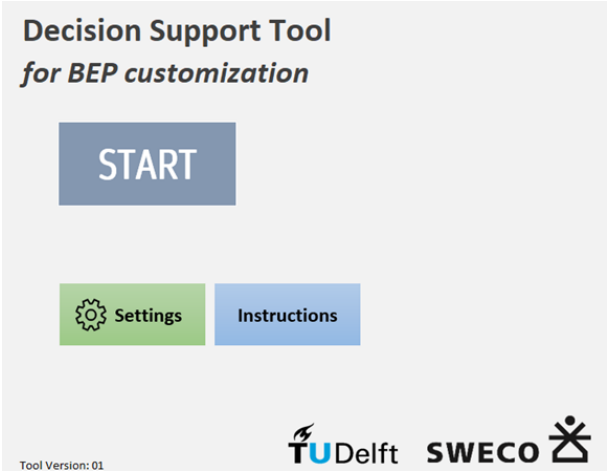


Figure 30 - The home screen of the Decision Support Tool (DST)

"How can the BIM Execution Plan (BEP) be tailored to fit the needs of a project based on predefined project characteristics?"
(Main R.Q)

The prior four research sub-questions are those that contribute to the answer to the main research question. A BIM execution plan can be tailored to fit the needs of a project if this project is assessed based on the predefined 15 project characteristics by the BEP author. This assessment is performed through the developed decision support tool (DST). This tool compiles all the research's outputs and recommends the extent of development of the BEP contents for a BEP that fits the project's needs.

8.2 Theoretical contribution

This subchapter discusses the theoretical contribution of the thesis. The proposed process for customizing a BEP to fit the project's needs is an overarching contribution to the theory. More specifically, the research combines literature research (LI.PCs) and practitioners experiences (EM.PCs) as a stepping stone to propose a process to customize a BIM execution plan based on project characteristics. This contribution is essential because the examined literature does not propose any methodical process from A to Z for tailoring a standard to fit the needs of a project.

The general logic of this "tailoring" process that is proposed by this thesis is:

1. Identify and decide on PCs relevant to the under examination standards, guide, method, etc.
2. Correlate the PCs with the contents/context of the under examination standard, guide, method
3. Decide how the PCs influence the under examination standard, guide, method, etc.
4. Assess a project based on the decided PCs
5. Obtain a recommendation based on the project's assessment regarding the tailoring of the under examination standard, guide or method, to fit the needs of a project

This comprehensive process is the thesis's initial and fundamental contribution to theory. The following figure illustrates this process.

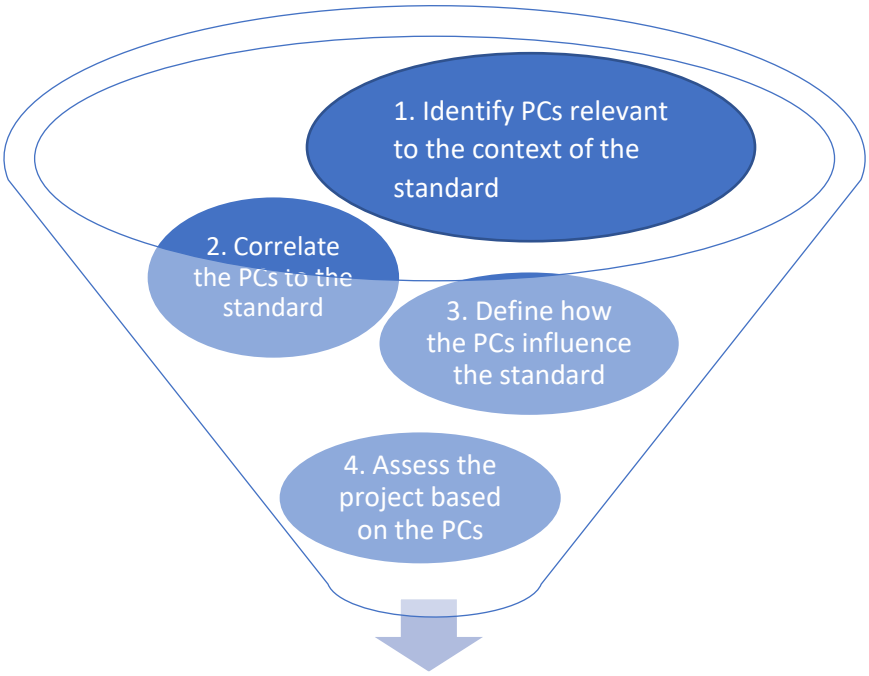


Figure 31: The "tailoring" process

Apart from the tailoring process, the thesis contributed to the theory in two other ways. At first, the thesis research proposes a list of project characteristics that can influence the customization of the BIM execution plan, BIM use, and use of the Information, Communication and Technology (ICT) systems in projects. Furthermore, this list of PCs contributes to the effective information production, management and exchange of information.

Secondly, this research does an extensive reference to ISO 19650 and BEP. Thus the thesis contributes to the literature as one additional source for this standard. It is worth noting that literature sources on standardization and construction are scarce (Peponi, 2019), while ISO 19650 is still under development.

8.3 Practical implication

Apart from the theoretical contribution of the thesis research, it is important to discuss its practical implication in the AEC industry and in Sweco. The practical implication of this thesis is the developed decision support tool. This tool practically captures the tailoring process and aims to support BEP authors to develop a BEP that fits the project's needs. Therefore, it is the practical implication of the thesis to the AEC industry in combating the pathogenesis of poor information management.

The sources used for the development of the decision support tool are not limited to sources by Sweco. Thus, it is expected to be more widely applicable to AEC firms tasked with preparing a BIM Execution Plan for a project.

Regarding Sweco, this process and the decision support tool can be practically and possibly immediately used to support its initiatives to develop a more content-wise and easy-to-read BEP. It will allow the company to find a balance between the standardization of the BEP using templates and the tailor-making of BEP as per the project's needs. The tool is expected to be used by BEP authors. The validation outcome underlined the usefulness of the tool. In addition, this tool can be linked and included in a tool for the better application of the ISO 19650 that is currently under development by Sweco. Finally, the tool can be utilized as a practical education method for less experienced and new BEP authors, assisting them in understanding the requirements of a project and adapting the BIM execution plan accordingly.

