PRIORITIZATION ISO 19650-1&2 CERTIFICATION

What knowledge line group do we start with?

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Preface

With pride, I can hereby welcome you to my bachelor thesis 'Prioritization of ISO 19650-1&2 certification at Movares'. For most readers, ISO 19650-1&2 will be an unfamiliar subject. It considers information management at the delivery phase of a project. At the beginning of my thesis, it was unfamiliar to me as well. Throughout the project it appeared that ISO 19650-1&2 is a sometimes challenging, but also a very interesting norm and topic for this thesis.

As the goal is to map the prioritization of certification to ISO 19650-1&2 for the knowledge line groups of Movares, it largely involved production of yet unknown knowledge. I chose to continue with this project as it provided lots of learning opportunities. Firstly, I was curious to see how information management takes shape in a large company like Movares. Next to that, it matched with my interest into digitalization of the construction market. Finally, the chance to gain relevant knowledge by interviewing appealed to me a lot, as I never did something alike before.

Without the support and participation of several people, the report would not have been close to its final result. Firstly, major thanks to Ron Rijkers, my supervisor at Movares. I will not forget our first meeting, where I responded to a vacancy for a more technically focused assignment on building information modeling. Here, Ron listened closely to my preferences and came up with a substantially more suitable project. Thereafter, he always provided valuable input and contributed greatly to the success of my thesis.

Furthermore, Hans Voordijk, my internal supervisor from the UT, has also proven to be indispensable. Especially in the beginning, he made me confident about the project, and supported greatly to the scientific basis of the assignment. During the project he provided the right amount of freedom and support where needed. For me it was always very useful and fun to collaborate. So thanks a lot Hans!

As a last word of thanks, I would like to address all people involved in the interviews. Their willingness to talk about the information management uses and needs for their knowledge line groups supported greatly to the outcome of the analysis.

Finally, I hope this report brings over my enthusiasm, and is informative and entertaining to read for you.

Jip Scheper,

Utrecht, 17th June 2022

Key words

Abstract

Digital technologies have risen awareness in the construction market over the past decades. More specifically, Building Information Management enables close stake holder participation in a shared online environment, increasing efficiency and client satisfaction. For Movares, it is essential to keep up with the market and obtain certification for ISO 19650-1&2, the norms around Building Information Management in the delivery phase of project.

However, it is yet unknown how this certification can be achieved within the knowledge line groups of Movares. Therefore, this bachelor thesis provides a recommendation for prioritization on ISO 19650-1&2 certification for the knowledge line groups of Movares. Each of the knowledge line group are involved in design and advice and focus on one more specific discipline. By performing one in depth interview at each knowledge line group, the current and desired situation of compliance to ISO 19650-1&2 can be mapped. This interview will contain statements in line with the content of ISO 19650-1&2 which are rated by the respondents on a Likert scale.

Thereafter, the relevance of the norm can be found by comparing the current and the desired state, and the effort needed to obtain compliance can be found as well. These results can be compared between the knowledge line groups. Finally, a total score will be computed to find the prioritization of ISO 19650-1&2 certification at Movares including the relevance of ISO 19650-1&2 and the effort of becoming certified.

As a result, it can be concluded that the prioritization of knowledge line groups focusing on design is the highest. For them, working in accordance with ISO 19650-1&2 will result in a better efficiency and a higher client satisfaction. Furthermore, miscommunications and risks considering timely delivery can be avoided.

Next to that, even the knowledge line groups focusing on provision of advice benefit from information management as it can improve collaboration. Also, it was learnt that the knowledge line groups working on security installations and safe infrastructure already have useful information processes in place. However, the knowledge line groups in the line Digital transformation and IT show that certification is not directly relevant but understanding of the norms is crucial to facilitate supportive software for the other groups at Movares according to the respondents.

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1. Introduction

In this first chapter, the context of the bachelor thesis assignment will be presented, followed up by the current problem and its relevance. Thereafter, the related literature is introduced as well as the scope and focus. Finally, the research objective and the research questions are discussed, along with the outline of the methodology.

1.1. Context

Construction is known as a field in which many technologies come together. Most projects require an interdisciplinary approach to achieve the best outcome for all stakeholders. Digitalization could facilitate an efficient way of coping with the needs of all parties.

In particular, building information modelling, BIM from here onwards, shows a great example of such a tool. BIM represent a new paradigm in the construction and engineering field, which encourages stakeholder participation. (Azhar, 2011) This is achieved by the integrated digital environment accessible to all participants, where information can be inserted, extracted, and used for decision making. (Z. Wu et al, 2019)

At Movares, found in Utrecht, BIM has also risen awareness and is currently used in multiple projects. To keep up with the market, they have need for certification on the ISO 19650-1&2 norms. These norms consider BIM during the delivery phase of the assets. ISO 19650-1 lines out the concepts and principles, while ISO 19650-2 specifies the requirements.

1.2. Problem and relevance

In a changing business environment, where digitalization is playing a significant role, Movares needs to stay up to date on the available information technologies and laws around them. More specifically, without the certification of ISO 19650-1&2, parts of Movares business operations might be endangered. Namely, it could be that Movares starts losing tenders if they do not keep up with the innovation pace of the market.

Mostly, there are still opportunities for complete implementation of BIM. By implementation of BIM, process efficiency and design quality can be improved. Certification on ISO 19650-1&2 will prove Movares is proficient at BIM Design & Construction. Furthermore, there can be less miscommunications, more efficient cost estimating and better possibilities for automated assembly. (Azhar, 2011) Finally, the costs and time needed for a project can decrease as a result.

The problem lies within short come in knowledge on how the ISO 19650-1&2 certification can be rolled out within the various knowledge producing groups of Movares. This bachelor thesis will contribute towards the plans for organisational wide certification for ISO 19650-1&2, as advice on the prioritization will be provided.

1.3. Related literature

The ISO norm itself is particularly useful for shaping the content of the analysis. ISO 19650-1&2 will be briefly introduced below and are further detailed in Chapter 2.1. Aside, it can be helpful to look at how the certification for ISO 19650-1&2 can be obtained, which is introduced as well.

1.3.1. ISO 19650

The international ISO 19650 norms are the norms for information management in the lifecycle of objects using BIM. In Table 1, the five sections of the ISO 19650 norms are displayed, detailing their topic and release date. The ISO 19650 norms have not been completely released yet. Namely, ISO 19650-4 is still to be approved. (ISO, 2022) In the end, only the certification for ISO 19650-1&2 falls within the scope of the bachelor thesis.

Table 1 ISO 19650 Norms, based on ISO (2022)

Norm	Title	Release yea
ISO 19650-1	Concepts and principles	2018
ISO 19650-2	Delivery phase of the assets	2018
ISO 19650-3	Operational phase of the assets	2020
ISO 19650-4	Information exchange	Not yet
ISO 19650-5	Security-minded approach to information management	2020

The ISO 19650 norms cannot be brought into place without the surrounding normative documents. Within the asset information cycle, there are three additional governing norms which should be considered, as illustrated in Figure 1. Namely, the ISO 55000 and 21500 detail on asset and project management, respectively. Additionally, there is ISO 9001 on organizational management

Figure 1 Project and asset information life cycle (ISO, 2019)

1.3.2. BSI certification

In the Netherlands, companies can obtain certification for one or more sections of ISO 19650 by the British Standard Institution, BSI. Consultation of the website of BSI, provides the overview of possibilities as detailed below. (BSI, sd) There is a distinction between several levels of certification, which can each be certificated by verification or kitemark. Verification will grant a company's services to fulfill the acknowledged norms for quality, safety, performance, and reliability. Kitemark certification adds that this fulfillment is shown in a successfully completed project.

Kitemark certification can be obtained for compliance with ISO 19650-1&2, to prove proficiency in BIM Design & Construction. Movares is aiming at obtaining this kitemark certification. Additionally, companies can obtain kitemark certification for compliance with ISO 19650-3, to prove proficiency in BIM Asset management, for BS 8542(1/6), to prove proficiency in BIM Objects and, lastly, for compliance with ISO 19650-1,2,3&5 to prove proficiency at BIM Level 2.

1.4. Scope and focus

In Figure 2, a simplified version of Movares' organisation structure can be found, only including the knowledge line groups. Within Movares there are four knowledge lines. These are subdivided into three to four knowledge line groups each. This part of the company focuses on knowledge generation for clients, like making designs or giving advice. In the end, it is strived to form a prioritisation for certification of 19650-1&2 per knowledge line group, so each group is to be analysed separately.

