Total BIM in the Swedish Construction Industry: MMI and FMI as Supporting Frameworks

Master Thesis in Design and Construction Project Management

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Abstract

The Swedish construction sector is moving toward more digital and model-based ways of working, where BIM models are expected to contain more of the project information. However, many projects still use Hybrid BIM, where models and traditional drawings are used in parallel. This creates uncertainties related to coordination and responsibility. This thesis explores the potential benefits, challenges, and consequences of using Total BIM in a Swedish construction context, with the help of two additional indices, Model Maturity Index (MMI) and Function Maturity Index (FMI). The study is based on a review of related work, five digital workshops, interviews with industry actors, and a qualitative analysis of the collected material. The study shows that MMI can make model-based work more structured by describing how mature model objects are and when they can be used for reviews, decisions, procurement, production, or handovers. FMI can complement MMI by focusing on the technical systems and functions. However, while MMI is more developed and currently tested in pilot projects, FMI is still under early development in Sweden. The study also shows that the main challenges are not only technical, but also organisational, contractual, and cultural. This requires better conditions, routines, a common language, and more trust in model information if Total BIM, MMI, and FMI are to work in practice. The thesis conclusion states that MMI and FMI can support a Total BIM workflow in Sweden, but if it is implemented and adapted into Swedish project standards, it needs to be useful and efficient for the people who will work with it.

Keywords: Total BIM, Hybrid BIM, Model Maturity Index (MMI), Function Maturity Index (FMI), AB25 & AB27, Promemoria (PM) changes

Preface

After five months of work with this report, the two of us have really created an understanding of the potential that digitalisation has and still can do for the construction sector. It will be interesting to follow this development in the future, whether or not we are included in this.

First and foremost, we would like to thank our supervisor and examiner, Mattias Roupé, for following us throughout these months, through both good and challenging periods. Not only has he given us good insights on the material, but also gave us the opportunity to write about this topic and, with that, provided us with more experiences regarding the concepts of Total BIM, MMI and FMI.

We would also like to thank everyone who participated in the workshops and interviews that were provided. Without your insights, this thesis would not have been possible to perform.

Gothenburg, June 22, 2026

Terminology

Below is a list of relevant terms that have been applied in this report, sorted in alphabetical order:

AB25 & AB27	An upcoming Swedish contractual standard framework for the construction industry that will give digital models a more central and legally significant role in project delivery. However, due to delays in publication, the framework is referred to as AB27 from the result chapter onwards. Both terms refer to the same proposed contractual framework.
Function Maturity Index (FMI)	A framework used to define and track the maturity of functions and technical systems throughout the construction process.
Hybrid BIM	A working approach in which traditional 2D drawings and BIM models are used in parallel as sources of project information.
Model Maturity Index (MMI)	A system used to define and track the maturity level of individual objects within a BIM model throughout different stages of a project.
Promemoria (PM) changes	A written document used to present analyses, changes, considerations, proposals, or recommendations on a specific topic. Within the construction industry, PM changes are commonly used to communicate technical, legal, or project-related matters among project stakeholders.
Total BIM	A model based approach in which the BIM model serves as the primary and shared source of information throughout the entire project lifecycle.

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1
Introduction

The Swedish construction sector is undergoing a comprehensive digital transformation in which Building Information Modeling (BIM) is increasingly used as the main carrier of information in the design and production phases of different projects [1], [2]. Despite this, significant challenges remain related to information management, responsibility allocation, and coordination between stakeholders [2]. A lack of structure in the information maturity of models can lead to uncertainty about constructability, late design changes, and increased costs in the form of promemoria (PM) changes (additions, alterations, and omissions).

Traditionally, drawings and documents have served as the governing contractual basis, but the development is moving towards digital models that assume a more hierarchically superior role in contractual contexts [2]. Upcoming Swedish contractual standards (AB25) indicate that digital deliverables will increasingly be given precedence in the contract hierarchy [1], [3]. This creates new requirements for clarity in model information content, allocation of responsibilities, and levels of maturity.

In parallel with the increasing use of BIM in both design and production, new approaches have emerged that aim to further integrate and streamline digital information flows in construction projects. One such development is the concept of Total BIM, which describes an approach in which the BIM model serves as a single source of information throughout both design and production, without relying on separate 2D drawings [4], [5]. In contrast, many current practices can be described as Hybrid BIM, where digital models are primarily used for design and coordination, while production is still governed by drawings extracted from the model. This parallel structure creates an incomplete integration of BIM into the construction phase and highlights ongoing challenges in achieving a fully model-based workflow [4].

This development is closely related to broader changes in how digital models are understood and used within construction projects. In this context, increased demands regarding information consistency, accessibility, and the contractual status of model data, are becoming more prominent.

Model Maturity Index (MMI) emerges as a structured framework for defining and communicating the level of information maturity in BIM models [6], [7]. By describing the maturity level of model objects using standardised levels, the development stage and information content of the model can be clarified throughout the different phases of a project [6]. This creates a common language among project stakeholders and enables a clearer connection between model information maturity, constructability, and decision-making, which can contribute to a more transparent and controllable design and production process.

The Function Maturity Index (FMI) complements MMI by describing the maturity level of technical systems and their functional completion throughout the project lifecycle [6], [7]. FMI is used to clarify the status of technical installations and systems and to ensure that they progressively achieve the intended functional requirements throughout the different phases of the project [6]. Together, MMI and FMI can thus contribute to more structured information management and improved communication among project stakeholders.

In Norway, MMI has been established as an industry-wide method for structuring the development of BIM models and linking the status of model information to project decision-making processes and production needs [6]. The use of maturity indices has contributed to a shared understanding of project status and supported a more systematic monitoring of both model information and technical systems throughout the project lifecycle. Experiences from Norwegian projects suggest that a maturity-based approach can function as an effective governance tool for coordination, decision-making, and constructability control.

The growing use of MMI in Norway has also begun to influence developments in Sweden. One notable example is the Kaj 16 project in Gothenburg, where maturity-based model management is being explored as a means of improving information transparency, coordination, and decision-making throughout the project lifecycle. This indicates that the principles underlying MMI are beginning to gain practical relevance within a Swedish context.

Despite these developments, the application of maturity-based approaches in Sweden remains limited and has not yet reached the level of industry-wide adoption as seen in Norway. Furthermore, while MMI is currently being tested in practice, FMI has not achieved a comparable level of implementation. This is largely because FMI remains less clearly defined and lacks the degree of standardisation and industry consensus currently associated with MMI.

As a result, there is still limited knowledge regarding how MMI and FMI can be effectively adapted and implemented within the Swedish construction industry. Given the similarities between the Norwegian and Swedish construction sectors, this raises important questions regarding the transferability of maturity-based approaches and their potential role in supporting a transition towards more model-based workflows in Sweden.

1.1 Purpose

The purpose of this master thesis is to investigate the potential role of Total BIM, together with two supporting indices, MMI and FMI, in the Swedish construction process. The study examines how these indices can contribute to more efficient information management within a Total BIM environment. The study aims to explore and analyse how a maturity-based framework can support existing design and production workflows throughout the project lifecycle. Furthermore, the report investigates how MMI can be described as a common language for maturity, status, and usability at the object level.

The thesis based on that MMI is already established in Norway, where it functions as a governance mechanism, linking model information maturity to buildability and decision-making. To enable a transition towards a Total BIM environment, industry practices, contractual structures, and the indices' role in the construction sector are considered, using the Norwegian implementation as inspiration.

Furthermore, the study considers the ongoing development of Swedish contractual standards, where digital models are expected to assume a higher governing role within contractual frameworks (AB25). Against this background, the thesis explores how MMI and FMI can serve as a structured framework to clarify responsibility, information maturity, and functional reliability in a construction process.

In collaboration with industry actors, the study ultimately seeks to explore the potential for the construction sector to successfully transition towards a model-based workflow and identify what is required to achieve this. In doing so, the study not only considers the technical aspects, but also the governance factors such as organisational, contractual and procedural.

1.2 Questions

To fulfill the purpose of this master's thesis, the study explores the following research questions:

1. How can MMI and FMI support information management within a Swedish Total BIM environment?

2. How can MMI function as a common language for describing information maturity, status, and usability at object level?

3. What opportunities and challenges are associated with potentially applying MMI and FMI within the Swedish construction industry, considering current industry practices, contractual structures, and governance frameworks?

1.3 Limitations

This study was limited to examining how the MMI, supported by the FMI, can be adapted within the Swedish construction process, with primary focus on the design and review phases. Although the adaption could affect the overall information flow throughout the project lifecycle, the operation and facility management phase was not examined in detail.

The research was based on interviews and workshops with disciplines across the construction industry and was therefore not connected to a specific project or a single organisation. Therefore, the empirical material, in which the results and analysis were based on, will be an interpretation of subjective findings such as experiences and perspectives. This means that the findings might be influenced by subjective opinions rather than representing an objective standpoint. However, this was still considered empirical material, as it provides insight on how Total BIM, MMI and FMI are perceived and used in practice.

Furthermore, the workshop and interview participants were also well versed in digitalisation which could create a risk of bias. This was taken into consideration when analysing the discussions in the workshops and interviews by identifying recurring themes and contradictions. This approach helped reduce the influence of individual opinions and perspectives, which also helped to strengthen the validity of the findings.

To gain an understanding of how Total BIM and MMI could be adapted in the Swedish construction industry, references from the Norwegian construction sector were researched. This was done through participation in workshops in collaboration with stakeholders from Norway and actors who have worked or work with them.

Furthermore, the thesis did not include a comprehensive legal analysis of the Swedish standard contracts (e.g., AB/ABT) or forthcoming revisions of general conditions (such as AB25). These conditions were addressed at a comprehensive level to examine how MMI and FMI may align with a contractual framework in which digital models are expected to assume a more prominent governing role.

Finally, the study did not involve the development of a technical BIM system or detailed software solution. Instead, the focus was on the organisational, procedural, and conceptual adaptation of MMI and FMI as governance frameworks for information maturity and allocation of responsibilities.

1.4 Disposition

This thesis begins with an introduction that provides an overview of the background of the studied topic, its relevance, and its connection to developments within the construction industry. Furthermore, the purpose of the report, the research questions it aims to answer, and the limitations within which the study is conducted are presented, see chapter 1.

Subsequently, the report presents the background and related work concerning the studied area, see chapter 2. The various chapters cover topics ranging from the fundamental concepts of the construction process to Total BIM, MMI and FMI, and further to sustainability goals.

The following chapter describes the methodology, including the design of the study, the data collection process, and the development of the interview questions that were applied, see chapter 3. Transparency regarding the use of AI is also addressed. The results are then presented in chapter 4, consisting of both findings of the interviews and the five workshops that were analysed. This is followed by an analysis and discussion section in chapter 5, where the results are compared with the findings presented in chapter 2.

The final part of the report addresses the conclusions of the study, see chapter 6, and provides suggestions for future research, see section 6.1, highlighting areas that were not explored in detail within the scope of this report. Furthermore, the references used throughout the study are presented, followed by Appendix A, which contains the interview questions.

2
Background and related work

This chapter presents the background and related work relevant to the study. The purpose is to provide the necessary context for understanding the research area, establish the theoretical foundation of the study, and position the research within existing industry developments and practices.

2.1 Construction processes and documentation

There are several key processes in a construction project that symbolise changes in what is prioritised and what is occurring [8]. These key processes can also be used to illustrate the progress of a project and identify which documents are necessary and should be presented, see Figure 2.1.

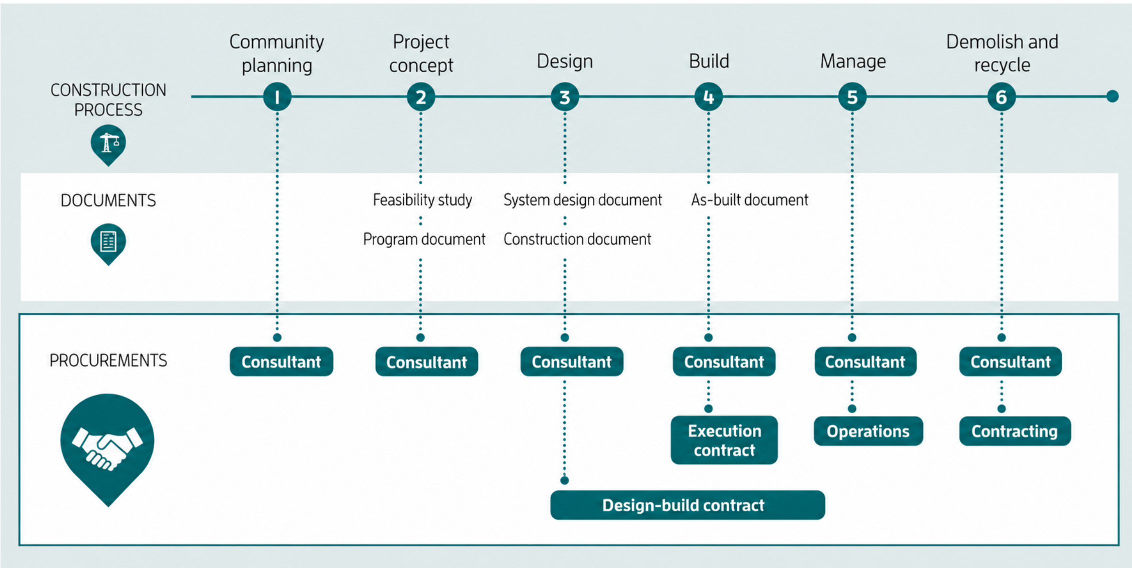

Figure 2.1: An illustration of the different stages in a construction project, its associated documents and procurement processes [8].

Starting from the project concept phase, the project is developed through the combination of a client coming up with an idea for a construction project and creating project delivery goals[9]. In this stage, the client chooses how the construction project is to be carried out, whether through turnkey, general, or execution contracts.