8.4 Recommendations

This section provides recommendations over the thesis topic for further development. Those could be utilized by academia and Sweco to gain inspiration for or to improve the standards tailoring process including the relevant created tool.

8.4.1 Recommendations for future research

The thesis was executed in a specific time range that forces the focus of the research to specific aspects of the under examination topic. However, the topic is broad, and there are aspects for future research.

To begin with, the ISO 19650 standard is suggested to examine the proposed tailoring process to other documents prescribed in it. One example would be applying this tailoring process to the Exchange Information Requirements (EIR). EIR is a fundamental document for that ISO and a prerequisite for developing an applicable and content-wise BIM Execution Plan (BEP).

This thesis focused on the tailoring of a specific BEP template. However, it is suggested to apply a tailoring process to a more conceptual level of the BEP to be more widely applicable.

In addition, a bigger list of project characteristics, complexity factors, success factors and others can be investigated by future authors. Those PCs can be later correlated to the BEP specifically or more generally to the context of information management.

A highlighted suggestion is to examine the relevancy of the European Norm EN 17412 for the level of information needed when using BIM. More specifically, it specifies the concepts and principles for defining the level of information need and information deliveries that are exchanged in an asset's life cycle when using building information modelling (BIM). The specification's objective is to prevent excessive information detail. On the contrary, it should be ensured that the right amount of information is exchanged for the agreed purposes (European Committee for Standardization, 2020). Therefore, one can understand that this norm presents interest and relevancy to the context of the present thesis. Thus, it is strongly recommended to be examined for further research and how it can help tailor a standard.

Lastly, the interviews indicated that occasionally a standard is not followed by project participants. However, all the interviewees agreed that following a standard, in this case, the BEP, can be beneficial. Therefore, it is recommended to examine factors and people's perceptions that hinder the actual application of standards in practice.

8.4.2 Recommendations for Sweco NL

The recommendations for the company are mainly related to the future development of the decision support tool, the tangible outcome of the thesis, and therefore of primary importance to Sweco NL.

A first recommendation concerns the development of different improved versions of the BEP templates. As aforementioned, the company's efforts are directed toward developing a concise, content-wise BEP. The author's recommendation is to keep a balance between the development of a universally applicable BEP template and its customization. As previously discussed in the research, one size does not fit all. Thus, the recommendation would be first to determine the primary contents of a BEP and then establish a procedure and continue developing the decision support tool to tailor it (the BEP).

The decision support tool needs to be tested in practice and based on the feedback of the tool's users, the list of project characteristics can be altered or enriched. This research provides a "pool" of many PCs (LI.PCs and EM.PCs) that can be utilized.

The third suggestion for Sweco NL is to examine the correlation of the PCs to BEP contents with a team of experts because for the thesis it has been used a Multi-Criteria Analysis method to decide this correlation.

As it is already recommended for future research, the company can examine the EN 17412 about the level of information needed when BIM is used and possibly relate it to its ISO 19650 processes.

In addition, concerning the DST, it is suggested to examine whether or not a RACI system can be incorporated into the tool. That means, depending on the experience of the BEP author and the tool's recommendation, other project participants might need to be informed, consulted, or advised. Besides, upgrading the tool into an online application could contribute to a more user-friendly approach while still serving as a formal corporation tool.

Lastly, the company can map the knowledge of the relevant Sweco NL employees about ISO 19650, the BEP, and their application to projects. In that way, the real internal level of knowledge can be monitored and take relative training informative actions to support the implementation of that ISO and the BEP.

8.5 Research Limitations

The research and the produced outcome need to be assessed for potential limitations, as those might restrict the validity of the research results and the extent that those can be generalized. The limitations are distinct into those associated with the research methodology and those associated with the decision support tool.

8.5.1 Research methods related limitations

Starting with collecting data for the research, the sample of the people who answered the questionnaire (n=13 respondents) and the semi-structured interviewees (n=15) limits the generalization and validity of the results concerning the project characteristics and their correlation to BEP contents. Furthermore, the small sample (n=3) examined during the structured interviews limits the generalization of the results about the extent of development categories of the BEP contents.

Additionally, all the questionnaire respondents and the interviewees are employees of the same company and mainly come from the water construction department. Thus, they might provide answers and perceptions based on maybe common experiences and stimuli and there is the risk to infer faulty research results. This challenges the applicability of the decision support tool and, consequently, the found project characteristics in construction projects in the AEC industry.

In addition, a Multi-Criteria Analysis (MCA) was executed twice and some minimum acceptance criteria were set to help make decisions on the research results (decide the 15 most important PCs and their correlation to the BEP contents). For these analyses, the criteria were set according to the best judgment of the author. That means the list with the most important PCs and their correlation to the BEP contents are subject to changes if the MCA criteria change. In addition, a potential limitation regarding the applicability of the decision support tool is that the BEP contents were extracted from the BEP template that Sweco Netherlands had developed and used.

Lastly, the tool was validated by a small sample (n=3) of experts, making the generalization of the results debatable.

8.5.2 Limitations related to the decision support tool

As described above, the research results used as input for the tool have some specific limitations. This might hamper the universal applicability of the tool in construction projects. For example, the PCs can sometimes not apply to a project or not be enough to capture the characteristics of a project and give safer results regarding the extent of development of the BEP contents.

The decision support tool is mainly applicable to the pre and post-tendering phase of a project when the BEP of the project is prepared. The decision support tool focuses mainly on the tendering and post-award phase of a project and assesses a project at this early phase. It can also be used as the project is in progress for reassessment and revision of the BEP. If a BEP is proved applicable and followed in a project, the project's parties get more familiarized with the BEP described processes. In that scenario, the decision support tool is no longer required for use because it has fulfilled its purpose. That means the tool's use is mainly limited until an efficient and practical BEP has been reached.

9. Reflection

This thesis is the last chapter of my student life and of my M.Sc in Construction Management and Engineering. My first degree in Civil Engineering equipped me with technical knowledge and a problem-solving approach. The master at TU Delft developed further this approach with a more fit-to-purpose logic. The execution of this thesis was challenging, mainly because little knowledge about the conduction of scientific research existed in advance. Another challenge was to balance the theoretical contribution and the practical output of the thesis. As a person, I am more curious about the "result" and the "how" instead of the "what" and "why". This mindset made even more complex the maintenance of a balance. Therefore, the existence of the graduation committee was significant for reminding me that the scope of thesis research is not to be a consultation report. To achieve that scope, the company supervisor was always supportive and helped stay focused on the final scope: the production of thesis research.