Knowledge Line	Digital transformation & IT	Environment & Processes	Industrial automation & Energy	Buildings & Infrastructure
	Digital Advise	Systems & Processes	Security installations	Integral building desing
Departments	Software development	Contract & Building management	Safe infrastructure	Civil engineering structures
	IT management	Mobility & Space	Energy	Railway engineering
		Environment & Conditioning		Cable infrastructure & Geotechnics

Figure 2 Overview knowledge lines and groups Movares (freely translated, based on Organogram Movares, 2022)

1.5. Research objective

As the problem description pointed out, Movares is interested in the certification into the ISO 19650-1&2 norms. The bachelor thesis will aim to contribute to this goal. First, a practice-oriented GAP analysis is conducted to map the differences between the desired and the current situation of ISO 19650-1&2 compliance. Then, a recommendation on prioritization between the knowledge line groups will be made, based on the results of this GAP analysis. Therefore, the research objective is:

'To make recommendation on the prioritization of ISO 19650-1&2 certification at the knowledge focussed business units of Movares, by analysing the gap between the desired and current situation.'

1.6. Research questions

Now that the scope and the research objective are clear, the research questions can be posed as detailed below.

1. What is the desired state of ISO 19650-1&2 compliance at Movares?

   1.1. Which specific requirements are put forward by ISO 19650-1&2?

   1.2. What importance have the requirements of ISO 19650-1&2 got at the knowledge business units of Movares?

   1.3. What are the critical success and risk factors towards achieving compliance with ISO 19650-1&2?

   1.4. What procedure does BSI use for the certification of ISO 19650-1&2?

2. What is the current state of ISO 19650-1&2 compliance at Movares?

   2.1. How close to compliance with ISO 19650-1&2 are the knowledge business units within Movares?

   2.2. Which points of improvement should be made in the integral building design department for achievement of ISO 19650-1&2 certification?

3. What do we learn by comparing the results from the analysis of the desired and current state of ISO 19650-1&2 compliance?

   3.1. How large is the gap between the desired and the current state of ISO 19650-1&2 compliance at the knowledge business units of Movares?

   3.2. What prioritization of ISO 19650-1&2 certification between knowledge business units of Movares would be recommended?

1.7. Methodology outline

Finding the answers to the research questions will be achieved by a combination of methods. First, available literature will be analysed. This will contribute to a better understanding of the exact scope by analysis of the ISO norms, but also to the broader context of the research by looking at critical risk and success factors for BIM implementation.

The knowledge production will be realised by conducting structured interviews, which will be further detailed in Chapter 3. When the data collection is completed, the results will be analysed and a prioritization of certification for ISO 19650-1&2 will be provided for the knowledge line groups. To establish if the results are accurate, verification will be applied by comparison of the results from the knowledge line group *Integral Building Design* to additional interviews and results from a GAP audit. Summarizing the way of working in a framework provides the overview depicted in Figure 3.
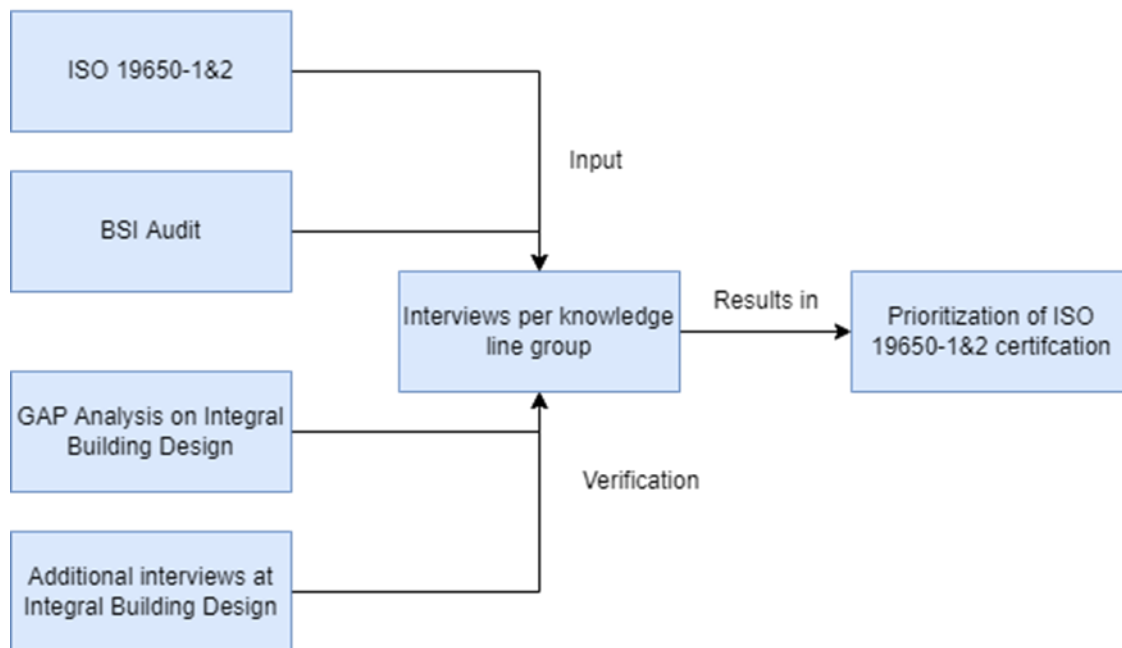
Figure 3 Research framework

1.8. Knowledge production

Mapping the gap between the current and desired compliance with ISO 19650-1&2 is essential for coming towards a prioritization of ISO 19650-1&2 certification for the knowledge line groups as it will disclose the relevance and effort of compliance. The knowledge production is therefore focused at providing such an overview for the knowledge line groups at Movares. Furthermore, the method of prioritization and the results aim at providing interesting insights for the company, which can be used in decision making by management of Movares.

2. Literature review

Before the interviews can be set up, a literature review has been performed. Within this review, ISO 19650-1&2 will be studied, as well as the critical success and risk factors for BIM. These topics answer sub questions 1.1. and 1.3, respectively.

2.1. ISO 19650-1&2

As the ISO 19650-1&2 form the content of the interview, they have been carefully studied. ISO 19650-1 introduces the main concepts and principles. Additionally, ISO 19650-2 specifies the delivery phase of the assets. Finally, the core concepts and normative rules are used for forming the statements which are to be used in the interview, further specified in Chapter 3.3.

2.2. Critical success and risk factors of BIM implementation

By certification on ISO 19650-1&2, it is proven that the certified body is competent with BIM in the delivery phase of construction projects. However, accomplishment of this state of BIM requires people, processes, and technology to be in line with its body of ideas. To obtain relevant insights in what factors affect the successful certification of ISO 19650-1&2, the critical risk and success factors of BIM implementation will be analyzed. It has been selected to use expert survey studies mostly, as the interviews will also rely on the respondents' reactions.

2.2.1. Critical success factors

Numerous studies have covered the success factors for BIM implementation. In Table 2, the results of three of these studies can be found. For each study the authors, year of publication, and number of factors considered are detailed. On the lower half, the ten most critical success factors are ranked from most to least important.

Table 2 Critical success factors BIM implementation

Title	Critical Success Factors for BIM Implementat Construction Projects	Critical Success Factors for Building Information Mo Implementation	Critical Success Factors for BIM implemen for power plant projects in Malaysia
Authors	A.M. Darwish et al.	G. Amuda-Yusuf	M.A. Aziz et al.
Year	2020	2018	2022
Method	Expert survey	Expert surveys	Expert survey
# Factors	51	28	13
Rank	Success factor		
1	Coordination between all project parties	Standard platform for integration & communication	Management commitment
2	Training and development	Cost of development	Availability software
3	Awareness level for BIM of the industry	Education and training	Central software system for information housing
4	BIM functions and features	Standardization (product & process)	Comprehensive client requirements
5	Collaboration between all stakeholders	Clear definition and understanding of users' requirements	Change of mindset and awareness for BIM
6	Perceived benefits from BIM to client	Stakeholders involvement	Adequate education and training
7	Availability of competencies and experiences	Communication of BIM objectives	Clear business plan, vision and mission
8	Establishment of a model of good practice for BIM	Appropriate hardware technology	Stable and fast internet
9	Availability of qualified staff	Evolutionary Development i.e. step by step implementation	Appropriate hardware
10	Make all the BIM programs work on an open source	End-user involvement	Systematic project approach

Table 2 shows results from the three considered show similarities, but also show distinctions. As A.M. Darwish et al. detail, the success factors are mostly considering collaboration, awareness, and training & availability of qualified staff. Thus, the social context and the education are found important. (A.M. Darwish, M. M. Tantawy and E. Elbeltagi, 2020)

Next to that, G. Amuda-Yusuf concludes that the use of a clear standard and client requirements are of large importance to the success of BIM implementation, focusing more on the processes. (G. Amuda-Yusuf, 2018)

Lastly, M.A. Aziz et al. agree on the importance of the client requirements, adequate training and standard project approach and software system. (M. A. Aziz, C. F. Wong, N. A. Haron, A. H. Ales, R. A. Azmeer, R. A. Effendi and O. K. Tan, 2022) Additionally, they underline the importance of supportive technology, including availability of software, internet, and hardware.