During the project concept phase, after an idea has been formed, the client needs to conduct pre-studies by procuring different consulting services to develop, for instance, a programme document [9]. It is also at this stage that the client, with the help of consulting services, can determine the need for a construction permit, whether areas or existing construction need to be reused, or whether the project requires the development of a whole new area. This process is necessary because a construction project is often complex and requires the coordination of many actors involved in a high-budget project. Therefore, it is recommended to develop a strategy by setting reasonable goals and milestones to create an efficient project workflow. Lastly, it is mentioned that sustainability goals are also defined early in the pre-study phase.

The next phase after the project concept is the design phase [10]. This phase is initiated after a construction idea has been finalised and a programme document has been created and agreed upon. In this phase, the ideas and processes are put into practice to achieve the goals and conditions set during the pre-study phase by the client. During the design phase, the client will require the procurement of additional consultants to cover the internal knowledge gap within the project team. This phase emphasises planning, strategising, and making accurate decisions, as project delivery is heavily dependent on the workflow between the realisation of a project idea and the finished construction.

During the design phase, the team is also expected to meet the expectations of the client and develop relevant strategies and implementation approaches to achieve the client's goals. If the task is deemed too large for the procurement contracts, additional contracts are expected to be created between the consultant and the client to ensure that a proper workflow is followed. To efficiently manage the project management process, project managers are often tasked with coordinating work. To more efficiently manage the design phase, a project planning document is also created. Lastly, because of a result of a final design phase, the construction project enters the build phase [11].

Throughout the duration of a construction project, there are several types of documents that provide information regarding how it will be carried out [12]. These documents include information on how the construction project will comply with laws and regulations, how it should be carried out efficiently, as agreed upon by the actors, and how the contracts are adhered to by the different actors.

As a construction project consists of many different processes, different types of documents are also required at different stages of the project [12]. Beginning with the programme documents, these are usually created at the beginning of a construction project and consist of information required for the project to start. In the programme documents, content such as the client's requirements and expectations for the construction project can be found.

In addition, in the construction process, the requirements stated in the programme document require complementary documents that contain more details about the project [12]. These documents are called project planning documents and contain more technical data on how the construction can be dimensioned and designed based on the requirements set in the programme documents. These include, for instance, the geometry of construction and the choice of materials presented in, for instance, drawings and technical descriptions. The information stated in the project planning document can be used to apply for a construction permit and to create documents, so-called construction documents, on which the entrepreneurs will base the construction on.

2.2 Total BIM

The construction industry has experienced a slow digital transformation over the past decades. An important work method that has emerged is Building Information Modeling (BIM). BIM helps improve design, coordination, and information management [5]. Despite this, even with BIM, the construction process isn't applying this concept to its full potential. The production phase continues to be dominated by traditional 2D drawings. Having two separate systems creates parallel workflows, leading to inefficiencies, increased costs, and loss of information. Against this, the concept of Total BIM has been introduced, particularly in Scandinavia, as an effort to fully realise the potential of BIM as the only source of information throughout the entire construction process [4].

2.2.1 From traditional BIM to Total BIM

Traditionally, BIM has been used for visualisation, clash detection, and coordination, mostly during the design phase [5]. But when projects move from the initial stages to the production stage, static 2D drawings are often created from the model and become legally binding documents, commonly referred to as "Hybrid BIM" [4], [5]. This means that the digital model loses its relevance and value [4].

Total BIM challenges this practice by eliminating parallel information flows [4]. Instead, the BIM model should be used as a dynamic, cloud-based information platform that serves as the single source of information throughout the entire project's lifecycle. This implies that traditional drawing production will no longer be needed, and instead, all information, including measurements, specifications, and work instructions, is extracted directly from the model by users on the construction site.

Although this change introduces new technology, it will also change the way people work and will restructure workflows and responsibilities [4]. BIM will then become the central part of a project's information system rather than just a helpful tool.

2.2.2 Total BIM as a dynamic platform for information

As mentioned in this section, Total BIM functions as a dynamic information platform, which means that the data in the model are updated frequently and that its information can be shared between various stakeholders [4]. Unlike static traditional drawings, BIM models make it possible to create an interactive management of project information where all users with access to the model can filter, visualise and analyse the data in real time.

In practice, this means that construction workers use digital devices to interact directly with the model both on-site and off-site [4]. From this, they can generate customised views, perform measurements, and document issues through the model. This changes the way construction work is planned, executed and offers multiple advantages.

- Increased precision and quality - Since the information is collected directly from the model, the risk of errors and misunderstandings is reduced.

- Improved communication efficiency - BIM serves as a shared platform where all stakeholders can access the same source of information.

- Reduced document management - The need to produce, distribute, and update drawings is eliminated.

However, this approach puts higher demands on the users working with the model, as construction workers must be able to independently navigate and interpret BIM models and the data within it [4].

2.2.3 Organisational and contractual implications

The implementation of Total BIM requires significant organisational changes [5]. One of the most important aspects is that BIM has legal status as a contractual document, replacing traditional methods of working where drawings traditionally have been the primary source of information [3], [5].

This development would create new requirements for model quality and accuracy [5]. As the models could and probably will become legally binding in the future, their information must be accurate, complete, and standardised. This leads to a greater focus on production-oriented design, where design decisions are made with consideration of how the information will be used in production.

Furthermore, Total BIM affects the relationships between project stakeholders [13]. Traditional roles, such as architects and engineers, will be affected, from working with drawings to working with model-based design. Procurement processes will also be affected, as contractors gain access to detailed model information during the tendering phase, which can result in more precise and comparable bids.

2.2.4 Challenges and limitations

Despite the potential with model-based workflows, the implementation of Total BIM presents several challenges [4]. First, it requires significant investments in technology, training, and model development. The initial costs may be higher in the beginning of the transition due to lack of understanding or habits of working model-based, especially during the design phase, although these are often offset by efficiencies gained during the construction phase.

Second, there are technical limitations related to software, interoperability, and the management of large models [4]. Previous studies indicate that insufficient functionality in BIM tools may prevent users from fully utilising the capabilities of the model and the information it contains.

Lastly, cultural and organisational barriers can complicate the implementation process [4]. Resistance to change, lack of competence, and established work practices can complicate the transition to a fully digital workflow.

2.3 Contractual standards supporting Total BIM

The contracts, AB25 and ABPU25, are newly developed contractual standards that are in the process of replacing the older versions used today, the AB04 and ABT06 which have existed since the 2000s [3]. These contractual standards present changes to the previous AB04 and ABT06 by adding new content, reorganising chapters, and information, and shifting the focus from traditional construction to a more digitally oriented construction sector. The idea is that the new contracts will provide a shift towards digitalisation and model-based construction by including content that AB04 and ABT06 did not cover. This will create opportunities for clients to implement fully digitalised and model-based work in construction projects. A crucial element of the newly created contractual standards is that there are statements that define what a digital model entails and even describe how a digitalised workflow is to be conducted. These standards also include statements that affect the order of juridical priority of documents. Lastly, they also contain information on data and cybersecurity regarding the information management of a digitalised workflow.

2.4 Level of Development

When talking about Level of Development (LOD) within BIM, LOD is used to describe how developed a model element is in terms of both geometry and related information, as well as how reliable the information is to use during a project [14]. This is different from just looking at how something is represented graphically. LOD shows the maturity of the model elements and indicates how the model can be used during different project phases.

It is important to know the difference between LOD and Level of Detail (LoD)

[14]. LoD refers more to the graphical or visual details within a model and its elements, while LOD includes both graphical representation and the development of non-graphical information. This means that a model can contain highly detailed amounts of data related to, for instance, geometry without providing reliable information for decision-making. This difference is important because it helps avoid misunderstandings about the information the model contains and to what extent the model can be relied upon.

LOD can provide a structured way to describe how reliable and detailed the information is in the model throughout the lifecycle of the project [14]. By defining different LOD levels, project stakeholders can better understand which information is available at a certain stage of the project and how the model can be used.

2.4.1 LOD Levels

The LOD system consists of several levels that represent different levels of development, details, and reliability [14]. These levels describe how BIM models develop from conceptual representations to fully verified as-built models throughout the project lifecycle. The levels within a LOD-based workflow are presented below:

- LOD100 Conceptual Design - An early level with approximate geometries to provide an overall understanding of the concept.

- LOD200 Schematic Design - More elements are applied and modelled but are still in an approximate stage with preliminary information.

- LOD300 Design Development - More precise and accurate geometries, used for construction and design planning.

- LOD350 Construction Documents - Like LOD300, but also includes connections to other systems, emphasising coordination.

- LOD400 Fabrication and Assembly - Models are ready for fabrication. Everything needed to understand the model is within it, including costs.

- LOD500 As-Built Model - A digital twin that matches the data within the building.

As the LOD level increases, the model becomes more detailed and reliable for different users throughout the project [14]. Lower levels are used mainly during the early design phases, while higher levels support construction, fabrication, and final documentation.

Higher LOD levels require additional time and effort to develop because more precise geometry and information must be included in the model [14]. Therefore, selecting an appropriate LOD level is important to balance modelling effort and project needs.

2.4.2 Relation to the BIM Process

LOD is closely related to the BIM process because this concept helps define how the model information develops throughout the project lifecycle [14]. Different LOD levels represent different stages of the project and indicate how the BIM model can be used at each of these stages.

The use of LOD and its levels can improve communication and reduce misunderstandings between project stakeholders by clarifying the reliability of the model information [14]. Confusion between LOD and LoD may occur due to its similar names and concepts and may lead to incorrect assumptions regarding the model and its intended use.

2.4.3 Level of Information Need

Based on EN ISO 19650:2018, Level of Information Need (LOIN) is a concept that refers to the information that is required for a BIM project [15]. ISO 19650 is an international standard series that guides the management of information in digital building models [16]. It establishes best practices for organising, sharing, and controlling digital data throughout a project's lifecycle, enhancing collaboration, and ensuring data quality in BIM-driven projects. This information from LOIN consists of its quality and quantity, and is used to define what is needed, when it should be delivered, and which actors it concerns in producing the information and receiving it. Using this concept, LOIN can support decision-making and execute project tasks.

2.4.4 Takt planning

Takt planning helps organise work into consistent periods or divided steps, making coordination easier and more transparent [17]. This method divides the project into smaller work areas, called takt zones, and schedules activities according to a predefined takt time. In an example presented in [17], construction activities were organised into different takt zones where the work teams systematically moved between zones every 2.5 or five days. As a result of using takt planning, this improved workflow, coordination, and transparency throughout the project.

2.5 Model Maturity Index

The Model Maturity Index (MMI) is a standardised framework within BIM designed to describe and define the maturity level of objects in digital building models using numerical levels [7], [18]. This framework provides a structured approach to assess the level of development of a model by analysing its geometric details, the information content, and its suitability for different stages within the construction process.

By establishing a common language, MMI helps reduce subjective interpretations and makes it easier for stakeholders to share information [7]. This leads to more consistent and transparent communication regarding what information is in the model and how reliable it is. Furthermore, MMI acts as a management tool, ensuring that relevant information is developed to meet the project's needs and is available at the right time [18].

Traditional drawing-based work methods are often characterised by subjective interpretations and inconsistencies in information transfer[7], [18]. MMI, on the other hand, can enable a more shared terminology and a clear communication channel among all project stakeholders. This includes actors such as architects, engineers, contractors, and clients. This creates a common language among project participants, where the model's content and reliability can be communicated in a consistent manner [7].

MMI is more than just a way to apply a technical classification within a model. It can also be seen as a tool that helps make the model's maturity levels much clearer in terms of key decisions and the allocation of responsibilities. This enables better coordination, planning, and control within the project [18].

2.5.1 Function

The main goal of MMI is to ensure that the right information is available at the right time in the project [7], [18]. By connecting the maturity level of the model to the specific requirements for the content of the information and geometric details, MMI helps reduce uncertainties in design and improves coordination between different disciplines [7].

Furthermore, MMI can support constructability assessments and reduce the need for late changes and change orders by ensuring that the model reaches a sufficient level of maturity before being used as a basis for decisions or production [7].

According to [7], MMI functions as a control mechanism to ensure that the information in the model is developed progressively according to the needs of the project. This means that the model does not need to be fully detailed in the early stages; instead, the level of information is adapted to the decision points and production requirements. In addition, MMI can help clarify the allocation of responsibilities among stakeholders, as each maturity level can be linked to specific deliverables and requirements.

2.5.2 MMI Levels and their meaning

The MMI system is built around several numerical levels, representing different levels of maturity [18]. These levels form a scale where each represents a certain degree of development. The most common levels are as follows:

- MMI000 Conceptual model - Objects are roughly sketched with approximate volume and geometry, suitable for early idea and concept stages.

- MMI100 Preliminary model - The intentions of the project are visible, but several alternatives remain and the model is not yet fixed.

- MMI200 Proposed model - Selected solutions begin to emerge, with few remaining alternative building components. Often corresponds to system design.

- MMI300 Detailed model - Detailed and coordinated solutions that are buildable and verified for design.

- MMI400 Production model - The model is used in construction for work planning and material management.

- MMI500 As-built model - Actual constructed objects with product-specific information, delivered to the client as documentation.

- MMI600 Facility management model - Relevant and updated model information for facility management and maintenance planning.

Each level has its own set of requirements for both geometric precision and information content [7], [18]. For example, MMI300 indicates that the object is developed enough for coordination between disciplines, while MMI400 means that the object is buildable and can be used as a guide for production.

MMI consists of a hierarchical level structure from MMI000 to MMI600, where each hundred represents a new stage in the construction lifecycle, from early sketches to facility management, see Figure 2.2 and 2.3 [7], [18]. Within certain levels, subdivisions exist in intervals of 25, 50, and 75 to further specify maturity. It is recommended that projects begin with the broader hundred-level steps (000-600) to build experience and gradually introduce more detailed steps. This approach allows projects to build experience and gradually introduce more complexity if appropriate.