The field of digitalization and BIM interested me before the initiation of my thesis. In addition, I am always eager and motivated to find solutions to practical problems and contribute to process optimization. This challenge always excites me! This thesis offered me the opportunity to work on a practical problem and fulfil at the same time the requirements of my master for thesis research. Therefore, I feel grateful that this thesis succeeded in making a theoretical contribution by proposing a process to customize a BIM Execution Plan (BEP) and resulted in a functional decision support tool for the recommended customization BEP contents. The combination of scientific research with the production of a practical end product was efficiently achieved under the guidance of the whole committee.

The interviews were an exciting part of the thesis project, although they were held online. The interviewees presented interest in the thesis goal, and all of them were willing to help anytime and anyhow. That helped a lot to have a smooth interviewing process. In addition, the development of the decision support tool triggered my interest and upscaled my excitement and willingness to build a tool that will be functional and user friendly—one of the most favourite tasks in the thesis. Next, I was inquisitive about the validation of the proposed BEP customization process through the decision support. Positive results from the validation mean that the proposed process for the BEP customization is applicable and fulfil its goal. Three experts validated the tool, two from Sweco NL and one from Sweco Belgium. One of the essential validation results was that this tool could be immediately used to support BEP authors in developing a BEP. However, validating the tool with more experienced BEP authors is advised to attain even better insights. BEP authors from other organizations could also participate in a broader validation.

I examined many literature sources about project characteristics, standardization and standard's customization. However, none of these examined or proposed any method or process to customize a standard to fit the project's needs based on project characteristics. Therefore, I feel happy with my contribution on the topic of standards customization. Lastly, this thesis journey equipped me with knowledge on ISO 19650, helped me receive feedback, balance different interests, and stay focused on a goal.

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Appendix A: List with the 47 Literature's Project Characteristics (LI.PCs)

Questionnaire survey code	Project Characteristic	Definition	Theme
NT_01	Appropriate organization structure	Existence of appropriate organization structure for lead appointing party, (lead) appointed party(ies), task team members, with the right people in the right roles.	Non-grouped (no theme) project characteristics
NT_02	Availability of dedicated (client's) staff	The client (lead appointing party) has a project manager or staff dedicated to this specific project, solving questions and discussing arising problems.	Non-grouped (no theme) project characteristics
NT_03	Availability of resources	Availability of resources regarding the ICT systems (software and hardware)	Non-grouped (no theme) project characteristics
NT_04	Client's involvement during design and construction	The client (lead appointing party) has an active role during design and construction and exists a feedback exchange relation among the client and the rest parties during those phases.	Non-grouped (no theme) project characteristics
NT_05	Commitment of parties	The commitment of involved parties (lead appointing party, (lead) appointed party, task team members) and of the top management to follow processes, roles and undertake duties as described in the contract, ISO 19650 and/or BEP.	Non-grouped (no theme) project characteristics
NT_06	Complexity of faith: Uniqueness of the solution	The design proposes a unique solution, that has not been dealt with in the past and requires further attention.	Non-grouped (no theme) project characteristics
NT_07	Need for training	Need for the training of the: - design team - consultant's team members - appointed and appointing parties for the use of the ICT systems, ISO 19650 and the status, revision of information process.	Non-grouped (no theme) project characteristics

		** The need for training should be examined separately for each involved party*	
NT_08	Number of contractors involved in the project	Number of involved contractors in the project	Non-grouped (no theme) project characteristics
NT_09	Number of designers involved in the project	Number of involved designers in the project	Non-grouped (no theme) project characteristics
NT_10	Organizing skills of high staff (e.g. BIM Director, Information Manager)	The organizing and coordination skills of high staff, (e.g. BIM director, Information manager). By the term "skills" is meant the ability of the high staff to organize task teams, etc.	Non-grouped (no theme) project characteristics
NT_11	Understanding of roles and duties	The roles and responsibilities within the project are well defined and understood by the involved parties	Non-grouped (no theme) project characteristics
NT_12	Use of facilitator	Existence of a person who can help with the communication among parties, guide the project team in the integration process, align individual goals and project goals, eliminate the fear of conflict, get commitment from the different stakeholders, make each party accountable for their responsibilities, and have leadership skills.	Non-grouped (no theme) project characteristics
T1_01	Experience of the design team in past projects	Experience of the: - design team in a similar type of projects with the use of similar/same ICT systems and the use of ISO 19650.	T1: Experience / Capability of the involved parties
T1_02	Experience of the consultant's team in past projects	Experience of the: - consultant's team members in a similar type of projects with the use of similar/same ICT systems and the use of ISO 19650.	T1: Experience / Capability of the involved parties
T1_03	Experience of the contractor and/or subcontractor in past projects	Experience of the: - contractor in a similar type of projects with the use of similar/same ICT systems and the use of ISO 19650.	T1: Experience / Capability of the involved parties
T1_04	Experience of the client in past projects	Experience of the: - client in a similar type of projects with the use of similar/same ICT systems and the use of ISO 19650.	T1: Experience / Capability of the involved parties

T1_05	Key staff (e.g. BIM Director) capability / experience	The capability and experience of key staff of the appointed party. As key staff are meant the Information Manager, BIM Director and BIM Coordinator.	T1: Experience / Capability of the involved parties
T2_01	Clarity of the ICT system operation	The clarity of the ICT systems operation that will be used for all the involved parties (lead appointing party, (lead) appointed party(ies)) and task team members.	T2: Use of ICT systems
T2_02	Different versions of software adopted by different parties	The use of different versions of ICT systems by different parties (lead appointing party, (lead) appointed party(ies)). The use of different ICT versions increases the probability of incompatibility between them.	T2: Use of ICT systems
T2_03	Effective IT department	Availability for this specific project of an ICT department able to resolve errors in ICT systems when they occur	T2: Use of ICT systems
T2_04	ICT use mandated in the contract	The use of all the ICT used in the project is mandated in the contract.	T2: Use of ICT systems
T2_05	Information production and exchange conditions are clarified sufficiently	It is sufficiently and clearly described how the information is produced and exchanged among team members.	T2: Use of ICT systems
T2_06	IT system's capacity for information exchange	Capacity in terms of files' size and speed of the ICT systems for information exchange	T2: Use of ICT systems
T2_07	Knowledge of used ICT	Team members that produce, check and approve the information, possess the required technological (ICT) skill that will enable them to complete their work by themselves.	T2: Use of ICT systems