2.2.2. Critical risk factors

Following a similar approach the critical risk factors will be mapped by comparison of three studies. These studies have been detailed in Table 3.

Table 3 Critical risk factors BIM Implementation

Title	Critical risk factors for implementing BIM: a Delphi-based survey	Identifying and assessing critical risk factors for BIM projects: Empirical s	Challenges with BIM Implementation: A Review of Literature
Authors	R. Khoshfetrat et al.	K.-F. Chien et al.	A. Criminale and S. Langar
Year	2020	2014	2017
Method	Expert survey (three round Delphi study)	Expert survey	Literature review
# Factors	36	13	36
Rank	Critical risk factors		
1	Lack of knowledge and need for soft ware training	Lack of available skilled personnel	Time needed for hiring/training people to use BIM
2	Including the new process and how to use BIM	Inefficient data interoperability	Cost of hiring or training people to use BIM
3	Project phasing and design separation	Lack of software compatibility	No official standard or process to evaluate the use of BIM
4	Monitoring and execution of the construction process	Model management difficulties	Copyright protection for ownership of data
5	Inefficiency in data and information exchanges	Project experience inadequate	Determining who owns data/ components used
6	Lack of unique program for BIM use	Rise in short-term costs	Reference to legal or contract issues
7	Managers' lack of knowledge of the technology	Workflow transition difficulties	Who is responsible for/ manages data entry
8	Lack of knowledge of BIM potentials	Additional expenditure	Cost of hardware
9	Lack of consistent attitude among managers	Unclear legal liability	Compatibility issues between Software
10	Resistance to change	Management process change difficulties	Who is responsible for inaccuracies and errors

R. Khoshfetrat et al. perform an expert opinion study using the Delphi technique to find the risk factors for BIM implementation. (R. Khoshfetrat, H. Sarvari, D. W. M. Chan and M. Rakhsanifar, 2020) The most critical risks include the need for software training, project phasing and inefficiencies in data exchanges. Thereby, it is shown that risks can be found on a wide variety of aspects involved in BIM implementation.

Mostly, K.-F. Chien et al. find similar critical risk factors to R. Khoshfetrat et al., using their ranking based on risk impact and probability. (K. F. Chein, Z. H. Wu, S. C. Huang, 2014) Additionally, they identify the rise in short term costs and the risk of unclear legal liability as further risks to BIM implementation.

Using another approach, A. Criminale and S. Langer identified the critical risk factors by a literature study. (A. Criminale and S. Langar, 2017) The most named risk factors in the considered literature are placed at the highest rank. In accordance with R. Khoshfetrat et al. and K. Cheng et al., the need for training, difficulties in data exchange and liability issues were identified as critical risk factors. Additionally, the lack of official standard for BIM evaluation has been identified as a critical risk.

3. Methodology

The goal is to recommend on the prioritization of ISO 19650-1&2 at the knowledge line groups of Movares, but it is not yet clear how this can be achieved. This chapter will detail the choice of methodology and the generated data output, answering research question 1.4 and setting up the framework to answer questions 1.2, 2.1. and 3.

3.1. Required knowledge

First, it is relevant to determine what knowledge is needed to contribute towards the research objective. To find the prioritization, it is strived to find what the current and desired state of compliance with ISO 19650-1&2 are per knowledge line group. Therefore, a rather in-depth empirical analysis should be used, which ideally collects accurate qualitative data. In line with these demands, the most suitable method will be chosen between surveying and interviewing in the next section.

3.2. Method selection

Surveys could provide a broad view on the current and strived state of compliance within a knowledge line group. Also, outliers can be identified, and more quantitative analysis would be possible. However, as the topic of the interview is rather in depth and might be hard to fill out without pre-knowledge, the chances of receiving accurate and complete output are estimated low.

Therefore, it is chosen to conduct 14 interviews with individuals based on a strategic sample of one respondent per knowledge line group selected in coordination with Ron Rijkers, BIM Manager at Movares. The respondents have been selected based on their experience and familiarity to BIM.

It is strived to obtain the current and desired state of ISO 19650-1&2 compliance, by interviewing only one member of each knowledge line group. Consequently, this choice limits the quantitative analysis possibilities of the data per knowledge line group. Limitations of this choice include vital importance of interviewee selection and large risks in personal bias, which will be further elaborated in Chapter 7.

It has already been determined that there will be one interview per knowledge line group. However, it is to be selected if the interviews will be unstructured, semi structured, or structured. Mostly, unstructured interviews are used when dealing with unknown or sensitive topics, where structured interviews allow for better comparison of results and assurance of objectivity. Therefore, it is chosen to perform structured interviews.

3.3. Interview content

As the interview is aimed at finding the current and strived state of compliance with ISO 19650-1&2, the norms will form a bases for its content. In research question 1.1. the requirements put forward by ISO 19650-1&2 have been detailed using a desk top literature research, focusing on the norms itself.

Aside from that, question 1.3. could prove helpful in forming expectations to the current situation and improvement points using a literature review. This would not serve as direct input but can help in determining what the focus of the interviews should be.

Moreover, the answer on research question 1.4. on the structure BSI uses in their audits, serves as input to the structure of the interview. A GAP analysis at the knowledge line group 'Integral Building Design' performed by BSI is attended on the 12th of April 2022. As a result, the structure of the GAP analysis is used to determine the structure of the topics of the interview.

The familiarity to ISO 19650-1&2 can differ between participants. Therefore, the interview starts with an informative section on the context. Here the relevance of the norm, project roles, project phases and the setup of the interview are discussed. In this way, it is strived to make up for these differences in pre-knowledge. Further ahead in the interview, the information models and requirements and the document statuses have been explained.

Finally, the structure of the interview can be found in Table 4 and Table 5. In total, 50 statements are depicted which will be brought up to the respondents. The content of the interview is aimed at covering the content of the ISO 19650-1&2.