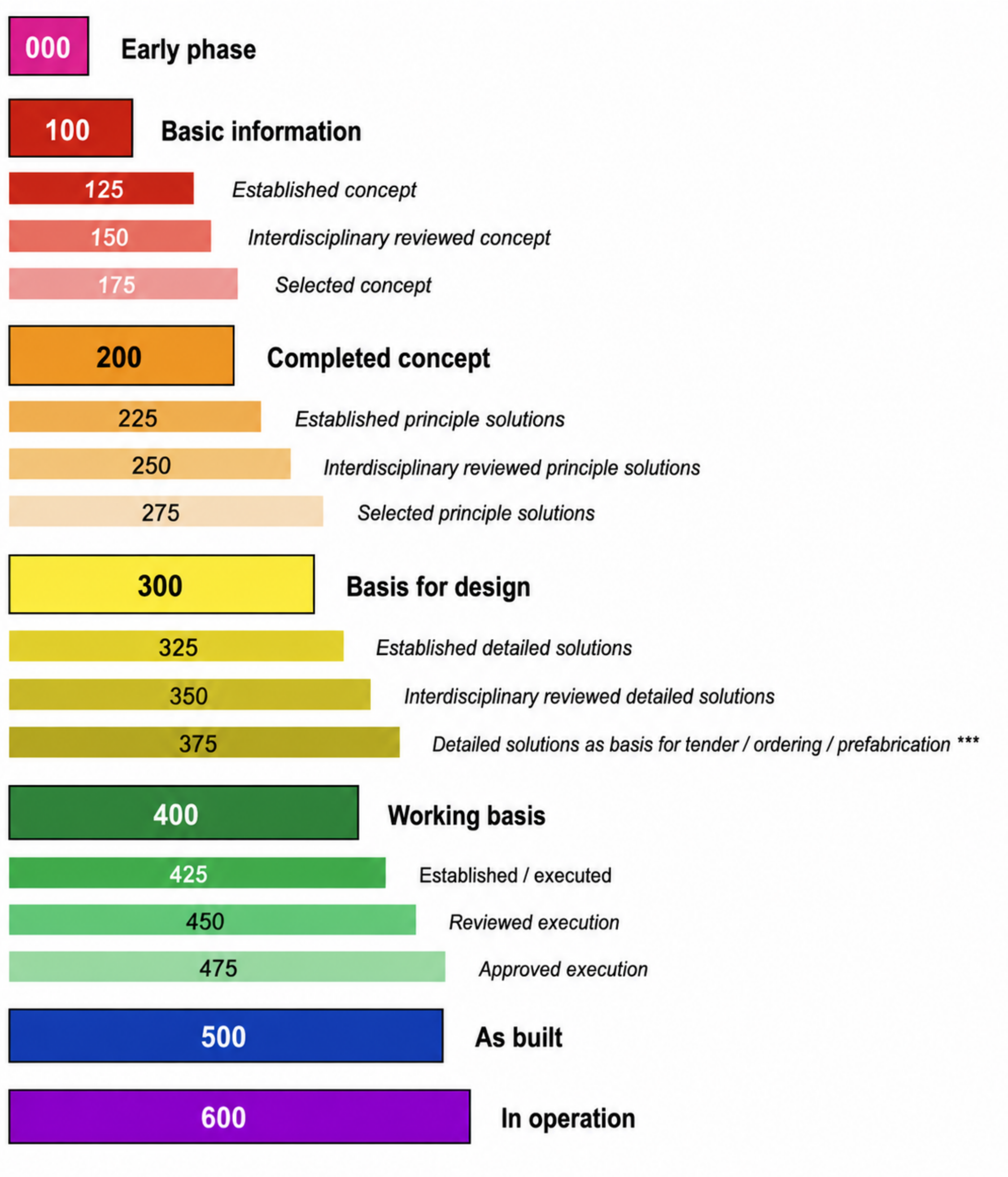

Figure 2.2: A diagram that illustrates the status levels of MMI in detail based on their progress in comparison to the project phase [7].

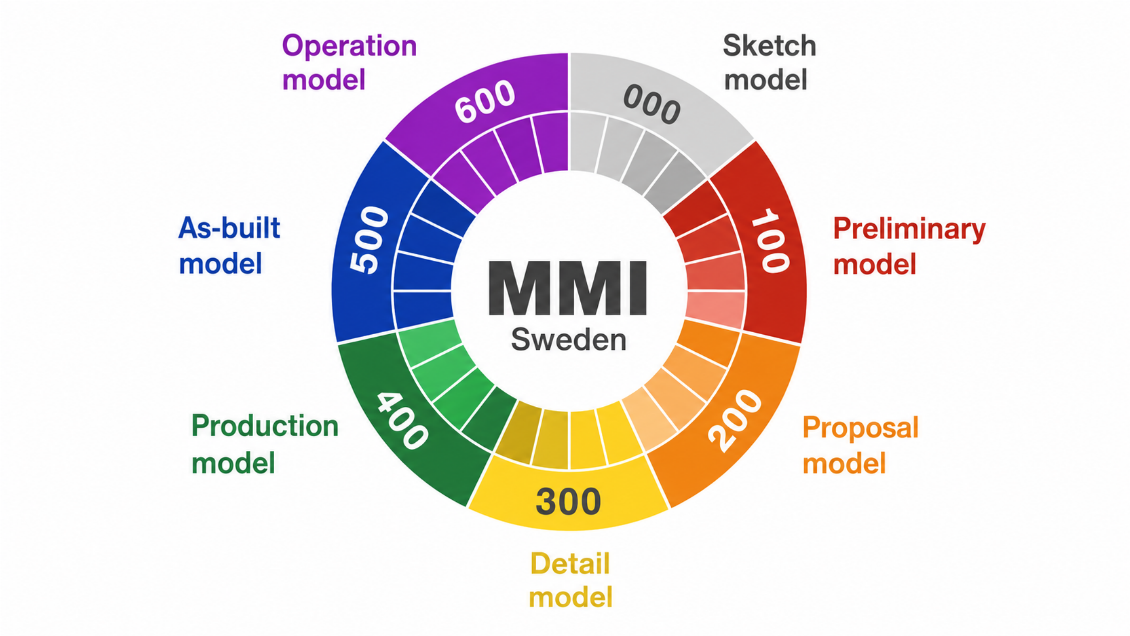

Figure 2.3: An illustration of the general status levels of MMI-based on their progress in comparison to the project phase [18].

2.5.3 Role in the BIM Process

MMI is closely integrated with BIM as both a platform and an information model in the construction process [7], [18]. By linking model maturity to different stages of a project's lifecycle, MMI ensures that the model meets the necessary requirements set for each project phase [18]. This means that project participants can use MMI to verify that models and objects are sufficiently mature before being used as a basis for decisions or in production, reducing the risk of late changes or quality issues in the project. The use of MMI can also be governed through delivery plans and BIM Execution Plans, according to ISO 19650, where deliverables and information requirements are linked to defined MMI levels.

In practice, the middle stages (25, 50, 75) are also used to provide a better understanding of how well coordination and control are. This can include collision detection or interdisciplinary review, which can further improve quality assurance, see Table 2.1 [7], [18].

Table 2.1: A table that illustrates the general status levels of MMI-based on their progress in comparison to the project phase [7]. Also showing colour codes and descriptions.

Code	Name	Description	Color code* (RGB) / Hex
000	**Early phase**	Processes that are prerequisites for construction projects, for example plan processes, architectural competitions, etc.	(215, 50, 150) #D73296
025	*Reserved***		
050	*Reserved***		
075	*Reserved***		
100	**Basic information**	Objects and information established as the basis for development of the project.	(190, 40, 35) #BE2823
125	Established concept	Concepts established as the basis for coordinating across different disciplines.	(210, 75, 70) #D24B46
150	Interdisciplinary reviewed concept	Interdisciplinary review and identification of potential deviations and corrections at an overall level.	(225, 120, 115) #E17873
175	Selected concept	Principle solutions selected and ready for decision on further development.	(240, 170, 170) #F0AAAA
200	**Completed concept**	Principle solutions developed and documented, clarified for further development.	(230, 150, 65) #E69637
225	Established principle solutions	Principle solutions are established and form the basis for further coordination across different disciplines.	(235, 175, 100) #EBAF64
250	Interdisciplinary reviewed principle solutions	Interdisciplinary review and identification of potential deviations and corrections at an overall level.	(240, 200, 140) #F0C88C
275	Selected principle solutions	Principle solutions selected and clarified for decision on further development.	(245, 230, 215) #F5E6D7
300	**Basis for design**	Principle solutions are developed and documented, clarified as the basis for detailed design.	(250, 240, 80) #FAF050
325	Established detailed solutions	Detailed solutions are developed and form the basis for further coordination from a disciplinary control.	(215, 205, 65) #D7CD41
350	Interdisciplinary reviewed detailed solutions	Interdisciplinary review and identification of potential deviations and corrections at an overall level.	(185, 175, 60) #B9AF3C
375	Detailed solutions as the basis for tender / ordering / prefabrication***	Approved basis for ordering, prefabrication, supplier design, tender documentation (general enterprise).	(150, 150, 50) #969632
400	**Working basis**	Ready for execution on the construction site. The basis can also be used for ordering, planning, execution and documentation.	(55, 130, 70) #378246
425	Established / executed	Design or execution on the construction site established.	(75, 170, 90) #4BAA5A
450	Reviewed execution	Execution reviewed against project design, and any changes compared with actual execution in the model.	(100, 195, 125) #64C37D
475	Approved execution	Execution approved against requirements, e.g. in relation to the systematic completion of the building.	(155, 215, 165) #9BD7A5
500	**As built**	Delivered according to ordering, deviating from supplier to buyer.	(30, 70, 175) #1E46AF
525	*Reserved***		
550	*Reserved***		
575	*Reserved***		
600	**In operation**	Clarified operational documentation delivered from buyer to operating organization.	(175, 50, 205) #9B00CD
625	*Reserved***		
650	*Reserved***		
675	*Reserved***		
700	*Reserved***		
800	*Reserved***		
900	*Reserved***		

* Color code applies to display in model software and model viewers for any color based on MMI code/level

** Reserved for future versions of MMI levels, e.g. codes for rehabilitation and demolition

*** At this level, the basis also serves MMI level for delivery: goods, supplier design and subcontracting. This must be clearly defined / agreed in the contract for the individual project.

In a broader digital context, standardised frameworks for information sharing, such as BEAst, can play a major role [19]. BEAst can complement BIM and MMI by creating standards in the form of guidelines that describe how information can be reviewed in different software such as Dalux and BlueBeam [20]. While MMI defines the maturity level of model information, BEAst focuses on how this information is presented and shared across different systems, supporting more efficient workflows and allowing different systems to work together within the construction process.

2.6 Function Maturity Index

In construction projects, especially large projects that contain more complex technical systems, it is common for elements in the technical systems to malfunction as the project closes in on project handover or the operation phase [6]. To combat this issue, the Norwegian guidelines have mentioned the implementation of Function Maturity Index (FMI).

2.6.1 What is FMI and why is it needed?

FMI can be used as a preventive solution to system malfunctions during handover by serving as an index to illustrate the functional maturity of a technical system [6]. FMI works by presenting an index at different levels, each of which has its own status and maturity level. In this way, construction projects can use the indices to communicate the maturity of technical systems and therefore indicate their development progress.

2.6.2 Different levels of FMI

FMI has multiple maturity levels. These are illustrated in a diagram according to the project phases they represent, see Figure 2.4.

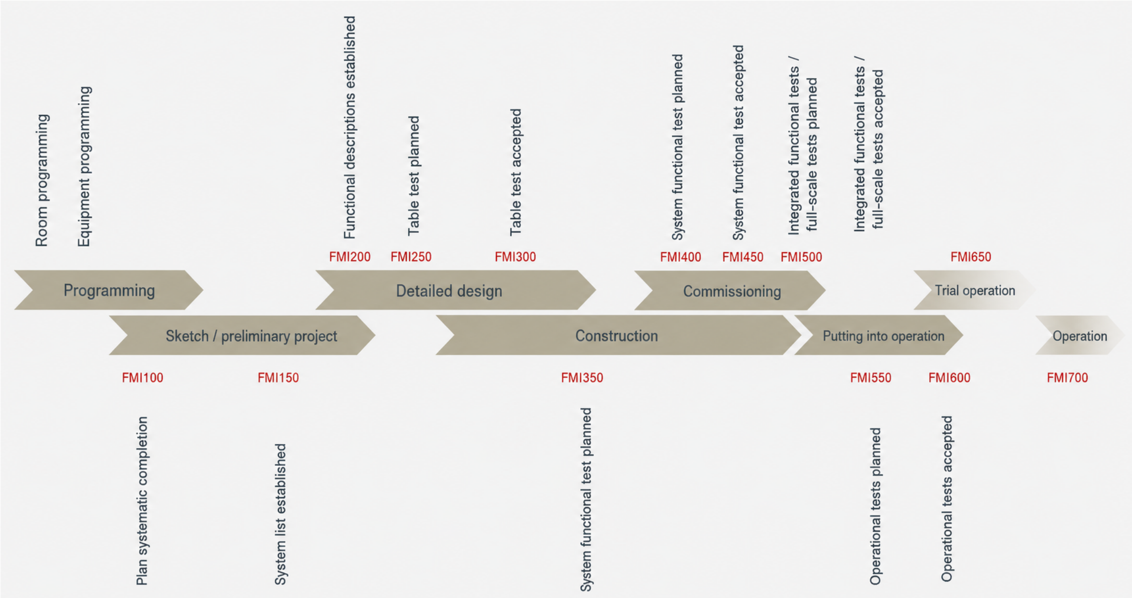

Figure 2.4: An illustration of the status levels of FMI based on their progress in comparison to the project phase [6].

In more detail, the FMI status levels range from FMI100 to FMI700, and their descriptions are as follows:

- FMI000 Early phases - At this stage, no information or content regarding systematic functions has been defined for the project.
- FMI100 Plan for Systematic Completion established - When functional conditions and requirements have been set, including a strategy or action plan to meet the expectations, and how the FMI levels are going to be regulated in the project onwards. This includes having a plan for Systematic Completion.
- FMI200 Functional description (for each system) completed - Upon reaching this level, the construction functions should have been registered and defined with technical descriptions and should be ready for table testing to be planned.
- FMI300 Table test accepted - A construction project is considered to have reached the maturity level of FMI300 when table tests have both been executed and accepted for the selected critical components and processes that require testing.
- FMI400 System functional test accepted - After the installed system is ready, a construction project reaches FMI400 when System Functional Test (SAT) has been conducted for the system function in its real environment and has been approved.
- FMI500 Fully accepted and integrated tests - The integrated tests between systems have been conducted, adjustments have been made, and the results

have been accepted.