T2_08	Minimum capabilities of ICT systems	Potential ICT systems' minimum capabilities and constraints to perform the required work (for example, constraints for BIM softwares can be their BIM uses).	T2: Use of ICT systems
T2_09	Use of customized ICT systems	The use of customized ICT systems (e.g. customized by the appointing party or appointed party) specifically for a project.	T2: Use of ICT systems
T2_10	Perceived ease of use of a system	The degree to which a person believes that using a particular ICT system would be free of effort	T2: Use of ICT systems
T2_11	Perceived usefulness of a system	The degree to which a person believes that using a particular ICT system would enhance his/her job performance.	T2: Use of ICT systems
T2_12	Remote accessibility of ICT systems	The capability to access remotely the ICT systems, for example at the construction site.	T2: Use of ICT systems
T2_13	Shared BIM model	The use of one BIM model that has the input of all team members is clearly understood for the involved parties and members.	T2: Use of ICT systems
T2_14	Use of electronic data exchange system	The use of one electronic data (information) exchange system/platform in the project, in which all of the involved and relevant parties and members have access.	T2: Use of ICT systems
T3_01	Change in the communication system	Probability of future change in communication system/platform that is used in the project.	T3: Communication among the involved parties
T3_02	Communication effectiveness within clients	Existence of an effective communication relationship between clients (lead appointing parties), without unresolved conflicts. (*In case that there are more than one client*)	T3: Communication among the involved parties
T3_03	Communication effectiveness within contractors	Existence of an effective communication relationship between contractors, without unresolved conflicts. (*In case that there are more than one contractor*)	T3: Communication among the involved parties
T3_04	Communication effectiveness within designers	Existence of an effective communication relationship between designers, without unresolved conflicts. (*In case that there are more than one designing firm*)	T3: Communication among the involved parties
T3_05	Communication in team	Maintaining open and direct lines of communication between all project participants at all times, with no restrictions.	T3: Communication among the involved parties

T3_06	Information updating frequency	The way and the frequency that the information will be updated, is clarified and planned.	T3: Communication among the involved parties
T3_07	Degree of matrixing (way of exchanging information)	In a project organization with a high degree of matrixing, members tend to adopt informal methods of information exchange. Conversely, in a project organization with a low degree of matrixing, members often adopt official methods of information exchange.	T3: Communication among the involved parties
T4_01	Clarity of requirements	Appointing party's requirements and specifically, the EIR are clear and sufficient for the development of the BEP.	T4: Project's information and documents
T4_02	Clear project goal and objectives	Project goals and objectives are clearly defined in the tender documents, can be easily stated in the BEP, and the stakeholders (e.g. appointed parties, team members) are informed about.	T4: Project's information and documents
T4_03	Clear project scope	Project scope is clearly defined in the tender documents, can be easily stated in the BEP, and the stakeholders (e.g. appointed parties, team members) are informed about it.	T4: Project's information and documents
T4_04	The extent to which tender documents allow additions to the scope	The extent to which tender documents allow future additions/changes to the scope.	T4: Project's information and documents
T4_05	Design complete before tendering	Percentage of completed design before tendering	T4: Project's information and documents
T4_06	Design complete at construction start	Percentage of completed design at construction start	T4: Project's information and documents
T4_07	Information completeness	Design data and documents are clear, complete, provide sufficient information and are adequate for the preparation of the BEP.	T4: Project's information and documents
T4_08	Delays / mistakes in design	Delays or mistakes in design documents.	T4: Project's information and documents
T4_09	Design changes	Design changes that usually occur due to changes in requirements.	T4: Project's information and documents

Appendix B: Questionnaire structure

The questionnaire consists of fifty-one (51) questions:

- three (3) questions about the respondent,
- forty-seven (47) for Literature's Project Characteristics (LI.PCs), and
- one (1) about any suggestion for Empirical Project Characteristics by the respondent

10.1 Questions about the respondent

1. **What is closer to your role regarding the BIM Execution Plans (BEP) ?** *

   ☐ BEP User

   ☐ BEP Author (Developer)

2. **What is your level of familairty with BIM Execution Plans ?** *

	Not Familiar (1)	Slightly Familiar (2)	Moderately Familiar (3)	Familiar (4)	Very Familiar (5)
Level of familiarity:	○	○	○	○	○

3. **How many different BIM Execution Plans have you used and/or developed ?** *

   ○ 1

   ○ 2

   ○ 3

   ○ Other

10.2 Evaluation of the LI.PCs

Forty-seven LI.PCs were evaluated. Those were provided to the respondents in four themes as is described in Chapter 2. The full list with the 47 literature's project characteristics (LI.PCs) is provided in Appendix A.

The respondent is asked to evaluate each characteristic with the following question.

	Not Important (1)	Slightly Important (2)	Moderately Important (3)	Important (4)	Very Important (5)	Characteristic is not clear
How important is it to consider this characteristic when preparing a BEP?	○	○	○	○	○	○

10.3 Suggestion for empirical project characteristics

The last question in the questionnaire asks the respondent if he/she has to add any other characteristic.

51. **Are there any other project characteristics that would you like to add? (If not, type N in the asnwer field)** *