Table 4 Interview statements 0 until 22 with explanation

#	Interview setup
	In this interview, several statements will be brought up for rating. To test if the setup of the interview is clear to you, first a test statement is shown.
0.	The setup of the interview is completely clear to me.
	Here explanation will be added to the statement, if that is applicable. At this statement, it is asked if the setup of the interview is clear to you. You can only select one answer for the current state, and one for the desired state.
	Invitation to tender
	At the invitation to tender, the client acknowledges their need for an order, after which companies can send in an response. At the invitation to tender, there is already some requirements on information delivery and management from the client, which will be further discussed in the ten statements in this section.
1.	The appointing party provides their information exchange requirements at the invitation to tender.
	These information exchange requirements consider organisation, asset and project information. For example, think of level of information need and the details in models.
2.	The appointing party clearly indicates the information standards at the invitation to tender.
	These information standards detail in what way the information is to be delivered, like the formats and manner of delivery.
3.	The appointing party provides possible required methods and procedures for information production at the invitation to tender.
	May it be that there are required methods or procedures for information production, this could already be established at the invitation to tender.
4.	The appointing party delivers good acceptance criteria for information requirements at the invitation to tender.
	When a information delivery is approved, it is to be tested against pre-accomplished requirements which are detailed by the appointing party. These requirements are to be provided at the invitation to tender, where there is accounted for possible standards and methods.
5.	The appointing party clearly indicated the milestones around information delivery are in the invitation to tender.
	The milestones for information delivery of the appointed party by the appointing party are to be provided at the tender invitation, where decision points, further obligations and the content of the to be delivered information are accounted for.
6.	The appointing party appoints someone responsible for the project information management at the invitation to tender.
	Before the invitation to tender, the appointing party needs to appoint someone for management of information which is important for the strategical goals of themselves.
7.	The appointing party accomplishes the reference-information and shared information resources at the invitation to tender.
	There is an indication of what documents are to be shared by the appointing party during the project. This could for example be policy document, models or maps.
8.	The appointing party establishes their Common Data Environment at the invitation to tender.
	To support the information production, the appointing party sets out in what digital environment they will be working during the project. Here, it is also considered what programs will be used.
9.	The appointing party details the information protocol at the invitation to tender.
	Within the information protocol it is detailed what the specific obligations of all parties are with regard to information production. Responsibilities, property rights, use of current asset information and shared resources and reuse of information after the project are set out.
10.	The appointing party provides requirements to the tender responds of companies at the invitation to tender. Possible concrete requirements for the tender reaction for companies need to be set out. Here it can be specified what the demands on the BIM execution plan, the competences and capacity of the delivery team, the mobilisation plan and the riskmanagement are.
	Tender response
	After the invitation to tender has been received, interested parties can send in an quotation. Here information questions of the lead appointing party are to be answered, which will be discussed in the 12 upcoming statements.
11.	Within my team a person is nominated to fulfill the information management function at the tender response
	The prospective lead appointed party has should appoint someone who is responsible for the effective management of information.
12.	My team at Movares formulates a plan for the fulfillment of the information exchange requirements of the client at the tender response.
	Concretely, this states that the prospective lead appointed party shall establish the delivery team's pre-appointed BIM execution plan, including feedback provision, for example.
13.	My team at Movares provides goals for the production of information by collaboration at the tender response.
	According to the norms, these goals are to be set per project, where for example the streams of information can be mapped.
14.	My team at Movares delivers an overview of the organization structure and commercial relationships at the tender response.
	The prospective lead appointing party needs to provide this information to the appointing party in the tender response.
15.	My team at Movares reveals the proposed federation strategy to be adopted by the delivery team at the tender response. *A federation strategy is a plan for the division of information pieces of a project, such that all involved parties have access to the appropriate resources. For example, this could be set up in a cloud service.*
16.	My team at Movares establishes the responsibility matrix at the tender response. *An responsibility matrix provides an overview of the responsibilities per specific project part, which is also linked to the milestones. For example, RACI could be used here, were the roles are categorized under responsible, accountable, consulted and informed.*
17.	My team at Movares controls the information standard of the tender invitation and proposes changes if that is necessary at the tender response.
	The client delivers the information standards, where the requirements, methods and procedures are detailed. However, it could be that adjustments could be needed, for example for the exchange of information to third parties.
18.	My team at Movares details a plan for the use of software, hardware and IT-infrastructure at the tender response.
	Even the version of the software that is to be used needs to be specified according to ISO.
19.	response.
	Here, it is been assessed whether the capacity and capability to deliver according to the information exchange requirements and the pre-appointment BIM execution plan.
20.	My complete team of Movares assess their capability and capacity to deliver the information in accordance with the plans at the tender response.
	The prospective lead appointed party combines the separate assessments of capability and capacity and checks if the total capacity is proficient to assure all agreements can be met for completement of the project in the tender response.
21.	My team within Movares establishes the mobilization plan at the tender response.
	The mobilization plan specifies prospective lead appointed party's plan for the delivery teams mobilization. This ncludes all preparations for information production, like testing the methods, software, hardware and IT, but also possible education or recruitment along with the time reserved for these preparations.
22.	My teams has a risk register at the tender response.
	The prospective lead appointing party establishes the delivery team's risk register, in which risks in relation to the timely information delivery are listed along with the plans for management of these risks.

Table 5 Interview statements 23 until 50 with explanation

	Appointment
	After the tender has been won, and the order is now to be executed by Movares, several further preparations need to be conducted. These will be dealt with in this section.
23.	Movares confirms the BIM execution plan after appointment.
	After appointment, the lead appointed party confirms all the agreements set out so far in accordance with each appointed party. Within the BIM execution plan, the information delivery strategy, responsibility matrix, production methods and schedule of software, hardware and IT are covered.
24.	Movares further details the responsibility matrix after appointment.
	Where the lead appointing party first only detailed the responsibilities per party, it is now added what the milestones, information exchanges, methods, and dependencies are.
25.	Movares details the information exchange requirements per appointed party after appointment.
	Within the information exchange requirements, the requirements from the client are extended with demands from the lead appointed party. Furthermore, de acceptance criteria, data and supportive information are established. This takes place per appointed party, which could be a part of a knowledge line group, but also an external party.
26.	Each task team establishes an plan for the information delivery after appointment.
	Here it is defined who is delivering what information at what level of detail, also it is considered what deadline is attached to it.
27.	Movares combines the information delivery plans into a master plan for information delivery after appointment.
	The lead appointed party makes a complete plan for the information delivery to the client, keeping in mind the separate plan per task team.
28.	The appointing party makes a clear appointment document for Movares.
	In this document, the agreements so far are detailed. The exchange information requirements, information standards, information protocol, BIM execution plan and master information delivery plan are included.
29.	Movares makes a clear appointment document for the other appointed parties.
	In this document, the agreements so far are detailed. The exchange information requirements, information standards, information protocol, BIM execution plan and task information delivery plan are included.
30.	Different perspectives, for example from other involved parties and the client, are taken into account proficiently.
	Different information management perspectives should be taken into account at the specification of requirement, planning of the delivery and the delivery itself.
	Mobilization
	After completion of the further preparatory steps, the preparations can be executed, which is named mobilization.
31.	Movares mobilizes all means in accordance with the mobilization plan before the start of information production.
	Here, the lead appointed party makes sure that all tasks teams are available to start working and possible trainings or education are performed.
32.	Movares mobilizes before the start of the information the information technology as specified in the mobilization plan.
	The lead appointing party makes sure the software, hardware and IT is available and working.
33.	Movares test the project's information production methods and procedures.
	The lead appointing party makes sure the way of working is tested, also the information containers accessibility should be tested.
	Information requirements and models
	Within the information production, there are several information parts which have to be produced. Here, some processes are set up to guide efficient information production.
34.	Movares develops requirements based on the high level strategical purposes of the client.
	These strategical purposes consider information for asset management, so it details what information is needed for execution and administration from a management perspective.
35.	Within my department we make a clear division between the requirements of the AIM and the PIM.
	Within a project, the AIM (Asset Information Model) which details information on the to be produced information, say a 3D model, to be separated from the PIM (Project Information Model) where all project specific information can be found.
36.	Within my department, setting up the requirements is done in accordance with the life cycle of the asset.
	Plans for development of asset information (what fits the interest of the client) needs to match its purpose of use and lifecycle.
37.	Movares provides an information exchange requirement per delivery moment based on the requirements from the AIM and the PIM.
	Per information delivery, the information exchange requirements should be kept in mind. These detail who produces what information, what level of detail is used and when it is to be delivered.
	Information production
	In the meanwhile, the information production can be started. This section will consider the process which come along with that.
38.	Each task team controls their access to the CDE (Common Data Environment) and the reference information before starting the information production.
	Per group it is controlled if they have acces to the shared documents using the bespoken software.
39.	Each task team produces information according to the plans.
	Per tasks team the information production of information should be performed as agreed with the information exchange requirements, in accordance to the shared documents and within the CDE (Common Data Environment).
40.	Each task team assesses their work on the information standards of the project.
	Before the documents can be assessed on their content, it should be checked if they fit the information standards (for example format).
41.	Each task team assesses their work based on the content.
	Here the information exchange requirements are taken into account, as well as the level of information need and the information required for other task teams.
42.	Movares assesses the complete information model.
	When the parts of the task teams are combined, Movares controls the result based on the information exchange requirements from the client and the master plan of information delivery.
	Document status
	Within the information production, strict procedures are prescribed for the use of document statuses, which will be detailed step by step in this section.
43.	Within my group, items which are being produced are clearly labeled as 'Work In Progress'.
	When an item is in this state, it is only visible by the other members of the task team.
44.	Documents which are controlled by the task team based on standard and content, are put forward for further assessment and marked as 'Shared'.
	When a document is under 'Shared', all members of the project team have access to it.
45.	When an information container only contains 'Shared' documents, it is checked on the requirements for coordination, completeness and accuracy. When sufficient, it is shared with the client and marked as 'Published'.
	Only when all information has been approved by some others in the project team, it can be shared with the client and labeled as published.
	Information delivery
	Now that the sections from the task teams have been combined, it can be delivered to the client.
46.	Each task team delivers its information for approval within the CDE (Common Data Environment).
	So all task teams work within the CDE and their information parts are ready.
47.	Movares assess the information model.
	Now that all the information is delivered by the task teams and merged, an extra assessment should be carried out by the lead appointed party. Here the information delivery masterplan, information exchange requirements of the client and the assessment criteria and level of information need.
48.	The client assesses the information model.
	The client checks the delivered information, where the information delivery masterplan, information exchange requirements of the client and the assesment criteria and level of information need.
	Project close-out
	When the client is satisfied with the delivered information, the project is ready to be closed out.
49.	The client archives all information containers.
50.	The client registers all the points of improvement in a knowledge storage facility.