- FMI600 Operational tests accepted - Operational tests have been conducted on site and are fully functional.

- FMI700 Normal operation - The system is now operational and functioning as intended.

2.6.3 Connection to Systematic Completion

FMI is an index mentioned in the guideline and developed to support the use of Systematic Completion and to follow the same principles as MMI [6]. Systematic Completion was developed to increase productivity in the construction sector. The goal was to ensure that the results of construction project deliveries function as intended while meeting the client's expectations. According to the guide, this can be achieved by earlier focusing on obtaining project delivery requirements and providing information on the responsibilities of each actor in each project phase.

2.6.4 Implementation of FMI

Regarding the implementation of FMI in projects, it is stated that the index at different statuses shows the maturity level of the technical systems in a construction project, using different codes [6]. This index is used in practice as a form of communication in construction projects to help project management follow up on the development of the technical systems which has been proven to be a challenge. In relation to the Systematic Completion, it is stated that a construction project should be clear about which documents to use as the basis for providing solutions. The implementation of FMI for the technical systems will therefore make it easier, as it provides a way to communicate the development of said systems.

Currently, the Norwegian standard for technical construction, "NS3935", describes how construction projects can be organised through the implementation of Systematic Completion, and therefore the implementation of FMI [6]. It is stated that the responsible actor for the implementation of Systematic Completion should also provide requirements and statements that are grounded in the contracts. The conditions should be how FMI will be used in the project and which FMI levels the systems will progress through.

2.6.5 Connection to MMI

MMI describes the maturity of the model's information, but to complement this, FMI describes the maturity of the technical systems within the project [6], [7]. Together, MMI and FMI form a comprehensive framework that enables the management of both model information and system functionality throughout all stages of the project. This is particularly important in complex construction projects, where the interaction between technical, functional, and information aspects forms the foundation for successful project delivery.

2.7 Sustainability goals

This section will discuss sustainability goals from the United Nations, EU, and Sweden.

2.7.1 United Nations sustainability goals

According to the United Nations website, 17 sustainable goals have been agreed upon by all UN member states [21]. This plan is called Agenda 2030 and was created in 2015 with the goal of creating peace and better welfare for people. The goals within the plan are called the Sustainable Development Goals and are centred around improving countries health and education systems, reducing and preventing the occurrence of inequalities, improving their economic status, and tackling ongoing climate change challenges.

Additionally, as presented in the Global Status Report for Buildings and Construction 2024-2025 published by the UN Environment Programme (UNEP) and the Global Alliance for Buildings and Construction (GlobalABC), the construction sector is highlighted as a main contributor to climate change, as buildings and construction processes are generally very resource-consuming [22]. As a result, the construction industry accounts for 32% of global energy consumption and 34% of global CO_2 emissions. Further, as mentioned in the report, the major contributors to the emissions have their roots in the use of cement and steel. However, the current state of the construction sector is that the CO_2 emissions from building operations have increased by 5.4% instead of decreasing, which creates a need to develop the construction sector in line with the sustainability goals.

2.7.2 EU sustainability goals

At EU level, sustainability actions have resulted in a legally binding law called the “European Climate Law”, which aims for European countries to reach climate neutrality by 2050 [23]. Additionally, there is a goal of reducing the net greenhouse gases (GHG) emissions by 55% by 2030. The goal of reaching net-zero GHG emissions means that European countries need to invest in and develop their countries through sustainable measures. This could be done by achieving greater efficiency in reducing emissions, investing resources and capital in technological advancements that reduce energy use or utilise green energy, and preserving the environment.

2.7.3 Swedish sustainability goals

Regarding Swedish sustainability goals, in 2017, Sweden took a stance on climate goals by introducing different initiatives to support and contribute to reach net-zero GHG emissions by 2045 [24]. Relating to the construction sector to combat climate change, Boverket has been tasked to coordinate the construction sector to work towards climate mitigation [25]. It is also written in Boverket that onwards, the buildings will have their emissions presented for their lifecycle [26].

3 Method

In the thesis work, the method used consisted of a review of related work in which relevant facts and background information were researched to further develop an understanding of the theme. As the thesis is regarding Total BIM and investigations on multiple perspectives, the study adopted a qualitative research approach. To gain further understanding of the subject, several workshops were held with industry actors, while interviews were conducted during a later stage to collect data on topics that either required further explanation or to fill in gaps of knowledge. A manual thematic analysis was also used to structure the data collection and interpretation process. AI usage throughout the thesis work was also introduced to show transparency in using these tools. Lastly, a description of choice of method was described to illustrate how different approaches could affect the overall results.

3.1 Background study for data collection

The first part of the thesis work was to establish a background based on related work. The key elements of the related work consisted of several perspectives on the subject.

To learn about the Swedish construction sector, sources were used from governmental websites such as Upphandlingsmyndigheten **upphandlingsmyndighetenB**, [8], [9], [10], [11] and Boverket [12], [26], as well as published research papers. These were used as reliable sources to gain an understanding of how the construction process works in Sweden, which documents are involved during the construction process, and also the standards used within projects.

To understand the key elements of the related work in the thesis, Total BIM, Level of Development (LOD), Model Maturity Index (MMI), and Function Maturity Index (FMI), several types of sources were used. Firstly, to learn about Total BIM, published academic papers from Svensk Byggtjänst [3] and Chalmers University [4], [5] were used. Secondly, to form an understanding of LOD, several websites were used, such as [14] and [15], as well as research papers on the related work [6], [18], [16] and [17]. Regarding MMI and FMI, several Swedish and Norwegian research papers were used, such as [6], [7], [18] and [20]. To gain an understanding of the upcoming contractual standard, AB25/AB27, and an overview of their content, data from Svensk Byggtjänst [3], was used.

Lastly, to gain an understanding of the current sustainability goals at the UN, EU, and national level, sources from Boverket [12], UNEP [22], the European Commission [23], Naturvårdsverket [24] and UNFCCC [25] were used.

3.2 Workshops

The workshop series conducted during the thesis consisted of five online workshops, which were focused on discussions regarding the potential adaption of Total BIM, MMI, and FMI within the Swedish construction industry. In total, eleven transcriptions were produced from these workshops, including general sessions, breakout room discussions, and summary sessions. All workshops and discussions were conducted digitally via Zoom, and no physical meetings were held.

The authors of this thesis participated primarily as observers and contributors in the workshop sessions. The authors of the thesis attended Workshop 3 and Workshop 5, by actively listening to the discussions that were held. The participants from different disciplines within the construction sector shared experiences, reflections, and perspectives regarding the implementation of model-based workflows and maturity frameworks. At a later stage, the authors introduced elements of the thesis work and preliminary findings.

In total, approximately 20 industry actors attended these workshops based on their interest in the topic on that workshop, see Table 3.3. These participants have roles within the construction industry with specialised knowledge in digitalisation and BIM, for example developers, project managers, researchers, and specialists. Prior to each workshop, discussion topics and questions were distributed to provide participants with an overview of the intended discussion themes.

Each workshop generally began with an introduction by the workshop leader, who presented the purpose, agenda, and structure of the session. This was followed by presentations on ongoing developments related to Total BIM, MMI, FMI, and associated implementation challenges. In several workshops, participants were divided into smaller breakout rooms and discussed predefined questions and topics in smaller groups. These discussions were later summarised and discussed in the summary session afterwards.

After each workshop, the transcribed material was analysed qualitatively to identify recurring themes, implementation barriers, practical experiences, and perspectives related to the Swedish construction context. Below, in Table 3.3, is a summary of each transcription, the type of session, as well as a short description of what was primarily discussed.

Table 3.1: Overview of workshop transcriptions, page 1

Transcription	Type of session	Description
1	Main workshop 1	Introduction to Total BIM and MMI as parts of a more model-based way of working. The main point was that MMI becomes necessary when the model takes a stronger role than drawings, since status must then be managed at the object level.
2	Breakout room discussion 1.1	The transcript focused on how MMI can be used practically at the object level, especially in relation to electrical design, checklists, status levels and buildability. The main point was that MMI clarifies what can be built, what should be reviewed and how changes can be linked to promemoria (PM) changes.
3	Breakout room discussion 1.2	The transcript discussed MMI as a tool for communication, requirements and quality assurance in the shift from document-based to model-based control. The main point was that MMI can improve prioritisation, progress tracking and redesign control, but requires clear requirements and organisational support.
4	Breakout room discussion 1.3	The transcript summarised and problematised the need for MMI, especially whether the industry needs a new system or can apply existing statuses at object level. The main point was that MMI is mainly seen to create clearer communication, filtering and maturity control in the model.

Table 3.2: Overview of workshop transcriptions, page 2

Transcription	Type of session	Description
5	Summary session 1	The transcript addressed both opportunities and doubts regarding MMI, as participants discuss whether additional status levels add value. The main point was that MMI can support process control, prioritisation and the transition toward Total BIM, but it does not solve basic issues such as poor model structure or unclear IFC data.
6	Main workshop 2	The transcript discussed the need for a clearer working method for Total BIM, especially through checklists, review routines and support for design managers. The main point was that MMI and FMI must be linked to practical control of what should be modelled, reviewed, tested and followed up in different phases.
7	Main workshop 3	The transcript introduced MMI as a possible common standard for information flow from early ideas to facility management. The main point was that MMI can increase trust in the model by clarifying status, traceability, buildability and the connection between design, production and operation.
8	Main workshop 4	The transcript concerned the planning of the Total BIM day and how the forum should communicate the difference between traditional work, Hybrid BIM and Total BIM. The main point was to frame why model-based work is needed, focusing on requirements, process, tools and changed ways of working.

Table 3.3: Overview of workshop transcriptions, page 3

Transcription	Type of session	Description
9	Breakout room discussion 4.1	The transcript discussed organisational and procurement-related barriers to implementing Total BIM in larger organisations. The main point was that clear client requirements, appropriate consultant procurement and active leadership are needed for model-based work to function in practice.
10	Summary session 4	The transcript focused on how the Total BIM day should begin by showing effects, benefits and concrete project results rather than only technology or culture. The main point was that the industry needs evidence that Total BIM can lead to faster, cheaper and more controlled projects.
11	Main workshop 5	The transcript presented the master students' synthesis of previous workshop material concerning the paradigm shift from drawing-based work to Total BIM. The main point was that MMI and FMI are highlighted as central supports for status, quantities, follow-up, review and decision-making, while organisational and cultural barriers remain.

3.3 Interviews

After the data were collected from background studies and workshops, interviews were conducted through Microsoft Teams to further deepen the understanding of the research topic. The purpose of the interviews was to complement the workshop data by addressing remaining uncertainties and gaining a deeper understanding of the meeting points by further asking the group members on their individual perspective. These interviews also helped answer remaining questions or confusion regarding the topic.

The interviews were based on a qualitative semi-structured model, meaning that interview questions were prepared beforehand but then improvised in the interview depending on the flow of the interview. The idea was to make use of prepared questions that answer the main confusion, and then during the interview period, make use of the time to develop follow-up questions.

The interviewees were chosen based on their contribution in the workshops. The aim was to include individuals who had already participated in the preceding workshops and had shown relevant experience and engagement in discussions related to Total BIM, MMI, and FMI.

The targeted participants represented different roles within the construction sector, and these were as follows:

- BIM Developer
- Electrical Engineer
- Contracting Engineer
- VDC Specialist
- Digitalisation Leader
- BIM Strategist

The interviewees were contacted via email. In total, approximately 11-12 individuals were invited to participate in the interview study. Among these, six individuals participated in the interviews. The interviews lasted between approximately 30 and 60 minutes, depending on the participant's availability and the depth of the discussion. The structure of the semi-structured interview containing questions can be found in Appendix A.

3.4 Qualitative analysis

The analysis of the collected data was carried out in several steps. The data collection generated a large amount of data from related works, workshop meetings, and interviews. The analysis therefore began by structuring the material into more manageable parts by identifying and planning an analysis structure. This resulted in an analysis similar to manual thematic analysis structure.

The first step in the manual thematic analysis was to become familiar with the data collected from related works, workshops, and interviews. This was done by re-watching the workshops and interviews and generating a text overview of the data using AI. The thematic analysis was then continued by creating codes in the form of highlights and notes taken during the correction of the transcription content generated by Microsoft Word for the workshops and interviews. By comparing the codes from the transcriptions with the overview generated using AI, recurring themes were identified. These themes were then reviewed by cross-checking whether they were potential analytical topics that were relevant to the purpose and research questions before moving to the next step.

After categorising the collected data into analytical topics, the material was repeatedly processed by reading and comparing different sources. This was carried out to determine whether there were similarities, differences, or contradictions. The idea was that the review of related works would serve as a theoretical background to the study. The workshop results were meant to provide data that represent statements from industrial and experienced industry actors, including their experiences and examples. Lastly, the interview findings served to reinforce data that were either missing, unclear, or required further discussion.

Regarding the legitimacy of data, a finding was considered reliable if it was a recurring topic across multiple workshops, and at the same time, was supported by the review of related works or interviews. At the same time, if a finding was only brought forward once or lacked supporting evidence, it would be considered more cautiously and therefore formed a smaller portion of the overall result.

3.5 AI Usage

Because of the large quantity of material obtained from conducting workshops and interviews, AI were used to assist the structuring and to gain a textual overview on recurring themes. AI was also used for the purpose of increasing efficiency in the thesis work and saving time. AI was also used to transcribe online workshop meetings. The content was then cross-checked against the audio files to ensure that the content was transcribed correctly. Lastly, AI were also used to highlight important parts of the transcriptions from workshops and interviews to code for manual thematic analysis. Several figures were also translated into English using AI.