Enter your answer

10.4 Demographics

Figure 32 - Questionnaire response rate

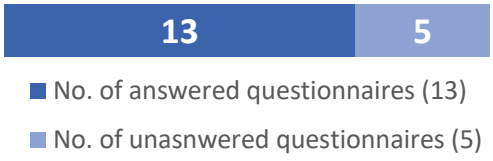


Figure 33 - BEP role of respondents

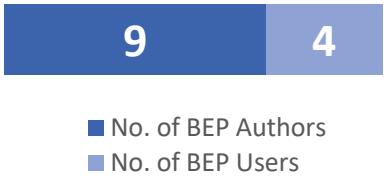


Figure 34 -

Respondent's familiarity with ISO 19650

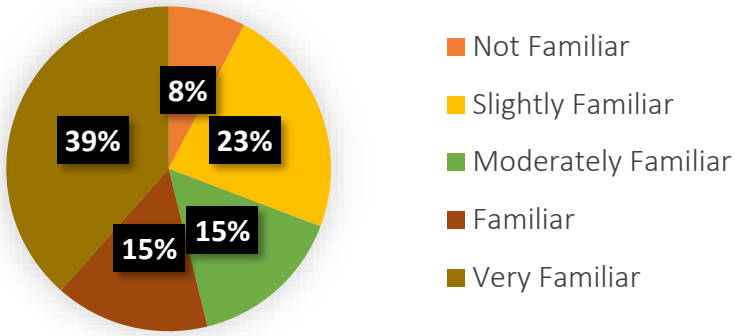
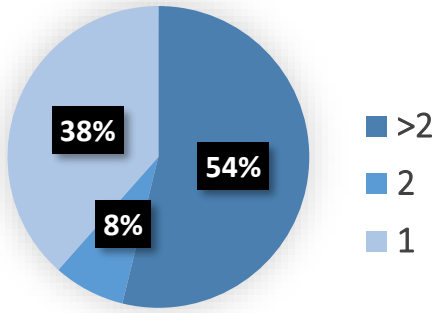


Figure 35 -

Number of BEPs that have been used/developed in different projects



Appendix C: Semi-structured interviews' structure

Table 19 presents the interview steps and explains the aim of each step, the result, and the mean used to facilitate the interview.

Table 19 - Semi-structured interviews: Detailed explanation of the interview steps, their aim, and the result

Step	**Aim**	**Action / Question**	**Result**	**Mean (MS Powerpoint, Conceptboard)**
1	Get to know each other.	Get to know each other slide	Get to know each other.	PPT
2	Provide introductory information about the thesis.	Playing of the introductory video	The interviewee is introduced to the thesis topic, goal and is aware of his/her contribution.	Video in PPT
3	Collect info about the interviewee and his role in projects.	Question 1: *What is your most usual role in projects?*	The most usual role of the interviewee in projects is recorded.	PPT
4	To understand the experience that has with the BEP.	Question 2: *Did you ever participate in the preparation of the BEP for the project?*	An overview of the experience that has the interviewee with the preparation process of a BEP.	PPT
5	To record the perspective that the interviewee "sees" a BEP.	Question 3: *What is closer to your role? BEP user or BEP author?*	The perspective of the interviewee regarding the BEP.	PPT
6	To record the level of familiarity of the interviewee with the BEP.	Question 4: *What is your level of familiarity with BEPs?* *From 1. Not familiar with 5. Very familiar*	The level of familiarity is recorded.	PPT
7	Record the challenges that arise in the preparation of the BEP, and later use them as an inspiration for the interviewee to brainstorm empirical project characteristics.	Question 5: *What do you consider as the top-3 major challenges regarding the preparation of the BEP for waterbouw projects?*	Challenges for the preparation of a BEP are recorded.	PPT
8	Put the interviewee in the "shoes" of a BEP author that can find any information he/she needs for the preparation of the BEP. This step facilitates without any constrain the brainstorming of empirical project characteristics relevant to the BEP preparation process.	A hypothesis is provided to the interviewee: "*Assume that,* *… you are assigned with the BEP preparation for a waterbouw project and later you need to work according to it,* *… you can have beforehand any information available about the project, its characteristics and the involved parties*"	Interviewee acquires a BEP author's perspective	PPT

9	Facilitate the brainstorming of the interviewee about project characteristics that are important to consider for the BEP preparation.	A question for discussion is provided: "*What would you like to know about …* *… the other involved parties?* *… Sweco?* *… the ICT systems that will be used?* *… other characteristics of the project?"*	Empirical Project Characteristics	PPT
10	-	Empirical project characteristics are transferred to the online concept board as sticky notes. Already pre-exist on the board the top-15 literature's project characteristics as sticky notes.	-	Conceptboard
11	Sorting of both the LI.PCs and the EM.PCs	Interviewee sorts the LI.PCs and EM.PCs in the following matrix. 	Sorted LI.PCs and EM.PCs. For the next step are kept the "Very important" and "Extremely important" project characteristics	Conceptboard
12	Correlate the sorted project characteristics to the BEP contents	The BEP contents pre-exist on the board. Interviewee correlates the "Very important" and "Extremely important" project characteristics to the BEP contents	Correlated project characteristics to the BEP contents	Conceptboard
13	Discussion on the extent of development categories of the BEP contents	Interviewees were asked to propose the number, titles for these categories and phrases that should be included in the description of each e.o.d category.	Recommended number and titles for the e.o.d categories. Phrases that should be included in the e.o.d categories were also collected.	Conceptboard

Demographics

Figure 36 -
BEP role of respondents

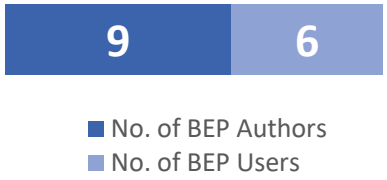


Figure 37 -
Respondent's familiarity with ISO 19650

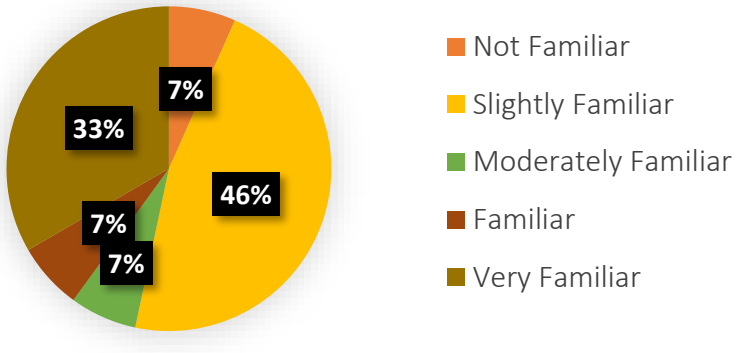
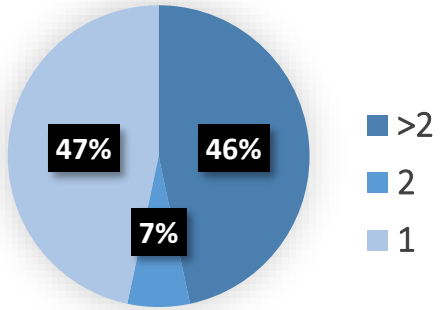


Figure 38 -
Number of BEPs that have been used/developed in different projects



Appendix D: Structured interviews' structure

Table 20 presents the interview steps and explains the aim of each step, the result, and the mean used to facilitate the interview.