3.4. Statement assessment

To make the qualitative data more comparable, it would be helpful to attach numerical values to the answers of the interviewees. Therefore, it is chosen to use rating of statements on a Likert scale.

Likert scales are used to map the numerical rating of an opinion towards a statement enabling interval measurements. A five step Likert scale ranging from 'Strongly disagree' to 'Strongly agree' is used. To make the output of the interviews easily comparable the ratings on Likert scale are then converted to numerical values, as detailed in Table 6.

Table 6 Conversion table Likert scale to numerical

Likert scale	Numerical value
Strongly disagree	-2
Disagree	-1
Neutral	0
Agree	1
Strongly agree	2

An example of this method is depicted in Figure 4, where the respondents were requested to rate the statement for the current and desired situation. The interviewer fills in the answers. Also, there is the possibility to make annotations for each statement.

1. The appointing party provides their information exchange requirements at the invitation to tender. *

These information exchange requirements consider organisation, asset and project information. For example, think of the level of information need and the level of details in models.

	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1.1. Current situation	○	○	○	○	○
1.2. Desired situation	○	○	○	○	○

Explanation statement 1

Voer uw antwoord in

Figure 4 Example - interview statement No 1

Using this format, the 50 statements will be rated. The set up of the interview has been evaluated by external interview pilot candidates without pre-knowledge and found easily understandable.

3.5. Data collection

Conducting the interviews took place from the 10th of May to the 7th of June of 2022. In total, 50 statements have been brought up to each interviewee. In Table 7, the discussed topics and the number of statements are shown. These topics cover ISO 19650-1&2 and show more statements in the early project phases. This is chosen as making agreements for information management early in the project is most beneficial according to Movares' BIM vision.

Table 7 Amount of statements per topic

Subject	# statement
Invitation to tender	10
Tender response	12
Appointment	8
Mobilization	3
Information requirements and models	4
Information production	5
Document status	3
Information delivery	3
Project close-out	2
Total	50

3.6. Output

Finally, the results of all filled out statements have been collected per knowledge line group. An example of the results for the knowledge line group *Cable Infrastructure & Geotechnics* can be found in Table 8, where the answers on the statements on the topic *Invitation to tender* are depicted. This knowledge line group has been selected as example as it shows logical outcomes, but also one statement in red. The interviewee was not able to answer statement six, so it has been marked in red and is disregarded for the computation of averages.

Table 8 Section of the results of the knowledge line group Cable Infrastructure & Geotechnics

Phase	Statement No.	Current	Desired	Difference
Invitation to tender	1.	0	1	1
	2.	-1	1	2
	3.	-1	-1	0
	4.	-1	2	3
	5.	1	2	1
	6.			
	7.	1	1	0
	8.	-2	1	3
	9.	-1	1	2
	10.	-1	1	2

3.7. Exception Knowledge Line Digital Transformation & IT

For the most knowledge line groups, the method could be followed. However, this does not apply for the knowledge line groups in the knowledge line Digital Transformation & IT. During the interviews, it appeared that the used interview setup was not suitable.

Namely, it appeared that within this knowledge line, most project group are working on internal projects aiming at facilitation of software and IT services. Projects are executed using the scaled agile framework and SCRUM teams working in Microsoft Tools. This process will not be further detailed, but shows a more adaptive process, which does not fit with the structure of the interviews. Furthermore, the interviewees were not acquainted with the topics and shared the thought that the interview would not bring any added value.

Therefore, the choice was made to instead perform one unstructured interview in each of the knowledge line groups. For Digital Advice, Software Development, and IT Management, it was verified that although certification of groups in this knowledge line is not directly relevant, knowledge of the content of ISO 19650-1&2 is required. The knowledge on the topics is required as it is to be integrated in the development of software.

4. Results

The collected data can be used to proceed towards the research objective. Namely, the output from the interviews can be further analyzed to find the relevance of ISO 19650-1&2 certification, and make an estimate of the effort needed obtain the certification. As detailed in Chapter 0, the method for interviewing the knowledge line Digital Transformation & IT has been changed. Therefore, these knowledge line groups will not be included in the ranking.

First the relevance of certification and effort to compliance with ISO 19650-1&2 will be computed per knowledge line group answering research question 1.2, 2.1, and 3.1. Finally, a combined ranking will be proposed answering research question 3.2.

4.1. Relevance of certification

Per knowledge line group, it is interesting to see what the relevance of the content of ISO 19650-1&2 is. By comparing the current and desired state of compliance to the interview statements, the ambition to improve can be found. This ambition is the added value of the norm and expresses the relevance of ISO-19650 certification.

The averages of all filled out statements have been collected per knowledge line group. The weighing per section is in accordance with the number of statements in it. The average values represent the average of all statements. The results are depicted in Table 9.

Table 9 Average scores for the current and desired state of ISO 19650-1&2 compliance per knowledge line group

Knowledge line	Group	Current state	Desired state	Difference
Environment & processen	Systems & Processes	-0,18	1,35	1,53
	Contract & Building management	0,28	0,93	0,65
	Mobility & Urban planning	0,29	0,56	0,27
	Environment & Conditioning	0,33	1,18	0,86
Industrial Automation & Energy	Security installations	0,42	1,25	0,83
	Safe infrastructure	0,74	1,09	0,35
	Energy	0,13	1,15	1,02
Buildings & Infrastructure	Integral building design	-0,17	1,25	1,42
	Civil engineering structures	-0,13	0,82	0,95
	Railway engineering	-0,10	0,98	1,08
	Cable infrastructure & Geotechnics	0,00	0,89	0,89

Ranking and plotting the scores per knowledge line group provides the results as depicted in Figure 5. The results are depicted on a Likert scale from -2 to 2, where the relevance is expressed as the desired state minus the current state. Where the difference is the highest, the relevance of ISO 19650-1&2 certification is the largest. The knowledge line groups have been ranked from left to right on the relevance of ISO 19650-1&2 certification according to the interviews, which can be read from the blue line. For example, the certification has appeared the most relevant to the knowledge line group *Systems and Processes* and least relevant to *Mobility and Urban Planning*.
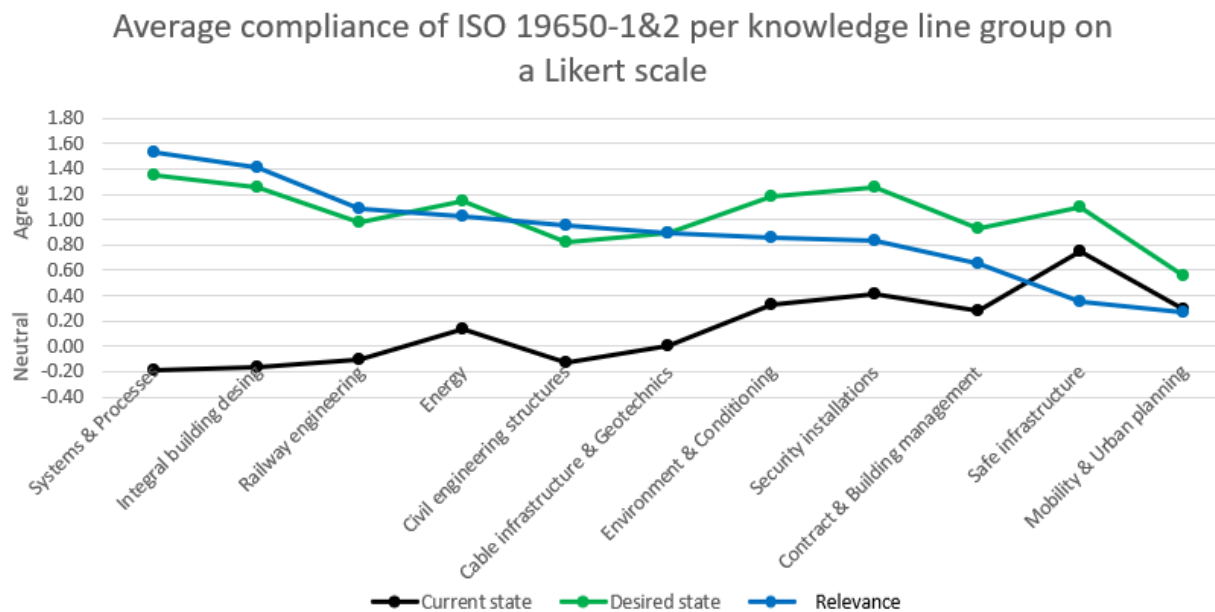

Figure 5 Average compliance with ISO 19650-1&2 per knowledge line group on a Likert scale from -2 to 2

4.2. Effort for certification

Aside from the relevance of the ISO 19650-1&2, the effort to obtain the certification is also important. Namely, starting with certification where it costs the least effort is more efficient working with limited resources.