3.6 Choice of method

As previously mentioned, the choice to participate in workshops and conduct interviews with workers actively engaged in BIM was made to ensure that the data collection related to MMI and FMI was supported. As these concepts are not yet implemented on a large scale within the Swedish construction sector, it was crucial to find respondents with sufficient knowledge of this subject to be able to generate relevant results. Therefore, most participants were already interested in these concepts.

It is also important to note that the empirical data generated from the workshops and interviews were based on the respondents' subjective experiences and opinions. The findings in the results should therefore be understood as reflections from experienced professionals from different disciplines who have previously worked with similar terms and data.

An alternative approach could have involved a broader range of participants with varying levels of knowledge about BIM and digital maturity. Such an approach could have provided a broader and wider range of perspectives from participants in disciplines that are less familiar with the concepts of Total BIM, MMI, and FMI. However, to be able to generate meaningful conclusions, rather than producing an argumentative discussion, the report had to be based on the potential benefits of digitalisation rather than the disadvantages.

4
Results

This chapter compiles the most important parts from the Workshops and the interviews conducted.

4.1 Workshop results

The workshop meeting results provided empirical material based on the five workshop discussions regarding the main themes of Total BIM, MMI and FMI. Although the workshop discussions have covered a wide range of topics related to these themes, this section is limited to the content that was considered the most relevant in relation to the aim and research questions of this study. The following subsections therefore present the key findings from the workshop discussions, with focus on the paradigm shift towards Total BIM and the potential of MMI and FMI.

4.1.1 A paradigm shift from drawings to model-based work

The central point of discussion in the workshops has shown that Total BIM has uses in both being capable of providing a new technical and management method for projects. By using Total BIM, the Swedish construction industry can adapt an alternative way of organising, managing, and following up on construction projects. Therefore, in the workshops, two ways of project management have been further discussed. The first project management process is the traditional way, centred around documents in which drawings and reviewed documents are key delivery elements. The second process discussed is the ongoing paradigm shift, to go from a document-centred work process to an information-centred work process, where the digital model contains the main source of data and information.

In the ongoing paradigm shift, the digital model is supposed to serve as a basis for status levels, quantities, decision-making, project management, and to support production and operation in the project. Currently, projects are mostly using digital models to visualise and coordinate projects, while drawings are still used as the final basis for decision-making, putting projects in a Hybrid BIM situation. It has also been mentioned in the workshop discussion that almost 41% of the design phase is spent on drawings which has been seen as a substantial amount.

Hybrid BIM is described in most of the workshops as an imperfect solution, being a work process that could risk undermining the entire model-based work process.

Many participants have mentioned that as long as both drawings and models are used in parallel, the situation creates room for wrong interpretations of data. A Business Area Manager has explicitly described in one of the workshops that Hybrid BIM creates more need of reviews and approvals. This results in more sources to extract information from, and consequently, increases the risk for misinterpretations.

Likewise, many other participants have pointed out that, in construction sites, many workers return to drawings whenever a stress-filled situation arises. The perception is that drawings are clearer to understand, not necessarily that the digital model is lacking information. This issue has been addressed in a previous thesis work mentioned in the workshop that industry workers in the construction sector have been tested to identify and correct notices at the site in two different platforms, one using 2D drawings and one using 3D drawings [27]. The results from the thesis work were that in a 3D model-based environment, time was less consuming to identify. Another study mentioned in the results was also that the mental strain of using 2D drawings was higher than using 3D models to identify issues or to look for data [28].

It was also highlighted that the paradigm shift from Hybrid BIM to Total BIM should be developed and adapted in smaller increments. Discussions in the workshop have shown that objects, geometries and rooms could partially be allocated a status level while others remain supported by drawings and traditional documents. This is to make sure that the transition is not too large at once for the organisations, and at the same time, understand model-based workflow and gain more trust in the model. These two different workflows can then be compared, and the organisations themselves can choose to adapt model-based workflows on a larger scale. This is especially apparent in the workshops, where discussions compare the different usage of BIM in Swedish and Norwegian projects, especially the ones that discusses Helse Bergen in BUS2, a Norwegian project. In these discussions, Helse Bergen has shown an example in their project in which the digital model has been used alongside takt planning and Systematic Completion as part of a coherent system.

In the workshop discussions, the development of Total BIM has also been linked to the upcoming contractual standard, previously acknowledged as AB25 but due to its delays, it is now referred to as AB27. A Researcher has also made an important point that, in future projects, to create a more standardised model-based work process, the client must take the step to add requirements and conditions in contracts that support the usage of such methods. In this discussion, AB27 has been highlighted on multiple occasions that it could serve as a strong supporting index to allow digital models and deliveries to have a higher contractual priority over the drawings and technical descriptions. Aside from the technical developments required to improve the usage and adaptation of Total BIM towards the paradigm shift, it is also important that the digital model is used as a decision-making tool and database for information. These are intended to be supported through different means such as having contractual standards for requirement conditions.

Although the results from the workshops have shown great potential in the paradigm shift towards Total BIM, the transition is still complicated as it cannot be reduced to solely a technical shift. Many participants throughout the workshops have addressed that even though the shift towards Total BIM has shown to produce many benefits, such as better reviewing processes, clearer communication of status levels, and more precise quantity takeoffs, there are still plenty of existing organisational dilemmas that need to be solved. To develop further towards the paradigm shift, Total BIM requires processes, a change in behaviour, and communication to be changed.

4.1.2 MMI as a common language for status on object level

One of the key findings in the results from the workshop discussions is that Model Maturity Index (MMI) appears as an attempt to provide the model-based process a new and more nuanced language to communicate. It recurs many times in the workshops that while the traditional document concepts, such as project planning documents and construction documents, still have a function in projects. However, they are perceived as being too vague in practice to accurately describe the information in a model. A BIM Developer has emphasised that traditional documents and statuses normally describe the delivery, while MMI creates an opportunity to express how far the progress of individual objects, zones, or rooms has developed.

MMI has also been closely linked to recurring discussions on why traditional status concepts are insufficient when projects become more model-based. In multiple workshop meetings, there were questions regarding if a new classification system is required. In these discussions, the main argument for MMI lies in the present traditional status concepts, project planning documents and construction documents. These are considered too vague and not precise enough to capture what has been finalised, changed, ready to be built, or are still open for editing.

The workshop discussions have also shown that MMI could be used as an index to combat issues regarding promemoria (PM) changes, and changing work after something is already being built. The argument is that an object that has already received a status could technically be followed up on changes and PM changes. Through this, MMI creates great potential in traceability for changes on items that have already been built and could be linked to processes such as cost follow-ups and PM changes.

At the same time, the workshops have also shown that MMI are seldom described as a complete substitute to existing documents. Instead, MMI is perceived as a complement to established administrative and juridical concepts. A BIM Developer has emphasised that MMI is not a concept that requires all traditional processes to disappear. Instead, it should support the digital model to be more usable and make the data more precise on object level. It should also be a common language to communicate maturity that supports project management, coordination and production.

Another central aspect mentioned in the workshops is that MMI should not be perceived as only a level system, but also to present the next steps in a project. A Managing Director has described MMI as a system that identifies which object or item in the digital model is ready to be used. MMI makes it clearer that the sub-levels should be seen as not only a development progress, but also in relation to project progress which could for instance, help actors from different disciplines to make use of the information.

Furthermore, there are also discussions on that, while participants agree upon the practical benefits of MMI, such as requiring the need for status on object level, several participants are also sceptical on expressing the status through numbers, like for instance MMI100, MMI200 and so on, see Figure 2.2. Multiple participants have described that the numbers have the benefit of making descriptions shorter, clearer, easier to colour code, and work with when filtering or using different views in digital models. A Senior Lead Advisor explains additionally that, for instance, MMI375 would practically be clearer than long descriptions if everyone agrees on what it means. It does not necessarily have to be numbers that represent the working process.

Continuing, several discussions have also linked MMI to approval processes, especially to answer the questions of how an approval process would look and manage when drawings are no longer the documents that need to be approved. In this context, it is presented that the status levels in MMI could be used to identify an area or part of the model that can be or is approved and ready to be further developed. These levels are also linked to contract forms, as the index could help control which components are ready for work, when material purchasing needs to be done, and how PM changes can be managed.

Lastly, the workshop discussions have also mentioned that MMI is yet to be fully developed and tailored to the Swedish construction sector. The Norwegian standard could only be seen as inspiration but not transferable, and therefore MMI needs to be further developed in accordance with existing relations such as BEAst and other processes.

4.1.3 FMI as a complement to MMI for functional systems

In parallel to the development of MMI, the other related index, the Function Maturity Index (FMI), is also needed. While MMI overall is related to the maturity status of objects, FMI is used to identify the maturity of systems and functions. It is mentioned in several workshops that the difference between whether something is considered “mechanically finished” or is “functionally finished”. Multiple participants have emphasised that an object could be built or assembled on the production site without the system working, could be tested, or ready for operation. Therefore, a main finding from the workshop discussions is that FMI is an essential complement to MMI, to provide information on the system and functionality, as status on object levels from MMI is insufficient to describe whether a project is fully functioning as intended or not.

This is important as discussions in the workshops have emphasised that functions and systems do not always develop in the same progress as takt zones or other tasked work areas. A Managing Director describes that functional maturity with an object perspective is insufficient, it also requires a system perspective. Continuously, the Managing Director explains that FMI is used to understand whether a technical system is ready to be tested and used, meaning that there is a need for several other conditions that are related to the system, needs to be fulfilled.

While there are benefits to FMI, there are also many existing issues that need to be addressed. FMI has been acknowledged as being an important complement to MMI, but it is still yet to be developed. The current state of FMI is perceived as being more abstract, harder to interpret and understand, and practically used. A BIM Developer has expressed scepticism on how and where this index is supposed to be implemented in a project. While MMI can be linked and implemented on an individual object, colour or level in a digital model, FMI is harder as it is linked to the project delivery requirements, system descriptions, and other descriptions that are outside the digital model. This creates a need the same way as MMI, to be developed and tailored to Swedish standards on how it can be used, communicated and followed up.

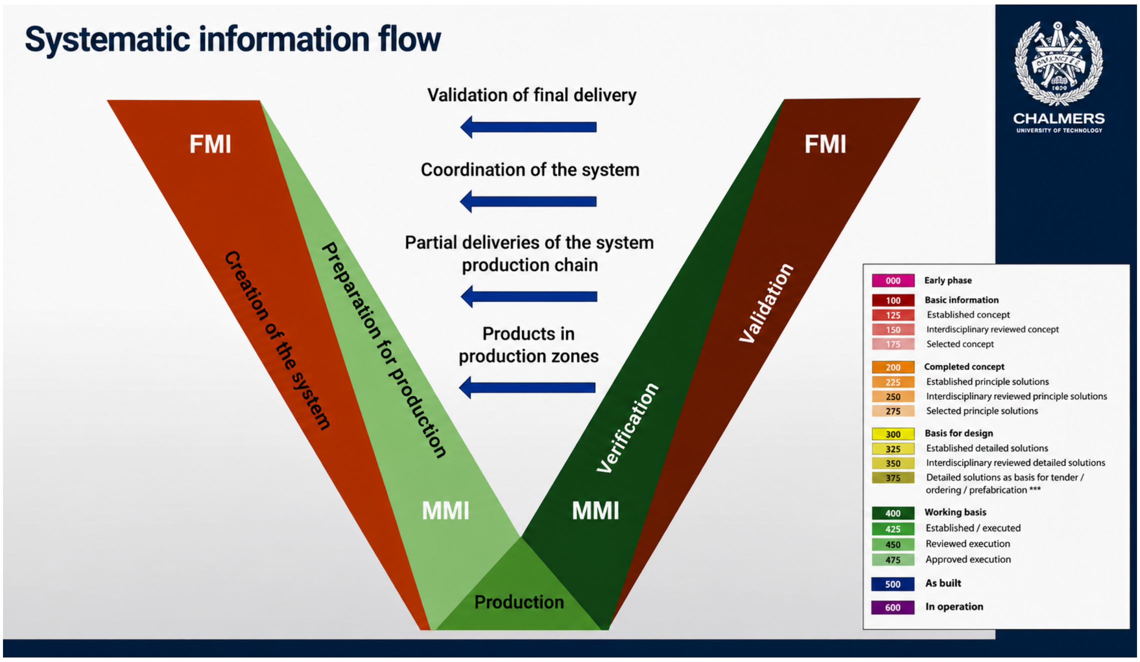

Figure 4.1: An illustration of how the FMI and MMI systems are connected and the recommended approach throughout the construction process [29].

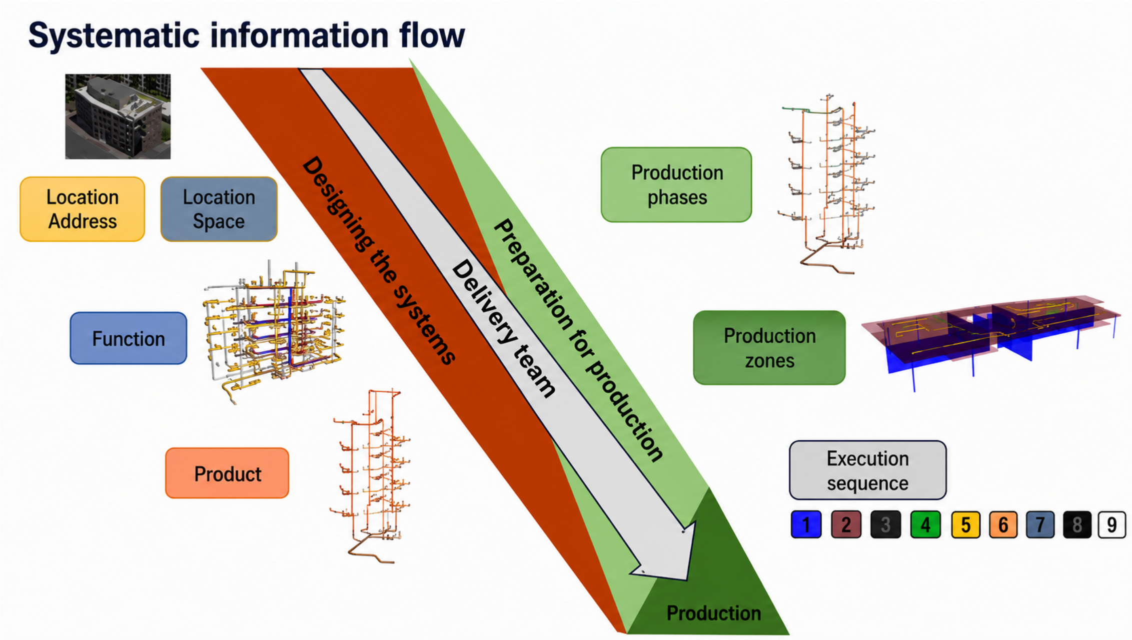

Figure 4.2: A more detailed illustration: the FMI and MMI systems are connected and used from the early stages of project planning to production [29].