Table 20 - Structured interviews: Detailed explanation of the interview steps, their aim, and the result

Step	**Aim**	**Action / Question**	**Result**	**Mean (MS Powerpoint, Conceptboard)**
1	Understand how the decision support tool will work and look like	Presentation of the tool's logic and example of its operation	Familiarize interviewee with the tool	Conceptboard
2	Collect recommendations on the number of the e.o.d categories.	Question 1: *How many e.o.d categories should exist?*	A recommendation on the number of the e.o.d categories (2 or 3)	Conceptboard
3	Collect recommendations on the title of the e.o.d categories.	Question 2: *What should be the title (name) for each of the e.o.d categories?*	A recommendation on the title of each e.o.d category	Conceptboard
4	Collect recommendations on the description of each e.o.d category.	Question 3: *What should be the phrases to include in the description of each of the e.o.d categories?*	A recommendation on the description of each e.o.d category	Conceptboard
5	Collect recommendations on where any additional explanation should be placed	Question 4: *Where should the additional explanation of the more extensive categories be placed?*	A recommendation on where any additional explanation should be placed (main BEP or Appendices)	Conceptboard
6	Collect recommendations on when any additional explanation should be placed in the main BEP document	Question 5: *When should the additional explanation of the more extensive categories be placed in the main BEP document?*	A recommendation on when any additional explanation should be placed in the main BEP document	Conceptboard
7	Collect recommendations on when a more extreme e.o.d category prevails	Question 6: *When a more extensive e.o.d category prevails?*	A recommendation on when a more extreme e.o.d category prevails	Conceptboard

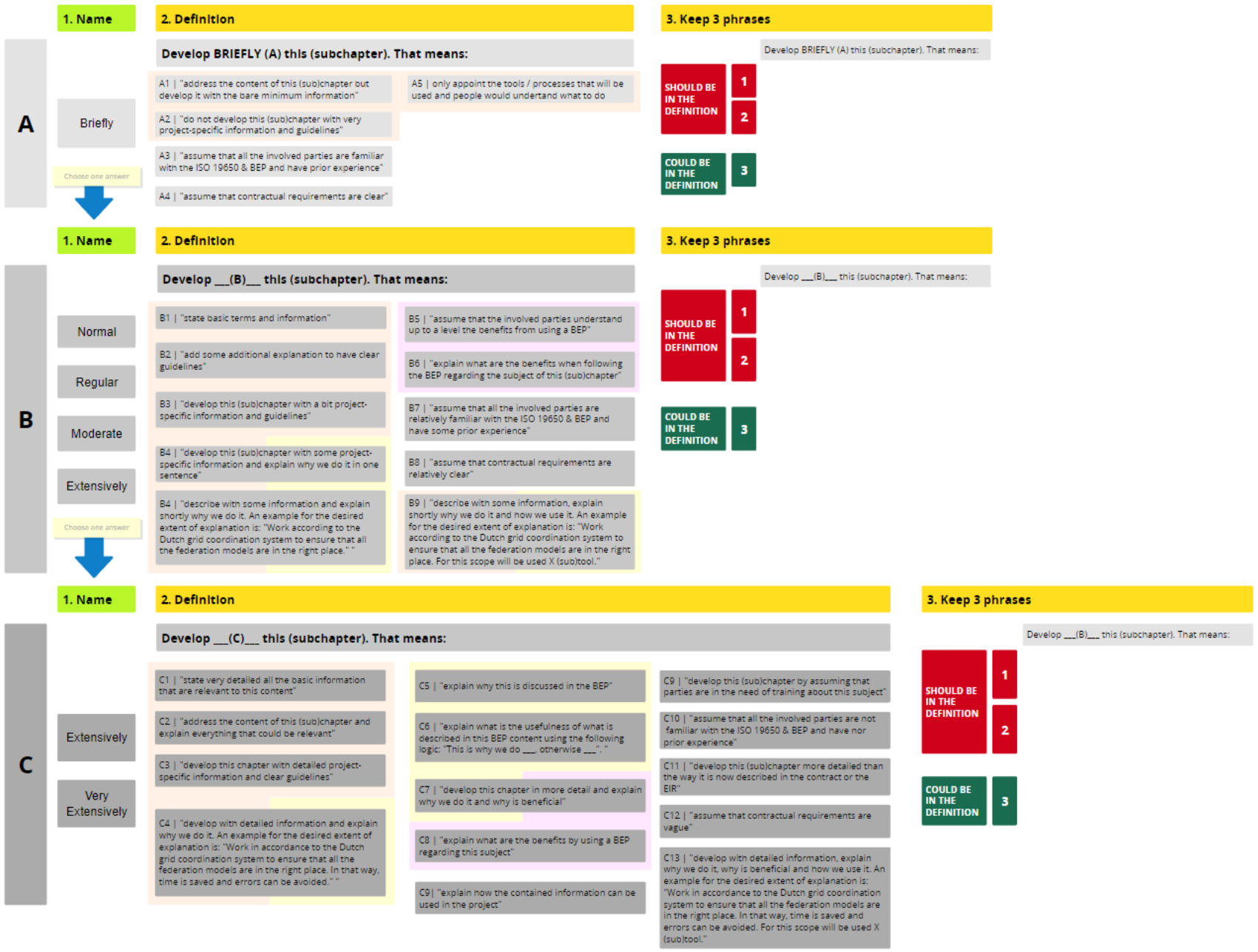


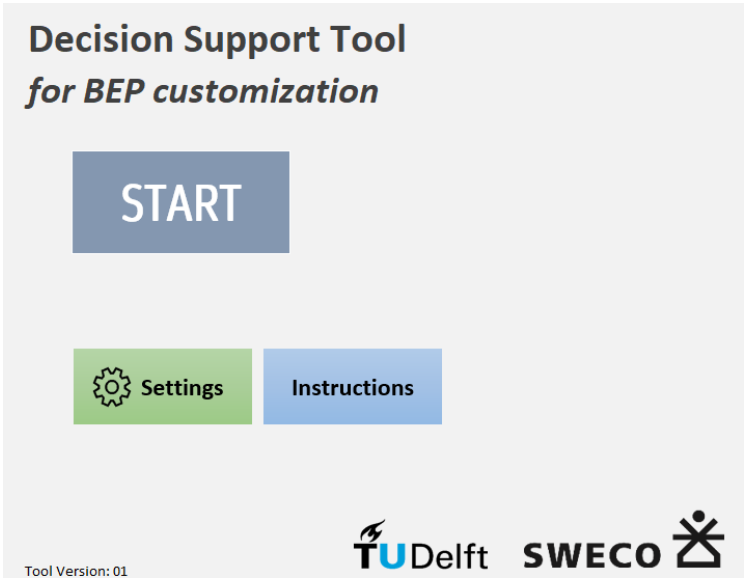
Figure 39 - The decision board on the phrases that should be in the definition of each extent of development category