Finding the effort per knowledge line group is be achieved by analyzing the difference between the current state according to the interviews and the state where the ISO norm is followed. The score is computed by subtracting the current state of the highest possible score, 2.

This has been done for the topics which are directly relevant for the day-to-day business in which Movares plays the largest role. The topics 'Invitation to Tender' and 'Project close out' from Table 7 have been excluded. The results are provided in Table 10 and illustrated in Figure 6.

Table 10 Current state and effort to certification on ISO 19650-1&2 of relevant topics per knowledge line group

Group	Current state	Effort
Mobility & Urban planning	0.32	1.68
Safe infrastructure	0.75	1.25
Contract & Building management	0.44	1.56
Security installations	0.29	1.71
Environment & Conditioning	0.30	1.70
Cable infrastructure & Geotechnics	0.19	1.81
Civil engineering structures	0.07	1.93
Energy	0.14	1.86
Railway engineering	0.05	1.95
Integral building desing	-0.03	2.03
Systems & Processes	0.11	1.89

Figure 6 Current state of and effort to compliance of relevant topics to Movares per knowledge line group
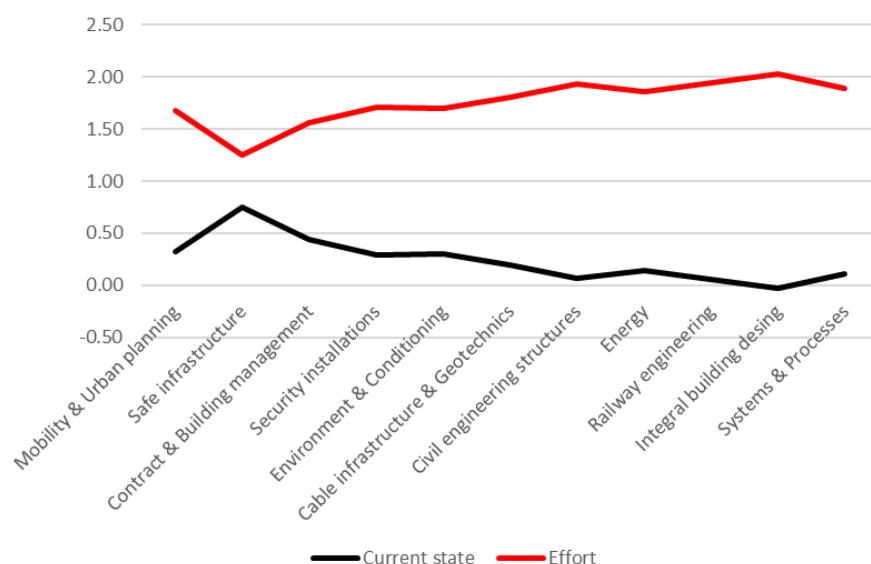
4.3. Combined ranking

In the meanwhile, rankings for relevance and effort have been acquired. By converting the Likert Scale outcomes to relative scores they can be combined and a final recommendation is formed.

First, the relevance is converted into a relevant score be division of all values by the maximum value, as shown in Table 11. Similarly, the relative effort has been computed. However, a high effort indicates an undesirable choice as it brings along high costs. Therefore, the inverse of the effort is computed by subtracting the effort of 1. Now there is an inverse relative effort score indicating that the higher the score is, the less effort it costs to improve. This score is named cost friendliness. Finally, the relative relevance and the cost friendliness are added to get to the final score.

Table 11 Computation total score per knowledge line group

Group	Relevance	Relative relevance	Effort	Relative effort	Cost friendliness	Total
Mobility & Urban planning	0.27	0.18	1.68	0.83	0.17	0.35
Safe infrastructure	0.35	0.23	1.25	0.62	0.38	0.61
Contract & Building management	0.65	0.43	1.56	0.77	0.23	0.65
Security installations	0.83	0.54	1.71	0.84	0.16	0.70
Environment & Conditioning	0.86	0.56	1.70	0.84	0.16	0.72
Cable infrastructure & Geotechnics	0.89	0.58	1.81	0.89	0.11	0.69
Civil engineering structures	0.95	0.62	1.93	0.95	0.05	0.67
Energy	1.02	0.67	1.86	0.92	0.08	0.75
Railway engineering	1.08	0.71	1.95	0.96	0.04	0.75
Integral building desing	1.42	0.93	2.03	1.00	0.00	0.93
Systems & Processes	1.53	1.00	1.89	0.93	0.07	1.07

The prioritization of the knowledge line groups for ISO 19650-1&2 certification can be obtained by ranking the total score, which is performed in Figure 7. The score decreases from the left to the right, meaning that there is the highest prioritization of ISO 19650-1&2 certification in the most left knowledge line group as the combination of effort and cost friendliness is best.
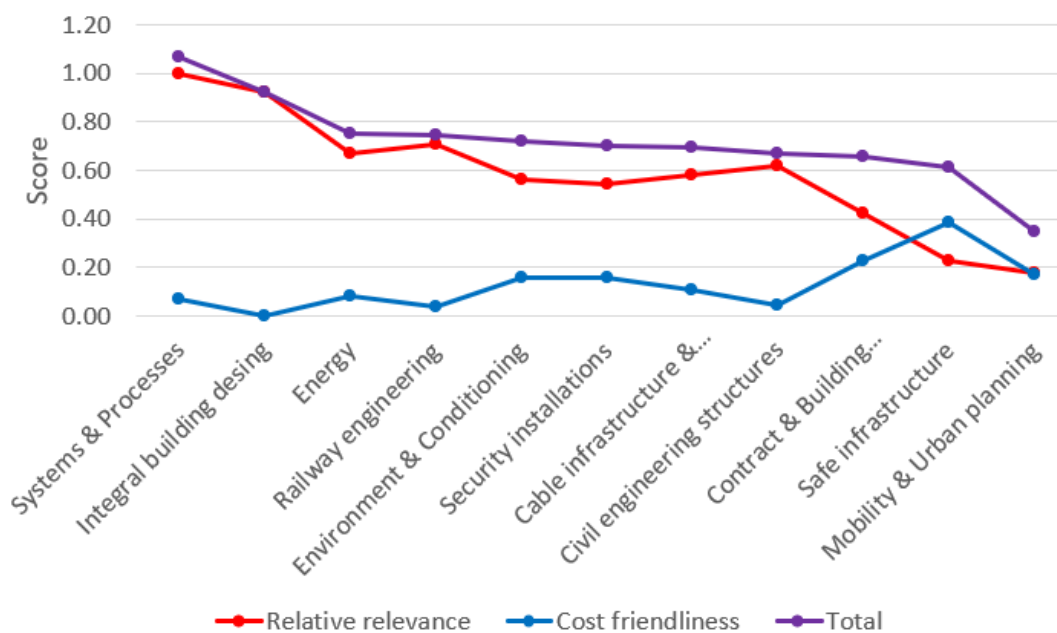

Figure 7 Total score per knowledge line group

5. Discussion

Last chapter has provided the results per knowledge line group, as well as a recommendation on the prioritization of ISO 19650-1&2 certification per knowledge line group. These results will be analyzed in this chapter. First, the results will be discussed per topic of the interview, after which the results will be analyzed per knowledge line group.

5.1. Discussion per topic

Even though the average results per topic have not been debated yet, as they are not directly influential to the prioritization of ISO 19650-1&2 certification, they might reveal interesting insights. The results per interview topic can be found in Table 12, where the ratings for the current and strived situation can be found. The total average is based on the average of all statements, of which the number differs per topic as illustrated in Table 7.

Table 12 Average results per topic

Average all knowledge line groups	Current	Strived	Difference
Invitation to tender	-0.14	1.07	1.23
Tender response	0.25	0.98	0.77
Appointment	0.07	0.96	0.99
Mobilization	0.05	0.86	0.85
Information requirements and models	0.39	0.78	0.39
Information production	0.30	1.04	0.75
Document status	0.48	1.09	0.73
Information delivery	0.50	0.95	0.55
Project close-out	-0.45	0.82	1.41
Total	0.15	1.04	0.90

On average there is an ambition to improve on all topics. This would mean that the topics in ISO 19650-1&2 are generally relevant for the knowledge line groups of Movares.