4.1.4 From general review to selective model-based review

In the workshop findings, the current process of reviewing is criticised for being inefficient, cognitively demanding, and poorly adapted to the amount of information that modern models contain. Reviews seem to take place relatively late and based on an extensive number of documents where multiple different issues are addressed simultaneously. Therefore, the results point toward that the understanding of reviews is developing from how they are conducted to reflecting what is being reviewed, when it is going to be reviewed and why it is being reviewed.

This is also closely linked to discussions about 2D versus 3D review environments. A BIM Strategist describes how traditional 2D reviews often generate many irrelevant comments, because the drawing becomes too broad and undefined as a review object. If everything is represented on the same drawing, it becomes difficult to maintain focus on the value the review is supposed to create. At the same time, several participants emphasise that the transition to 3D review is not straightforward, especially for experienced project managers and specialists accustomed to 3D drawings. Therefore, the need for more integrated environments is also discussed, where users can move between 2D and 3D without having to switch tools or create confusion. Effective model review is not about abandoning 2D overnight, but about creating practical work environments where the right information is easy to find and comment on.

Another important aspect is that review in the material is clearly linked to zones, focus areas, and reduced cognitive load. Several discussions highlight that people struggle to review entire buildings or very large amounts of information at once.

The work becomes significantly more manageable when the building is divided into smaller control zones or when specific focus areas are selected as particularly critical. Another BIM Strategist describes how an infrastructure project organised its reviews by identifying ten critical focus areas, first reviewing the texts and then using the model as support. In this way, the material moves from describing reviews as a problem to showing how reviews can be reconstructed into a more selective, cognitively reasonable, and model-based process.

MMI also plays an important role here. Several participants argue that maturity levels could help project management specify which statuses should include reviews. If the reviews are no longer directed at entire drawing packages, but at specific components that have reached a certain level, it can become more relevant and more directly linked to project progress.

Multiple participants in the workshops have mentioned that project managers often lack sufficient guidance on how to organise model-based reviews. This creates a need for more clearer checklists or guides that specifies what should be coordinated at different project phases. During one of the workshops, a checklist was explicitly requested that clarifies when it is time to start designing certain parts, which dependencies need to be resolved, and what needs to be reviewed before the project can proceed.

4.1.5 Practical value of model data

Several participants describe quantities as one of the strongest reasons for a more model-based way of working. The reason is that quantity data is often not limited to one task process but to multiple project processes, such as cost estimations, procurement, planning, logistics, Life Cycle Assessment (LCA) and other environmental calculations. A BIM Strategist has also repeatedly returned to the importance of quantities and describes them to gain control over the project.

At the same time, the material shows that the mere ability to extract quantities from the model is not sufficient. A recurring issue is that different actors use different information sources depending on what they trust. A Researcher describes that different disciplines extract their quantities from the sources they feel confident in, and an understanding of why model-based quantities can be trusted is required if actors are to use them consistently. Similarly, the BIM Strategist provides a practical example from Kaj 16, where estimation and procurement are based on model quantities, while some people in production later revert to taking measures from drawings for quantities.

This has led to several discussions about how the industry can make quantity data easier to access and understand. Power BI, dashboards, colour coding, tags, and custom views are mentioned during the discussions as ways to present quantity data in a more understandable way for different disciplines. An example has been brought up by the BIM Strategist that live visualisation of data in Power BI has supported the Kaj 16 project when design and construction was ongoing at the same time. A Business Area Manager similarly highlights that quantity lists, as part of each delivery, can help consultants more quickly to take responsibility for ensuring that their coding and model information are reasonable.

The discussions have also shown that model-based work is not to remove the drawings completely. Rather, the focus lies on changing the role of drawings in which they are treated as views generated from the live model information, instead of from independent project documents. The discussions have also shown that many actors in production still need support in their daily work through PDFs or plan views. However, these should ideally be generated from the model so that designers can spend more time on improving the model quality instead of manually producing drawings. Similarly, plan views in tools, such as StreamBIM, are described as potentially live and traceable views of data rather than detached drawing documents.

The material also shows that quantities are linked to both productivity and economic value. In Norwegian and Swedish examples, quantity data is used as a basis for more efficient work planning, earlier procurement, reduced preparation time, and better logistics. At the same time, the workshop findings emphasise that late or inaccurate quantity takeoffs can result in significant cost increases. If the materials are purchased urgently, it might lead to higher list prices. Similarly, if the cost estimations are based on assumptions, rather than reliable model data, the project could also risk facing additional costs. Several participants therefore point out that quantity takeoffs become more useful when they are used throughout the project process and can support many project processes. Time wise, a Contracting Engineer has described an example from their cost estimation and tendering workflow in which a model-based quantity takeoff could reduce the cost estimation task from approximately 40 hours to 1 hour. This was done by using quantity takeoffs from models and more automated workflows in comparison to manual quantity takeoffs from drawings or other documentations.

An interesting part in the material concerned how modelling in the early stages of a project can generate direct economic value. A PhD Candidate describes how a housing project, in which increased detail in the model systems during the project planning design phase, enabled a reduction in shafts and installation spaces. This saved approximately 15-20 m^2 of usable residential area which spared several millions in improved project economics for the client. Thereby, modelling was also framed as a means of improving decision support and increasing economic value. It was thus suggested that more detailed and integrated model information can, in some cases, produce financial benefits by enabling better decisions earlier in the process.

4.1.6 Control zones, 14-0/17-0, and Systematic Completion

Another theme presented in the material is that MMI and FMI only become meaningful when they can be integrated with working methods and process executions. This is particularly relevant when discussing takt planning, takt zones, 14-0, 17-0, and Systematic Completion. 14-0 and 17-0 are planning and control methods that structure the transition from design to production through a countdown of 14 or 17 weeks before construction starts. These methods create milestones, deliverables, and maturity requirements to ensure that information, coordination, and decisions are sufficient before construction can begin. The aim of these methods is to create predictions by resolving issues during the design stage rather than during construction. Several participants often return to the idea that maturity levels themselves do not create value unless they are utilised within a framework with clear decisions, reviews, and handovers between design, production, and later verification.

Control zones are therefore an important function as it divides the project into smaller areas. It becomes possible to coordinate, review, and build the model progressively. A Researcher describes how Helse Bergen divided a project into manageable control zones of 500 m^2, which are then linked to takt planning in both design and later production. Several discussions emphasise that people struggle to review and understand an entire building at once, but that smaller zones make it more practical.

The concepts, 14-0 and 17-0, are used in the material as ways of linking design and production over time. The key point is not the specific week numbers themselves, but that design must systematically begin preparing a zone before production. A Managing Director repeatedly emphasises that what matters is what an area or object is ready for in the next step. By integrating maturity levels to the methods, the levels can be used as signals for when reviews can take place. The maturity levels can also clarify when the model information is sufficiently reliable to be locked and ready for production.

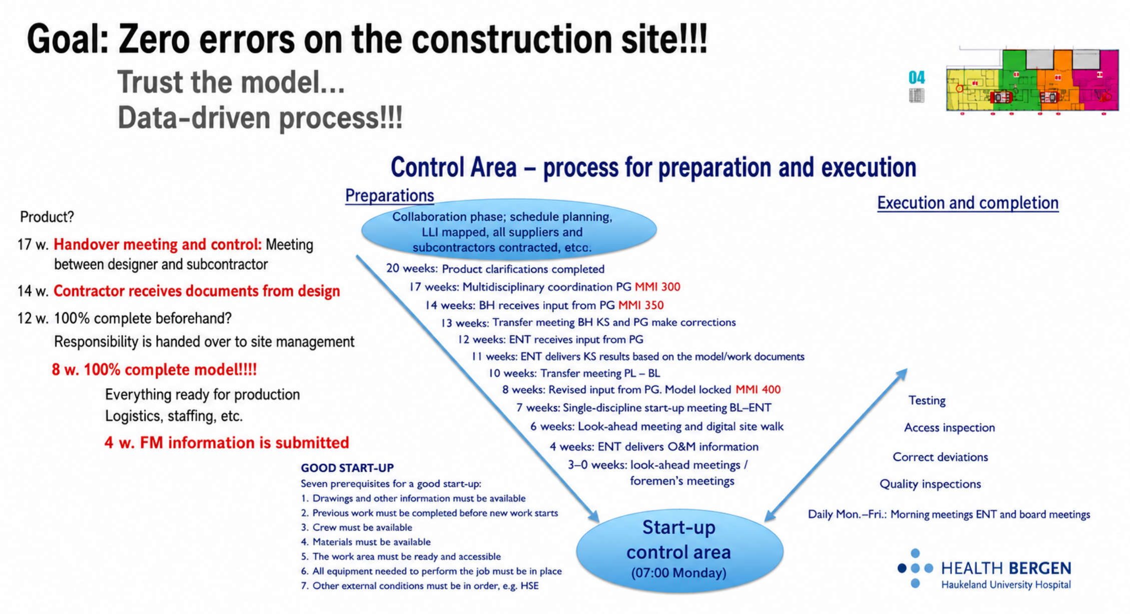

Figure 4.3: An illustration of the 14-0/17-0 methodology as a timeline from early design to construction start and execution. Source: Helse Bergen.

Systematic Completion further deepens this logic by connecting the left side of the process where requirements, functions, and conditions are established, with the right side, where systems are tested, verified, and commissioned, see figure 4.4. FMI becomes particularly important in this context, as it represents the functional maturity of various systems that extend across multiple control areas. While MMI asks the question of whether an element is “ready to be built”, FMI focuses on whether it is "ready to be tested, used, and operated”. Together with control zones and takt logic, these two indices contribute to a broader framework to be able to support the entire process chain, from design, through verification, and lastly, into operation.

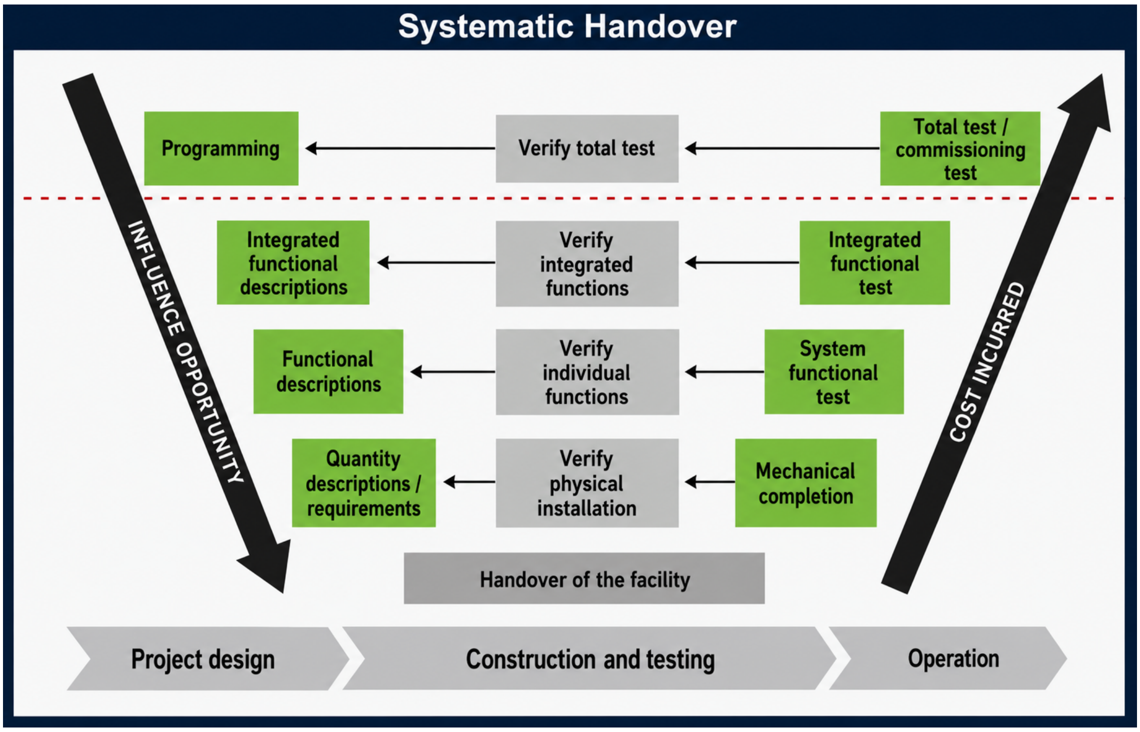

Figure 4.4: An illustration of the principle of systematic completion in the construction process, where verification and testing are carried out progressively from design to operation [29].

4.1.7 Barriers to Total BIM implementation

A clearly recurring aspect in the material is that the barriers related to Total BIM do not appear to be technical. Instead, the core problems lie in requirements definition, procurement, leadership, communication, and organisational maturity. This creates an importance in who sets the requirements, how the project is organised, and which roles receive support to work in new ways. Several participants note that the transition to Total BIM is often described as a specialist issue, when in fact it is largely a management and client issue.

The role of the client is particularly emphasised. The material shows that clear client requirements function as a key factor in creating confidence in projects attempting to implement a model-based approach. A BIM Strategy Manager describes how a client creates opportunities for action within the project organisation. This reduces internal uncertainties regarding whether the approach should be used and instead focuses on how it should be implemented in practice. If the client is unclear, the transition is often left to enthusiasts, engaged project managers, or individual site managers, making the change much more dependent on individuals and more fragile.