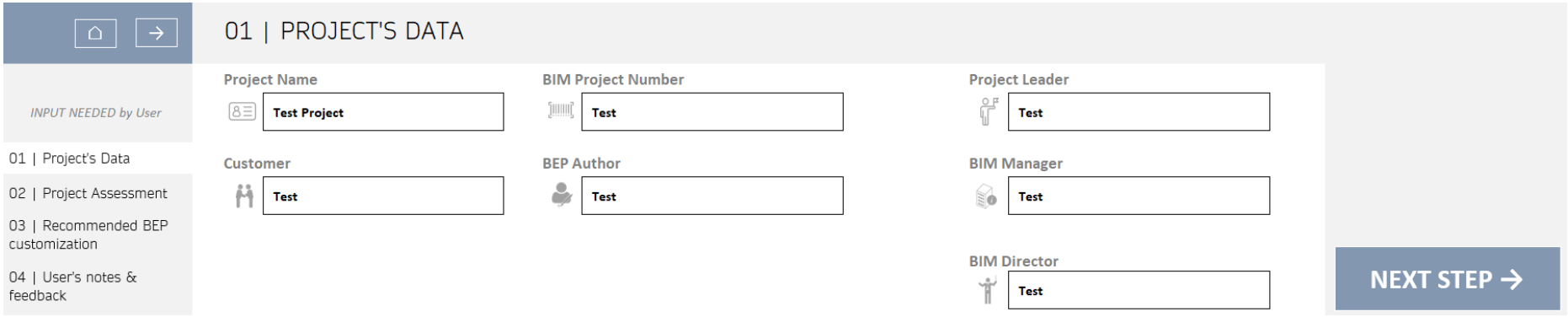
Appendix E: The contents of the BEP template

This content is confidential.

Appendix F: The Decision Support Tool

This section presents the decision support tool's main windows (screens). The tool's user navigates in the tool through the following windows. The following tool's windows concern a random assessment of a hypothetical project to get an example of the tool's recommendation about the BEP customization.





02 | PROJECT ASSESSMENT

Project: Test Project

INPUT NEEDED by User

01 | Project's Data

02 | Project Assessment

03 | Recommended BEP customization

04 | User's notes & feedback

	Project Characteristic (PC)	Description	Applicable PC?	Scoring Scale 1	2	3	Project's Score (1-3)
1	Centralized communication system	With this characteristic is assessed whether or not is used in the project a centralized communication system (CCS). That means the communication (emails, phone calls, online meetings, etc.) happens in one place: a centralized communication platform-system.	Yes	Communication is not centralized	Communication is partly centralized	Communication is completely centralized	1
2	Clarity of information production and exchange conditions	With this characteristic is assessed whether or not it is sufficiently and clearly defined how the information is produced and exchanged among projcet's parties and team members.	Yes	Not clearly defined	Relatively clearly defined	Clearly defined	2
3	Clarity of project goal and objectives	The degree to which project goal and objectives: • are clearly defined in the tender documents, • can be easily transferred and captured in the BEP, and • are understood and agreed by the project's parties. As project's parties are meant: the lead appointing party, the (lead) appointed parties (i.e. client, consultants, designers, contractors, subcontractors).	Yes	• Not clearly defined goal and objectives, and/or • not easy to capture in the BEP, and/or • most of the project's parties do not understand and agree on them	• Relatively clearly defined goal and objectives, and/or • moderately easy to capture in the BEP, and/or • some project's parties understand and agree on them	• Clearly defined goal and objectives, and/or • easy to capture in the BEP, and/or • most of the project's parties understand and agree on them	3
4	Clarity of project scope	The degree to which project scope: • is clearly defined in the tender documents, • can be easily transferred and captured in the BEP, and • is shared and understood by the project's parties. As project's parties are meant: the lead appointing party, the (lead) appointed parties (i.e.client, consultants, designers, contractors, subcontractors).	Yes	• Not clearly defined scope and/or • not easy to capture in the BEP and/or • not shared and understood by most of the projcet's parties	• Relatively clearly defined scope and/or • moderately easy to capture in the BEP and/or • shared and understood by some projcet's parties	• Clearly defined scope and/or • easy to capture in the BEP and/or • shared and understood by most of the projcet's parties	2
5	Clarity of requirements	The degree to which the appointing party's (client) requirements and specifically the EIR (Exchange Information Requirements) are clear and sufficient enough for the development of the BEP.	Yes	Not clear requirements	Relatively clear requirements	Clear requirements	2
6	Clarity of the ICT systems' operation	The degree to which the operation of the project's ICT systems is clear to all of the project's parties and task team members. As project's parties are meant: the lead appointing party, the (lead) appointed parties (i.e. client, consultants, designers, contractors, subcontractors). As task team members are meant the internal teams of the different parties that work on project's tasks.	Yes	The operation of the ICT systems is not clear	The operation of the ICT systems is relatively clear	The operation of the ICT systems is clear	2
7	Commitment of project's parties	The degree to which project's parties and the top management are committed to follow processes, roles and undertake duties as described in the contract, ISO 19650 and/or BEP. As project's parties are meant: the lead appointing party, the (lead) appointed parties (i.e. client, consultants, designers, contractors, subcontractors). As top management is meant for example, team managers, project	Yes	Not committed parties and top management	Relatively committed parties and top management	Fully committed parties and top management	3
8	Experience, Capability and knowledge of project's parties about ISO 19650 and BIM Execution Plan (BEP)	With this characteristic is assessed the project's parties': • past experience and knowledge about ISO 19650 and the BEP • capability to deliver their work in accordance to the BEP	Yes	Not capable project's parties or without prior experience & knowledge	Relatively capable project's parties with some prior experience & knowledge	Capable project's parties with prior experience & knowledge	3
9	Incompatibility between software inputs-outputs	This characteristic assesses the degree to which are used in the project different software that lurk the risk of incompatibility between their inputs and outputs.	Yes	In the project are used different software that lurk a high risk of incompatibility	In the project are used different software that lurk a medium-low risk of incompatibility	In the project are used different software that do not lurk any risk of incompatibility	2
10	Information risk-based management	This characteristic assesses whether or not the information management is risk-based. That means, whether or not the information management related risks are assessed and monitored frequently. For example, risks can be related to people's knowledge level about the use of project's ICT systems, or the existence of many different of stakeholders, etc.	Yes	Information management is not risk-based	Information management is partly risk-based but risks are not assessed and monitored frequently	Information management is risk-based and the risks are frequently assessed and monitored	1
11	Knowledge on who are the project's parties	The degree to which is known: • who are the project's parties, their departments and teams, and • with which parts of the scope they are working on. Having this knowledge facilitates the coordination of the parties.	Yes	Not known	Partly known	Known	1