Furthermore, the topics *invitation to tender* and *Project close out* show the lowest current state and the largest ambition of improvement. Interestingly, these topics both are the responsibility of the appointing party according to ISO 19650-1&2. (ISO, 2018) It could be explained by reasoning that this is outside of the direct influence of Movares and therefore fell behind and leaves large ambition of improvement, from the perspective of the respondents from Movares.

5.2. Discussion per knowledge line group

Per knowledge line group it will be discussed whether their ranking seems suitable. An example of the results per topic for the knowledge line group *Integral Building Desing*. The highlights are named and possible explanation is provided. The scores for differences indicate the average ambition to improve on the statements of one topic and thereby the relevance of the norm.

Table 13 Average results per topic for Integral Building Design

Average ***Integral Building Design***	Current	Strived	Difference
Invitation to tender	-0.60	1.90	2.50
Tender response	-0.50	0.92	1.42
Appointment	-0.50	0.88	1.38
Mobilization	0.00	0.50	0.50
Information requirements and models	0.50	1.75	1.25
Information production	0.20	1.40	1.20
Document status	1.00	1.00	0.00
Information delivery	1.50	1.50	0.00
Project close-out	-0.50	1.00	1.50
Total	-0.17	1.25	1.42

Systems & Processes

On top of the list, the knowledge line group *Systems & Processes* can be found. As the core tasks of this department are giving advice on processes, it is in line with expectations that there is a large ambition towards compliance with ISO 19650-1&2. The large gap is mostly to be found within the topics *invitation to tender, appointment, mobilization,* and *project close out* with differences of 2.20, 2.29, 3.33 and 2.00 points. Although this knowledge line group shows large ambition, it can be argued that certification on ISO 19650-1&2 is not as relevant. This because type of work shows less similarities as *Systems & Processes* is mainly involved in provision of advice to other knowledge line groups, and is not involved in design themselves.

Integral Building Design

The knowledge line group *Integral Building Design* is placed secondly. The core tasks of this group are the design of buildings, so it is not surprising to find a large relevance to ISO-19650 as there is large overlap between the work and the content of the norm. For the added value of certification to ISO 19650-1&2 can be found within the topics *invitation to tender* and the *project close out* showing differences of 2.50 and 1.50 points. It is outstanding that the current state of compliance is -0.17, indicating that the department has not proceeded as far. It might be that the interviewee of integral building design is more critical on their compliance with the ISO 19650. This could be because they are more familiar with the norm compared to the other interviewees.

Energy

In third place ends *Energy*, a knowledge line group which is focused on design and advice. Here there are high desires and an above average current state of compliance. On all sections, there is added value of ISO 19650-1&2 certification, especially in the topics *tender response*, *information delivery* and *project close out* with differences of 1.44, 1.33 and 1.50 points. Also, the respondent indicated that there are large ambitions to improve on working with BIM in their knowledge line group.

Railway Engineering

Another design focused group, *Railway Engineering*, comes in fourth. Although the current state on the topics *information production* and *document status* score relatively high there is still added value in certification on ISO 19650-1&2. Namely, it will largely contribute to the topics *invitation to tender* and *project close out* with differences of 1.44 and 2.00 points. The respondent indicated that working with BIM is now starting up, and there is plenty ambition to improve.

Environment & Conditioning

The knowledge line group *Environment & Conditioning* works on advice and design. This group is placed on the fifth rank. Distinctively, most progress can be established later in project at the topics *document statuses,* the *information delivery*, and the *project close out* 1.33, 1.33 and 1.50 points. This could be explained by a small part of the knowledge line group working on design, causing short comes in established processes for these phases.

Security Installations

Interestingly, *Security Installations* shows a rather high desired rate of compliance with ISO 19650-1&2, yet it still ends in the sixth place. The ambition to improve is smaller as the current rate of compliance is also high. Most added value can be found within the topics *mobilization* and the *project close out* with differences of 2.00 and 1.50 where the other sections score shows a maximum ambition to improve of 1 point or less. Namely, within this knowledge line group, there are lots of procedures which are followed already in relation with certifications on safety. Therefore, certification with ISO 19650-1&2 shows lower added value.

Cable Infrastructure & Geotechnics

Within *Cable Infrastructure & Geotechnics* there is a focus on design and advice. This group stands on rank seven. Here the ambition to improve mostly lies at the topics *invitation to tender*, *information production* and *project close out* at differences of 1.56, 1.40 and 2.00. Focusing on *information production* is standing out, as most knowledge line groups score well on information production. It can be declared as working within the Common Data Environment and provision of feedback internally are found to need some attention.

Civil Engineering Structures

In eighth place, ends *Civil Engineering Structures*. This department is involved in the design phase mostly. The desired state of compliance with the norms is found lower than expected at 0.82. This might be due to the lack of interest of the specific interviewee. For example, on the topic *invitation to tender*, the interviewee disagreed with the need to comply with almost half of the statements and obtains a difference of 0.88 points where the average of all knowledge line groups is 1.23. For example, it was rated useless to let the client set out their CDE and appoint someone responsible for information management. Despite these concerns, on average there is still an added value in certification on all sections.

Contract & Building management

Ending on the ninth spot ends *Contract & Building management*. This is a knowledge line group which focusses on costs estimation, planning and advice. Therefore, it is in line with the expectations that it is ranked lower. However, there still is a reasonable added value of working in compliance with ISO 19650-1&2. Namely, the topics *information requirements and models* and *information delivery* show the largest difference at 1.33 points both. This indicates that the ISO 19650-1&2 is found relevant for procedures within this knowledge line group.

Safe Infrastructure

Like *Security Installations*, Safe Infrastructure shows a rather high current and desired state of ISO 19650-1&2 compliance. Because of current regulations and certification, the processes around information management have already taken shape. Therefore, there is less added value in certification on ISO 19650-1&2 and can they be found in tenth place. The topics with the largest added value are *information production* and *document statuses* at differences of 0.60 and 1.00 points.

Mobility & Urban planning

On the bottom of the ranking, *Mobility & Urban Planning* can be found. As this knowledge line group is mostly active in advice and 2D design, there appears to be a small difference between the current and desired state of ISO 19650-1&2 compliance. Based on the interview results, there is hardly any ambition to improve as the current state suffices in most topics. Largest points of improvement possibilities are found within the topics *invitation to tender* and *information production* at differences of 0.60 and 0.40. This outcome seems to be underestimating the relevance, especially as the interviewee indicates that use of formats would greatly improve their work efficiency and quality.

6. Verification

In this chapter, it is strived to find out if the presented results are truthful and accurate. Verification will be established by comparing the results to additional interviews and comparing the results to the GAP analysis answering research question 3.2. Both are performed on the knowledge line group *Integral Building Design*.

6.1.   Additional interviews

Establishing whether the results of one interview are representative for the department is performed by having additional interviews. At the knowledge line group Integral Building Design, two additional interviews have been performed. Likewise, the accuracy and truthfulness can be established.

Comparison of the collected data provides significant differences per interviewee in the same department, as can be seen in Table 14. Although the original matches well with the second additional interview, there are differences to the first additional interview. Namely, comparing the original interview with the first additional interview, shows that the current and desired situation are rated about halve a point higher. This means that it is highly likely that the scores of individual interviews do not provide an accurate score for the current situation of the group.

Table 14 Average results for the three interviews

Interviewee	Current	Desired	Difference	Current relevan
Original	-0.17	1.25	1.42	-0.03
Additional nr.1	0.33	1.82	1.51	0.57
Additional nr.2	-0.11	1.05	1.19	0.03

The differences in the collected data lead to changes in the final score as well, as illustrated in Table 15. Like the results, the total score differs between the original and the first additional interview, where the original and additional interview are closer.

Table 15 Score computation for the three interviews

Interviewee	Relevance	Relative relevance	Effort	Relative effort	Cost friendliness	Total
Original	1.42	0.93	2.03	1.00	0.00	0.93
Additional nr.1	1.51	0.99	1.43	0.71	0.29	1.28
Additional nr.2	1.19	0.77	1.97	0.97	0.03	0.80

From this verification analysis, it has appeared that the results differ within one knowledge line group. Therefore, it is necessary to keep the limitations of the presented results in mind and conduct further investigations on this topic to increase the accuracy.

6.2.   Comparison to the GAP analysis

On the 12th of April 2022, the knowledge line group *Integral Building Design* took part in a GAP analysis by BSI on ISO 19650-1&2. This GAP analysis maps the differences between how *Integral Building Design* is currently working and what they should do before they can be certified. Although the setup of the interview is different from the audit, the content and findings can be compared.