Continuingly, several participants describe how projects with high digital ambitions stall before design even begins because consultants and contractors have not been procured under the right conditions. The BIM Strategy Manager points out that procurement functions often lack an understanding of what Total BIM or model-based project control entails. Furthermore, a Project Manager also warns that procurement that mainly focuses on lowest price or traditional risk transfer can counteract digital approaches. In practice, this could reward hybrid solutions and duplicate work rather than model-based processes. As a result, the project risks starting with conflicting values on how the work should be carried out.

Leadership is another recurring theme, especially in larger organisations. A Project Manager describes how smaller actors can more easily start a new way of working, while larger organisations must build systems that function beyond the input from individual enthusiasts. At the same time, it is emphasised that leadership at the project level is crucial even in large companies. If project management lacks confidence or perceives the model-based approach as financially risky, the likelihood increases that they revert to traditional methods.

One of the discussed implementation barriers was related to roles such as project managers, site managers, estimators, and procurement managers. Several participants mentioned that design teams are generally able to adapt when the requirements are clearly defined, and that tradespeople can work in model-based workflows when they are provided with sufficient inputs. The difficulty instead arises among those responsible for leading, coordinating, planning, procuring, and following up the work based on the model. The same Project Manager notes that their daily work has not necessarily become easier with a more model-based project, since tools, filters, and information structures are still often designed around engineers' needs rather than site managers.

This is linked to the need for better filtering, production phases, and more role adapted tools. The same PhD Candidate argues that zones alone are not sufficient, since a zone only indicates where something happens, not what should be done at a given production stage. If site managers are to use the model as a control tool in the future, the information must therefore be organised so that responsibilities, content, and dependencies can be filtered in a way that reflects the actual logic of the work. At the same time, the workshops emphasise that the transition to Total BIM principles also depends on client and facility management. A Senior Lead Advisor points out that if facility management does not know what it wants in the future, it becomes difficult to define the right information deliveries today.

4.2 Interview results

The interviews largely confirm the central tendencies already identified in the workshops, but they also move from exploring the subject, to a more concrete and implementing discussion. Since all respondents were asked similar questions, the interviews largely preserve the same thematic structure identified in the workshops. However, they also contribute to new insights through more in-depth and reflective follow-up questions, illustrating how the issues are interpreted from different professional perspectives, including design, VDC leadership, contractor practice, BIM strategy, and client-side information management.

4.2.1 MMI as an emerging industry practice

Across the interviews, like the workshop results, a key finding is the agreement that MMI becomes increasingly relevant as projects adopt more model-based approaches. Multiple respondents have described that documents, such as project planning documents and construction documents, may still serve administrative purposes but provide limited insight into the maturity of model objects. In the interviews, MMI is therefore repeatedly described as a way of moving status from document level to object level. This is also seen in the interviews with the BIM Strategist, the BIM Developer, and the Electrical Engineer, where MMI has been described as a precise way of describing what is buildable, reviewed, coordinated, or mature enough to move forward.

The BIM Strategist expresses that if the sector is to work object-based, then object level statuses are not optional but a necessity. At the same time, it was described that the actual labels could in principle have been called something else. What matters more is that the whole sector works according to a shared logic rather than each actor inventing their own terminology.

The interviews have also shown that MMI is not fully interpreted as a complete replacement for everything that exists. While the BIM Strategist argues that existing systems become insufficient once a project wants the model to govern information, the Lead VDC Specialist gives a counterargument by pointing out that large organisations already have milestone structures such as partial deliveries and internal status logics that resemble MMI. The interviews therefore showed that the key issue is not simply whether the sector already has statuses, but whether those statuses are detailed enough to support procurement, quantity takeoff, review, and handovers. The BIM Strategist has also strengthened the argument that there are currently many existing classification systems which were never used such as LOIN or LOD besides pedagogical purposes, but MMI has been used several times in practice.

4.2.2 From concept to implementation

A recurring theme identified in the interview results is that the respondents are concerned with how it would be introduced in practice. Several respondents have similarly stated that if no client, contract, or project instruction requires a model-based maturity logic, then most actors will most likely continue without changing. The Contracting Engineer has then added that if there is no requirement, contractors will generally not add new innovative solutions voluntarily. The interviews therefore support the workshop findings that adaptation does not begin with enthusiasm alone, but with explicit requirements. At the same time, the Contracting Engineer adds that the implementation cannot begin too hard, but neither can it be too simple. If the requirements are too strict, actors may avoid the project in the tendering phase, which can reduce competition. However, if the requirements are too weak then they risk being treated as optional, in which the transition toward Total BIM and MMI will be protracted.

Furthermore, the interviews suggest that setting requirements alone is insufficient. The Lead VDC Specialist argues that even when a requirement exists, production and project teams still need to understand what the requirement gives them, otherwise it will be experienced merely as another imposed demand. The BIM Developer describes the same issue from another angle that MMI must become part of the project's everyday language. This means that people must begin to ask what has reached a certain maturity level rather than only thinking in terms of ordinary document deliveries. The interviews therefore complement the workshops by showing that implementation is not only about writing MMI into contracts or manuals, but also about translating it into everyday routines, language, and decision-making practice.

4.2.3 The usability of MMI in comparison to FMI

A very consistent finding across the interviews is that MMI is perceived as significantly more developed and practically used than FMI. The BIM Developer states this by arguing that MMI is easier to connect to the model to present information, while FMI is more about systems and functions which is harder to define. The VDC Specialist reacts in a similar way but treats FMI as yet another classification that would need major anchoring. It was further discussed that the organisation already uses simpler properties such as whether something has been tested or not. The Electrical Engineer, despite direct experience from Kaj 16, also confirms that the project has, so far, worked only with MMI and not with FMI in any strong sense. Even the BIM Strategist, who argues in principle that a fully object-based and data-driven process should ideally include both MMI and FMI, admits that in practice has managed with MMI alone. The Contracting Engineer further mentions that introducing both systems at once may simply double the workload in already time-pressured projects. It was therefore emphasised the importance of slowly introducing simpler requirements to ease the transition and make the process more manageable.

In terms of software usage, the Electrical Engineer suggests that functional maturity may need to be used in room-based requirement systems such as dRofus rather than directly in the geometric model. Based on the interview material, dRofus is a database-based room function program for requirement management that can later be integrated with other softwares, such as Revit and StreamBIM. The interview findings therefore show that while FMI is relevant, it still lacks the practical clarity, shared vocabulary, and implementation that MMI has begun to develop.

4.2.4 Insufficiencies in the existing systems

The interviews make it clear that one of the main tensions in implementation is if actors experience MMI as merely another way of saying "construction documents approved", then the new system risks being undermined. The Lead VDC Specialist argues that this issue needs to be addressed but at same time still see the value of the intermediate levels of MMI. The BIM Strategist's interview findings further adds that even if the exact classifications could have been named differently, a common system in the sector is still needed if model-based work is to be developed further. Otherwise, the industry risks ending up with more local solutions that all try to express the same maturity logic but in different ways.

A final addition that emerges, particularly from the BIM Strategist's interview, is that implementation is not only about maturity levels and contractual support, but also about the interfaces between actors. It was stressed that the need to define boundaries clearly between architect, structural engineer, and prefab designer, to avoid duplicate work in the model are essential. This means that a common maturity system alone is not enough. The project also needs a structured way to tell who owns which parts of the model and when, otherwise the benefits might be undermined by risk of double work and conflicting information.

4.2.5 Organisational barriers to implementation

The interviews indicate that the main barriers are not simply software limitations or lack of theoretical concepts. The construction sector already has the machines, tools, and softwares. The more difficult part is convincing people, changing habits, and getting actors to work in new ways. Instead, the obstacles are mainly organisational, linguistic, cultural, and competence related. The BIM Developer emphasises the difficulty of making MMI part of everyday working language while the Lead VDC Specialist highlights that many actors still think primarily through drawings, descriptions, and separate documents. The Digitalisation Leader's interview then complements this by arguing that the sector's real problem is often risk and reward. Even if a more model-based process promises gains, the person responsible for the project may not be willing to carry the risk of trying something new when the potential reward is not proportional to the testing. The BIM Strategist points out that successful implementation can be difficult if it depends too heavily on a few committed individuals.

While some workshop participants had shown reluctance to leave drawings behind, the interview respondents have explained that this reluctance is not only about comfort. It is also about professional identity, data usage, internal routines, too many codes, and the scale of organisational change. The interview material shows that implementation requires a reorganisation of how people interpret information, coordinate responsibilities, and perceive the value of their own competence. This also relates to both the Electrical Engineer and the BIM Developer, who in different ways point out that people need to be brought into the transition without feeling that their earlier knowledge has become irrelevant.

4.2.6 Value, risk and tendering conditions

The interviews with the Contracting Engineer shows that even when the need exists, there is a concern that stricter requirements may reduce tendering competition if only a small number of actors can meet them. The cost of training and competence development was also highlighted and argues that implementation therefore needs to be phased: too weak and nobody follows it, too hard and actors become afraid or excluded. The Electrical Engineer and the Lead VDC Specialist reinforce the same broader point from different directions. The Electrical Engineer shows that once a project genuinely works without drawings, MMI becomes practically useful very quickly, but also that it requires discipline-specific adaptations, tool developments, and more detailed object-level work than many are used to. The Lead VDC Specialist adds that the real cost problem does not lie primarily in software, but in maintaining hybrid ways of working where new model-based logic is layered on top of old routines.

The Contracting Engineer also adds that the ability to work with Total BIM and MMI can become a strategic advantage in future tenders. While actors who learn these methods early may be better positioned when such requirements begin to appear more often, the same early move could also end up exposing them to risk if something goes wrong in the project. The Electrical Engineer further said that disciplines experienced the transition from 2D schematics to a model-based way of working as demanding but workable, and even as a positive challenge. Continuingly, they stated that with the right support and motivated individuals, the move into a fully model-based workflow can be experienced as relatively smooth.

The BIM Strategist additionally stated that Kaj 16 could serve as a potential future reference point for Total BIM oriented projects. If a project has shown that object-based maturity logic, model governance, and role adapted information can function in practice, then it becomes not only an example, but a kind of practical template for future attempts. In that sense, the interviews show that innovation is needed and successful pilot projects are essential as proof that the industry can move forward by testing new ways of working.

5

Discussion

The discussion chapter integrates the empirical material gathered from related works together with workshop findings and interview results to form an analysis.

5.1 Governability as an additional issue to digitalisation

A first finding is that the transition is more fundamentally about the governability of information. As [4], [5] already shows, BIM can be implemented in multiple ways, from a coordination method to Total BIM, where the model becomes the primary source of information. Specifically, Section 4.1.1 suggests that Swedish projects can use digital models without necessarily having to change how the project is governed. Therefore, digital maturity and governance maturity do not necessarily have to develop in parallel. A project may rely heavily on models while still depending on traditional decision structures that contain familiar routines and rely on drawings and documents that are perceived as trustworthy information. This helps explain why the transition to using Total BIM principles appears to be slow in relation to technological advancement. The main point is if the industry is willing to have object-based data carry the kinds of commitments, approvals, and responsibilities that have traditionally been attached to drawings and documents. This points to a deeper institutional shift, from documentation and drawings carrying the main project information, to model-based workflows taking on that role. This is perceived as a more demanding transition than introducing new tools or software. This interpretation is further supported by Section 4.1.1, where the workshop material describes Hybrid BIM as a phase where models become increasingly more important, while drawings still contain information that is used for approvals and decision-making.

5.2 MMI as a commitment management system

Another analytical point is that MMI has its full potential when it is committed as part of a management system rather than solely as a maturity label. In [7], [18], MMI is described as a framework that links the maturity of information in models with the project phases, decision-making, and buildability. The empirical material, especially Sections 4.1.2, 4.1.6, and 4.2.1-4.2.4, suggests that this is also where its value is located. This means that rather than only describing objects, the value of

MMI lies in defining when a project is sufficiently prepared to transition towards the next step. This may concern review, procurement, handover to production, quantity takeoff, or other forms of action. This means that MMI could potentially improve the timing of foreseeing risks, making it possible to take more clear and decisive actions earlier in the process. From this perspective, MMI can be interpreted as a way of structuring to notify when actors can safely act on information. This is also supported by the interview material in Section 4.2.1, where MMI is repeatedly described as to what an object is ready for rather than what it is.

5.3 Using MMI to reduce uncertainty between project phases

In the literature, particularly [7], [18], MMI is presented as a maturation of objects that progresses from initial design to production and finally represents what is built on site. However, the empirical material in Sections 4.1.2, 4.1.6, and 4.2.4 has also shown that the most challenging part is not the transition between the main levels of MMI that develops in increments of hundreds. Instead, the difficulty is concentrated in the sublevels in between, where information is too developed to be treated as being in early development but still not mature enough to be confidently used for construction, procurement, or formal approval.

MMI can therefore be used as a way for managing uncertainty between project phases where information is neither preliminary but not developed enough to get full approval. This interpretation is important because it also helps explain why some respondents question whether a completely new system is needed at all, given that milestone-based structures already exist such as Level of Information Need (LOIN) and Level of Development (LOD). However, the material suggests that there is a lack of precision in how transitional states are handled. The strength in MMI is in making the sub levels governable in a way that current practice does not fully support. The Lead VDC Specialist has also emphasised that the practical value of MMI lies in signalling when an object is ready to move forward, rather than simply assigning it a label.

5.4 FMI and system thinking

The literature describes FMI in [6] as a necessary complement because complex construction projects cannot be evaluated only by whether objects are installed. The systems must also be functionally complete, tested, and progressively approved. However, the empirical material, especially Sections 4.1.3 and 4.2.3, suggests that FMI is less implemented in practice than MMI. This does not only mean that FMI is underdeveloped, it also shows that the Swedish construction practice appears more prepared to govern objects than functions. This shows that MMI and FMI cannot be treated as two parallel frameworks developing at the same pace. They address different governance challenges, MMI fits more naturally with existing structures around objects, visual modelling and staged delivery processes, while FMI requires projects to define technical functions and systems. As a result, FMI therefore requires a different type of information structure and a different type of organisational discipline. This suggests that a realistic implementation in Sweden should start with MMI, but over time, it would need to develop into stronger connections between objects, technical systems, and functions. The Electrical Engineer in Section 4.2.3 mentioned that functional maturity can possibly be connected to room-based requirement tools such as dRofus which shows potential in adaptation.