12	Project's key staff capability and experience	With this characteristic is measured the capability and experience of the project's key staff regarding the ISO 19650 and BEP (BIM Execution Plan). As key staff are meant the Information Manager, BIM Director and BIM Coordinator.	Yes	Not capable key staff or without prior experience	Relatively capable key staff with some prior experience	Capable key staff with prior experience	2
13	Roles, Responsibilities and Ownership of data	The degree to which: a) the roles and responsibilities and b) the ownership of data and models are known and clear to all the project's parties. Ownership is related to the roles and responsibilities of parties and refers to the production of data, models and documents.	Yes	Not known and not clear to most of the project's parties	Relatively known and clear to some of the project's parties	Known and clear to most of the project's parties	3
14	Shared BIM model	With this characteristic is assessed whether or not is used a shared BIM model type in the project for the same purpose, in which have access, use and provide input all the task team members. As BIM model types are meant the models that serve different purposes, for example the Architectural BIM model, the Structural BIM model, etc. As task team members are meant the internal teams of the different parties that work on project's tasks.	Yes	It is not used only one shared BIM model for the most of the different model types (purposes)	It is used only one shared BIM model for the majority of the different model types (purposes)	It is used only one shared BIM model for all of the different model types (purposes)	2
15	The number of external project's parties	With this characteristic is measured the number of externals (apart from Sweco) project's parties. The bigger the number is, the higher the chance for complexity it is. As project's parties are meant for example: designers, consultants, contractors and subcontractors.	Yes	The number of the external project's parties is: $n \leq 3$	The number of the external project's parties is: $4 \leq n \leq 6$	The number of the external project's parties is: $n > 6$	1

Return to the top

03 | RECOMMENDED CUSTOMIZATION FOR THE BEP CONTENTS

Project: Test Project

SAVE as PDF
the BEP recommendation

Category	Definition	Color codes
Briefly	Develop BRIEFLY this (sub)chapter. That means: 1. address the content of this (sub)chapter but develop it with the bare minimum information, 2. appoint only the tools / processes that will be used in the project assuming that readers would undertand what to do, 3. assume that the contractual requirements are clear, and 4. assume that all the involved parties are familiar and have prior experience with the ISO 19650 & BEP.	Briefly
Regular	Develop REGULAR this (sub)chapter. That means: 1. develop this (sub)chapter with some project-specific information and guidelines, 2. explain shortly why we do it (e.g. following a process/or using a tool) and how we use it (e.g. process or tool). An example for the desired extent of explanation is: "Work according to the Dutch grid coordination system to ensure that all the federation models are in the right place. For this scope will be used X (sub)tool, 3. add some additional explanation to have clear guidelines, and 4. assume that all the involved parties are relatively familiar and have some prior experience with the ISO 19650 & BEP.	Regular
Extensively	Develop EXTENSIVELY this (sub)chapter. That means: 1. develop this chapter with detailed project-specific information and clear guidelines, 2. explain why we do it (e.g. following a process/or using a tool), why is beneficial and how we use it (e.g. process or tool). An example for the desired extent of explanation is: "Work in accordance to the Dutch grid coordination system to ensure that all the federation models are in the right place. In that way, time is saved and errors can be avoided. For this scope will be used X (sub)tool.", and 3. assume that all the involved parties are not familiar have no prior experience with the ISO 19650 & BEP.	Extensively

BEP Chapter		Recommended Extent of Development	Color indicator	Recommended location for the additional explanation for categories Regular and Extensively ?
SUM	**Summary**	Briefly		Main BEP document
1	**Preface**	Not influenced by any PC		
2	**Project Information**			
2.1	Project Details	Extensively		Appendices
2.2	Project Description	Extensively		Main BEP document
2.3	Contactual Milestones	Extensively		Appendices
2.4	Strategic BIM objectives	Extensively		Main BEP document
3	**Roles, Responsibilities and Authorities**	Regular		Main BEP document
4	**Project Team Capability**			
4.1	Delivery Team Capability & Capacity Assessment Crit	Regular		Main BEP document
4.2	Training Requirements	Regular		Main BEP document
4.3	Project BIM uses	Regular		Main BEP document

05 | NOTES AND USER's FEEDBACK

Project: Test Project

SAVE as PDF
the user's notes & feedback

5.1 | NOTES / RECOMMENDATIONS ABOUT THE PROJECT

5.2 | ARE THERE PROJECT CHARACTERISTICS THAT NEED TO BE FURTHER CONSIDERED IN THE PROJECT?

◯ Yes ◉ No

If yes, choose from the list those project characteristics		*Notes*
Consider:		
and		
and		
and		
and		
and		
and		

5.3 | IS THERE SOMETHING TO IMPROVE IN THIS TOOL,

Regarding the list with the list of project characteristics?

Check any applicable options

- ☐ Yes, the list should include more PCs
- ☐ Yes, some PCs should be replaced
- ☐ Yes, I will specify in the following text box
- ☐ No

If yes, please specify in the following text box

Regarding the tool's recommendations for the BEP contents?

Check any applicable options

- ☐ Yes, some recommendations are not logical
- ☐ No

If yes, please specify in the following text box

For more information about the decision support tool, the reader of this thesis can contact the thesis author by email. The email is given on the 3rd page.