Linking the points of improvement found by BSI to the statements of the interviews provides the results as depicted in Table 16. On the left, the point of improvement from the GAP analysis has been listed, were the next column details the number similar interview statement(s) as in Table 4 and Table 5. On the right side, the rating of the interviewee of the knowledge line group *Integral Building Design* has been depicted.

Table 16 Interview scores points of improvement

Point of improvement	Statement No	Current	Desired	Difference
Use of Pre-BUP	16 & 18	-0.50	1.00	1.50
Implement assessments	19 & 20	1.00	1.00	0.00
Use mobilization plan	21	-2.00	0.00	2.00
Define BIM specific risks	22	1.00	1.00	0.00
Use planning correctly	26 & 27	-0.50	0.50	1.00
Document statusses	44 & 45	1.00	1.00	0.00

Although the interview yielded more extreme differences for other statements, there are no contradictions in the data. For example, it is not the case that the results from the interview state one statement is already done very well, scoring 2, were BSI found it as a point of improvement. Therefore, this would suggest that the output of the interview is sensible although not precisely similar, and the content matches proficiently.

7. Limitations

The limitations will be discussed for the literature review, the interviews, and the result analysis.

7.1. Literature review

Although the literature research has formed useable input for setting up the interviews, it also lacked direct relation to the studied subject. Here, the general limitation could be identified that one is completely relying on previously published works. Namely, there was not any literature available on how other companies form a strategy for ISO 19650-1&2 certification, for example. It could have been useful to investigate how companies set targets for certification by other methods, but this fell out of the scope.

The literature research focusing on the content of the ISO 19650-1&2, and detailed in Chapter 2.1, resulted in an overview of its content, summarized in Table 4 and Table 5. Although the norms have been fully read, it might be that the interviews do not exactly match the ISO 19650-1&2 by difference in in interpretation.

Lastly, the critical risk and success factors for BIM implementation have been identified in Chapter 2.2. Relevant insights in the factors in how certification of ISO 19650-1&2 were obtained. It could be remarked that the studies have been carried out in other countries, where it might slightly deviate in the Netherlands.

7.2. Interviews

Even though the same interview has been held per knowledge line group, there are various factors which could change the outcome of the interviews. Firstly, it should be kept in mind that the pre-knowledge on the topic might differ per interviewee. Although the choices in the design of the interview aimed at minimizing this issue, it might be that some interviewees better understood the matter and its relevance.

Because of the different knowledge fields that the knowledge line groups deal with, the jobs of the interviewees also differ. It might be that the interviewees provide answers based on their perspective. Also, it was found that some were not able to answer all statements.

Additionally, the years of experience at Movares and social demographics of the interviewees might have played a role in how the interviewees answered the statements. For example, more experienced employees are known for working more structured, but also are more reluctant to changes. Therefore, they might have a harder time imaging and acknowledging the relevance of the norms. Also, social demographics like age, gender and level of education might have played a role.

Lastly, the setting of the interviews has not been constant. For example, the interviews were sometimes conducted at Movares and some were online.

7.3. Result analysis

The result, a recommendation for ISO the prioritization of 19650-1&2 certification, has been obtained by looking at the difference between the current and desired situation from the interviews. Likewise, the relevance of certification and cost friendliness can be found per knowledge line group.

Firstly, as there is only one interview per knowledge line group, quantitative result analysis per knowledge line group is not possible. Instead, the results are compared to the ones of other knowledge line groups. This issue could be addressed by having more interviews per knowledge line group. However, this fell outside the scope. Also, another method like surveying or observing case studies could have been used. However this has not been chosen as surveys would fall short in the depth of knowledge, and case studies make acquiring and comparing results more difficult.

Also, there are more factors which might influence the prioritization of ISO 19650-1&2 certification. For example, it could be useful to more explicitly test if the content of ISO 19650 links with the tasks of the knowledge line group. Also the size of the knowledge line group, demand by costumer or the availability of personal to put forward these changes, could influence the ranking.

Furthermore, looking at the direct output of the interviews might lead to different outcomes. It could be argued that using the combined ranking, considering the relevance and the cost friendliness, does not lead to the best prioritization. The relevance of the norm seems to outweigh the cost friendliness, as these scores are higher on average. This can be explained by the smaller variation in the effort, where values lie between 1.25 and 2.03.

Other options like rating both factors on a scale from 0 for the lowest score to 1 for the highest have been considered. However, here the problem arose that the score for the current situation plays a role in both the computation of the relevance and effort. This as the relevance is the relative score for desired state minus the current state. The cost friendliness is the inverse of the relative scores of the ideal minus the current. Scaling the scores was found to lead to skewed results.

8. Recommendations

Even though the results from the in-depth interviews provide a good basis for the recommendations on prioritization of certification for ISO 19560-1&2 for the knowledge line groups of Movares, there are plenty suggestions for further research.

First, the literature review limited itself to analysis of the content of ISO 19650-1&2 and the mapping of critical risk and success factors of BIM implementation because of the scope. However, it would be valuable to find how other companies made a strategy for ISO 19650-1&2 certification. Although there might not be any literature available at this point, this could also be used using another methodology. For example, one could interview the managers at different companies at how they obtained certification and what choices they made to get there.

One of the main limitations of the used methodology, is found to be the mediocre accuracy. Only one interview has been conducted per knowledge line group, which limited the accuracy. Plenty of factors could limit the representability of the results. In the verification it has been found that the scores can differ substantially within one knowledge line group. Therefore, it is recommended to expand the analysis by use of a survey, such that more quantitative data analysis becomes possible.

Also, the content of the analysis can be broadened. Namely, for determination of the prioritization, only the relevance of the content of ISO 19650-1&2 and the cost friendliness have been included. However, there are more factors that could play a role in decision making. For example, it would be interesting to look at the size of the knowledge line groups, as the number of employees can differ substantially. Also, it might be interesting to evaluate if the type of work a group delivers fits ISO 19650-1&2. Lastly, it could be beneficial to look at the other ISO 19650 norms, 3 until 5. In the end, the opinions of the group managers and BIM manager from Movares are also relevant for decision making.

Further analysis of the collected data is recommended as well. By the in-depth interviews, it became clear what the current strengths and weaknesses are, and what the ambition to improve is per knowledge line group. This information could also be used for making recommendation for actions.

Lastly, it can be recommended to reconsider the computation of the final score for the prioritization. Currently, the relative scores for the relevance and the cost friendliness have been used. The cost friendliness has been found by taking the inverse of the relative effort, which are high values. As a result, the scores for the cost friendliness contribute to a smaller part of the total score. This method of computation has been selected in cooperation with Movares, as it added to the original of only looking at the relevance while managing a workable scope. However, it could be changed based on reconsidering the underlying values.

9. Conclusions

By use of structured interviews where statements are rated on a Likert scale, in depth knowledge has been generated on the current and desired state of ISO 19650-1&2 compliance. One interview has been performed on the information management in all project phases per knowledge line group of Movares.

As a result, relevant insights in the relevance of certification and effort to certification on ISO 19650 have been obtained. It appeared that knowledge line groups focusing on design show most ambition to work in accordance with the norms. Following the concepts and proposed processes could result in more efficiency and higher customer satisfaction. Next to that, miscommunications, and risks in terms of timely delivery can be minimized.

Furthermore, it was found that the knowledge line groups focusing on advice could benefit from information management, as it can improve collaboration. Also, it was learnt that the knowledge line groups *Safe Infrastructure* and *Security Installations* show less ambition to comply with ISO 19650-1&2 as other certifications regarding safety already set out clear processes. Another outstanding result is that the knowledge line groups in the line *Digital transformation and IT* indicate that certification is not relevant, however understanding of the norms is to facilitate supportive software for the other groups at Movares.

Not only can the results be used for decision making on the strategy for ISO 19650-1&2 certification at Movares, as the data of the in-depth interviews leaves possibilities for further analysis. For example, it could be used to formulate actions per knowledge line group, as the current strengths and weaknesses can be found using the results from the interviews.

Although the gathered data provided a good basis for comparative analysis, the quantitative data analysis opportunities are limited. Also, only having one interview per knowledge line group results in a low accuracy. Namely, the verification showed that within one knowledge line group there can be substantial differences due to several factors. For example, the pre-knowledge of the topic, demographics, sort of function and years of experience might play a role.

Lastly, several suggestions for further studies are found. There could be an analysis on how other companies set up a strategy for ISO 19650-1&2 certification. In additional, it might be useful to add to the factors for the prioritization and consider more factors like the size of the knowledge line groups and the type of work they are executing. Additional analysis of the obtained data can also be advised, as it might prove insightful for recommendation of actions.

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