5.5 Translating MMI and FMI logic into Swedish context

Another analysis topic is that the Norwegian references should not be treated as something that the Swedish construction industry either copies or rejects, as the project logics are different. Therefore, the sector must translate the underlying logic into Swedish contractual culture, project organisation, language, and existing milestone traditions. This is also reflected in Section 4.1.2, where the workshop results show that the Norwegian standard can serve as inspiration, but not something that is going to be directly transferable.

The interviews further show that the real difficulty lies in compatibility with Swedish contract structures, existing delivery systems, and how the sector talks about different project and document steps. This is also reflected in the interview with the BIM Strategist that what matters most is not the exact label, but that the sector develops a communicative structure and standard for project communication.

5.6 Making maturity information useful for project governance

Another aspect identified is that the most difficult implementation zone lies in roles such as managers, estimators and procurement managers. The study on related work discusses the organisational and contractual implementation of model-based work, while the results point toward problems around project management, procurement, review, planning, and support for these actors, particularly in Section 4.1.7. The difficulty is seen to be in roles that are actively working for transitioning the design to execution. These actors are still working within a governance system that is centred around documents, milestones and broadly defined delivery packages.

As a result, implementation success depends more on whether the maturity information in the model can be made clear, usable, and trusted. This interpretation is strengthened by the BIM Developer's comments regarding the routines and reflects that everyday practice depends on shared languages and habits may result in more usability and understanding of the content. At the same time, the Lead VDC Specialist's reflections are hesitant to use yet another status system in addition to the existing ones, as it can lead to confusion. This shows that the current industry needs to define a standard way of working with status levels to avoid confusion.

5.7 Selective implementation of MMI and FMI

Another analytical implication is that the material does not point toward a single solution that works in all projects and disciplines. Instead, it points towards the solution being scenario-based, where maturity logic is likely to provide more benefits. This is shown in, for instance, complex projects that require a large number of complex installations and objects in combination with strict project delivery conditions. Analysing the study on related works in Sections 4.1.5 and 4.1.6, quantities, control zones, and process integration are described as particularly strong drivers of model-based value. This means that although MMI and FMI are not practically beneficial to implement in all scenarios, it should not be perceived as a drawback. Instead, a more realistic implementation of the indices in Swedish construction will most likely proceed first through a mix of pilot projects and innovative company challenges or clients' specific requirements. As the construction industry is in an ongoing paradigm shift, to successfully implement the indices and Total BIM, there is a need to create routines, a common language in the industry, rather than being implemented hastily. This is also aligned with the interview findings where participants have stated that Total BIM and MMI is currently tested in Kaj 16 as a pilot project where it is deemed necessary and beneficial to work with status on object level.

5.8 Sustainability aspect of MMI and FMI

The study of related works on sustainability has shown through Boverket [12], the UNEP and GlobalABC report [22], the European Commission [23], Naturvårdsverket [24], the Government of Sweden and UNFCCC [25], that the construction sector is related to energy use, emissions, and lifecycle performance. These findings suggest that MMI and FMI are not sustainability tools themselves but serve indirectly as drivers toward more sustainable decisions because they may improve how information is structured, timed, and trusted throughout the project lifecycle.

From that perspective, the sustainability relevance of MMI lies mainly in reducing resource waste through a more efficient project process. The related background work, especially [7] and [18], describes object maturity as something that is related to project needs, decision-making, and buildability. In combination with the workshop results, a BIM Strategist describes quantities as one of the strongest drivers of model-based work because they connect estimation, procurement, logistics, cost control, environmental calculations and Life Cycle Assessment (LCA). A Researcher adds that model-based quantities only become valuable when actors trust them. A business area manager has also pointed out that creating quantity takeoffs can make consultants take greater responsibility for the quality of their work. Analytically, this shows that MMI may support environmental sustainability indirectly by reducing late changes, rework, and waste created by uncertainties. Furthermore, this creates a more precise follow up on material and environmental planning.

Compared to MMI, the sustainability aspect of FMI is different and is more connected to performance during the operation phase. [6] describes that technical systems may be installed without being functionally completed, and that FMI could support Systematic Completion and operational readiness. Combining the empirical material, the analysis shows that FMI could support both environmental and social sustainability by reducing problems at operation, improving the performance of systems and functions.

5.9 Tendering as a governance threshold

Tendering is one of the areas where the transition towards Total BIM becomes practically visible, where model information starts to affect prices, procurements, and risks. The BIM Strategist connects model-based quantities with improved project control, while the Researcher points out that quantities only become useful when actors trust the model as an information source. This means that tendering is more about whether the model is mature and reliable enough or not, rather than only extracting quantities.

This also makes MMI relevant in the tendering process. The BIM Strategist, the BIM Developer, and the Electrical Engineer describe MMI as a way of transitioning status from document level to object level. From an analytical point of view, this means that MMI can clarify which parts of the model are mature enough to support quantity takeoffs, procurement, reviews, and handovers. This is important because contractors need to know what model information they can rely on and where there still are uncertainties.

At the same time, tendering also highlights the challenges related to digital requirements. The Contracting Engineer argues that the requirements cannot be too strict, since this may make some actors avoid the project during tendering. But at the same time, it cannot be too weak either, because then they may be treated as only optional. A Project Manager also warns that procurement, based on lowest price or traditional risk transfer, can work against model-based processes and instead encourage hybrid solutions or duplicated work. Tendering therefore becomes a balance between ambition and usability, where client requirements, model maturity, trust, and risk allocation must support the same way of working.

5.10 Implications for the research questions

For the first research question, MMI and FMI are most valuable in Swedish construction when the indices themselves are used as a governance tool rather than as additional BIM labels. When it comes to MMI, it appears to be a more practical starting point compared to FMI for the paradigm shift as it indicates when the model information is mature enough to support decision-making. FMI is also important for the paradigm shift but it needs a stronger integration with requirements and tests before it can become usable like MMI.

For the second research question, MMI can function as a common language when it is used as not only a label that classifies an object based on its status on object level, but instead to describe what the object is ready for. To ease into the usage of MMI as part of common language, the numerical system could support filtering, colour coding, and the generation of custom views. These processes could simplify the communication of information between different roles and increase usability. However, the findings could also be interpreted that the importance lies in actually having a shared understanding of what each level means rather than focusing strictly on the exact numbers. It is also important to have someone responsible for approvals and determine through MMI as part of decision-making on what action to take.

For the last research question, the main opportunities relate mostly to reviews, progress monitoring, when to make decisions, improved quantity management, and stronger connections between design and production. MMI and FMI may also help project teams identify which parts of a model are ready to be used, making it possible to act on more reliable information without waiting for an entire document package to be completed.

The main challenges are organisational, contractual, and cultural rather than technical. Trusting in the drawings, unclear client requirements, procurement based mainly on lowest price, limited data competence, and uncertainties regarding responsibilities can all be reasons for why the adopting takes time. However, requirements that are too demanding may instead risk excluding digitally matured organisations and actors, while requirements that are too vague may provide little practical value. As a result, implementing these indices in Sweden will likely depend on contractual frameworks and industry terminology, supported by guidance, training, and practical pilot projects.

6
Conclusion

The purpose of this master's thesis is to investigate the potential role of Total BIM, together with two supporting indices, Model Maturity Index (MMI) and Function Maturity Index (FMI), in the Swedish construction process.

Based on the data collection from related works, workshops, and interviews, the study concludes that the main dilemma is regarding how information is governed in a Total BIM project. In current Hybrid BIM practices, models are often used for visualisation, coordination and information support, while drawings and traditional documents remain as the final basis for decisions and used in production. This creates a fragmented situation where several information carriers exist in parallel. If different actors continue to rely on different sources of information, Total BIM will not reach its full potential.

The findings show that MMI can support the paradigm shift by creating a clearer structure for model maturity at object level. However, the value of MMI is not mainly the fact that it adds new labels to model objects, but rather that it can clarify what an object is ready for. Instead, MMI can be understood as a governance tool for project planning and decision-making. It can help stakeholders determine when information is mature enough for review, procurement, quantity takeoff, production planning or construction. This is especially relevant in the transitional stages between the main project phases, where information is partially developed but not yet fully reliable. This reduces uncertainties by making partial readiness between project phases more visible and manageable.

The thesis also concludes that FMI is an important complement to MMI but that it currently is under early development and not utilised. While MMI focuses on objects and model information, FMI focuses on technical systems and functional maturity. This is important because a construction project cannot be evaluated only by whether objects are modelled, coordinated or installed. Technical systems must also be tested and verified to function as intended for the client at handover. FMI therefore contributes a system perspective that is necessary in complex projects, especially in relation to Systematic Completion, testing and operation. At the same time, the study indicates that FMI requires further development and connection to contractual frameworks before it can become as practically useful as MMI.

The thesis further concludes that the implementation of MMI and FMI in Sweden should not be treated as a direct copy of the Norwegian model. Norway can provide inspiration and practical experience, but Swedish implementation must be adapted to Swedish contractual structures, existing project phases, industry language, and standards. MMI and FMI are more likely to be accepted if they are connected to project logics that actors already recognise, rather than introduced as external systems without clear relation to existing practice.

Another important conclusion is that the main barriers to Total BIM, MMI and FMI are organisational, contractual and cultural rather than purely technological. The necessary software and modelling tools already exist to a large extent. The main focus areas lie in changing routines, requirements, procurement processes, leadership structures and trust. Drawings still have a strong position in Swedish construction because they are familiar, established and connected to contracts. For models to take on a stronger role, they must become not only technically accurate, but also trustable by organisations and stakeholders. This means that a successful implementation would depend heavily on clients, project management and organisation lead. At the same time, stakeholders need to receive proper practical support to turn the maturity information into action such as clear routines, checklists, and review structures.

The potential benefits of MMI and FMI are mainly related to a clearer coordination, better timing of decisions, reduced uncertainty, improved review processes and stronger connection between design information and production needs. The thesis also shows practical value in model-based quantities, where reliable model data can support the process of quantity takeoffs for estimations, procurement, logistics, cost- and environmental assessments. However, these benefits depend on trust in the model. If estimation, procurement and production continue to use different information sources, the value of Total BIM principles is being reduced.

There are also risks connected to implementation. If model-based requirements such as using maturity indices are introduced too strictly or too early, then they may increase competence thresholds and make it more difficult for smaller or less digitally mature actors to participate in the tendering stage. If the requirements are too vague, however, then they may not change the work practice at all.

Overall, the thesis concludes that the Swedish construction sector does not necessarily need MMI and FMI as the only possible frameworks, but it does need a more structured way of managing information maturity in model-based projects. MMI and FMI represent two possible tools for this development. Their value lies in helping the construction industry move from a fragmented document-based information management towards clearer governance of model-based information. For this to happen, the sector must learn to govern information differently.

6.1 Future research

Potential further research should study how MMI and FMI can be implemented in Swedish construction projects over time. Since this thesis is based on workshops and interviews, rather than a full case study of one or multiple projects, future research could follow a project from early planning and design to production and handover in order to examine how maturity levels are actually used in decision-making, review, procurement and production planning processes.

Another relevant area for future research is the connection between MMI, FMI and Swedish contractual frameworks. This thesis has discussed contractual development at an overview level, but a more detailed legal study could be needed to examine how model maturity, responsibility and contractual status could be formulated in practice. This is especially relevant if digital models are given stronger contractual importance in future standards such as AB27.

Further research should also examine how FMI can be made more operational. The results of this thesis indicate that FMI is conceptually important, but less practically established than MMI. Future studies could therefore investigate how FMI can be implemented in Swedish projects.

Lastly, future research could focus on the organisational side of implementation. This includes how clients, project managers, design managers and production actors can be supported through guidelines, checklists, role descriptions, and training. Since the main barriers identified in this thesis are not primarily technological but rather organisational, further studies should focus on how trust, responsibility and everyday project routines can be developed to support a more model-based way of working.

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A

Appendix - Interview questions

1. As a tool used alongside Total BIM, MMI, and FMI have shown potential and provide benefits to projects. Therefore, we are wondering how MMI and FMI can be practically implemented in the Swedish construction sector. How can we proceed with the implementation?
    - Through laws and regulations?

2. How can we argue for the implementation of MMI when we have similar systems used in the construction sector?
    - For instance, partial deliveries, classification systems such as programme and construction documents?

3. A lot comes down to someone needing to take responsibility and dare to try using MMI in the construction industry. What could the industry or other stakeholders do to support this?
    Could the state, company, municipality, or subsidies contribute?
    - The up-and-coming AB27?
    - Requirements?
    - New or current EU laws and regulations?
    - Environmental requirements?

4. How can we merge the usage of FMI with MMI? How do these methods go hand in hand when it comes to projects?

    - Do we need both in a contract before projecting?
    - How are FMI and MMI determined in the construction process?
    - How can project leaders proceed to implement these?
    - Because we have not heard that this has been implemented yet, how do you think it could work in the future?

5. Which difficulties or drawbacks are there to implementing MMI and FMI in the Swedish construction sector?

    - How can we tackle these challenges?

6. There are currently many existing statistics that prove 3D-modelling and Total BIM are more effective than drawings. What are we lacking and need to

do when we need to open the eyes of other people?

7. What are your thoughts on Level of Development and Level of Detail, as these terms are very close to MMI and FMI?
    - How are LOD and LoD used today?
    - Could we somehow merge these concepts?
    - Can we take inspiration from LOD and LoD implementation to MMI and FMI?
    - If we add MMI and FMI, what will be left of LOD and LoD - system?

    How are LOD and LoD used today?
    Could we merge these concepts somehow? Can we take inspiration from LOD and LoD implementation to MMI and FMI?
    If we add MMI and FMI, what will be left of LOD and LoD - system?

8. Is there something else besides what we have mentioned that you think we are missing or want to bring up?

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