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MMI in design process Findings and improvement opportunities from a case study

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Abstract

Norwegian contractors are more involved in design management than before due to an increased number of design build contracts, and they continuously improve their design management processes. In 2018, the Norwegian Consulting Engineers' Association launched the Model Maturity Index (MMI) for BIM to support planning and control of design management. This study assesses how MMI, project sectioning, delivery lists, scheduling and follow-up procedures can improve design management processes.
After an initial literature review, qualitative data from a case was collected by semi-structured interviews with the design manager and six designers. Observations in sixteen design meetings and a document study were used to supplement the data from the interviews. The case study revealed that MMI was used to control achieved maturity for each discipline BIM model rather than for design planning. Geographical zones and discipline models – not technical systems – were used to create an overview of necessary design tasks, and the zones gave a structure for design meetings. It was neither created delivery lists for the individual disciplines, nor schedules with delivery milestones – despite recommendations in literature. As a result, the case project strived with planning the maturity level for the involved disciplines' BIM and follow-up on the design process. Recommendations on how the MMI-framework should be used in future projects are identified. For example, some improvements of coordination between MMI300 and MMI350 are suggested. Future projects should explicitly consider both geographical zones, technical systems and discipline models when creating MMI plans. Future projects should also support MMI plans with delivery lists containing tasks and milestones for each maturity level for each discipline model. Finally, the design manager should re-plan MMI-related tasks and milestones not reached in a Plan-Do-Check-Act related manner during design.

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1. Introduction

In Norwegian architecture, engineering and construction (AEC) projects an increase in design-build contracts is observed. By giving the responsibility for design to contractors, clients reduce their own risk [1], and allows contractors to implement ideas with higher internal efficiency [2]. In other words, productivity can be increased when using design-build contracts.

Research reveals that Norwegian AEC projects are struggling with the productivity in design [3]. Early design is one of the most important phases in projects [4], and complex projects cause confusing and demanding design processes that often needs close monitoring [5]. Design processes in complex projects should sometimes be carried out synchronously rather than chronologically, at least when the processes are mutually dependent.

The use of building information modelling (BIM) can improve communication in design processes [6], but it is still possible to increase productivity [7]. For example, there are examples from the Norwegian oil and gas industry where design teams utilize lean philosophy combined with model maturity management to better control design processes with BIM [8].

In 2018 a group financed by the Norwegian Consulting Engineers' Association published a framework providing a language for planning and control of BIM maturity during the design process [9]. The framework, called model maturity index (MMI), provides guidelines for planning design processes and consists of standardized indexes with descriptions of model maturity.

There are few practical studies on how contractors could use MMI. However, some literature on the structure and implementation of MMI exists (se for example [10], [11]). Still, there is a need for documenting experiences from use of MMI design processes in the AEC industry. To address this need, the following three research questions (RQ) were formulated:

RQ1: How is the model maturity index used?
RQ2: What are the strengths/weaknesses of using model maturity index?
RQ3: How should model maturity index be used in future projects?

2. Research method

The research consists of a literature review and a qualitative case study. The literature review identified a knowledge gap in the theory and built theoretical background. Keywords were used in different search engines to find relevant literature. The search started by using generic keywords as *design management* and *AEC.* Subsequently, the search was narrowed by supplying with *BIM, collaboration, LoD* and *MMI.* After the initial search the articles were reviewed using Arksey & O'Malley's [12] framework for scoping studies.

After the scoping study, a qualitative case study following the prescriptions of Yin [13] was initiated. The case was chosen because of its novel use of MMI in design and because the first author – part time employee with the contractor – had access to design meetings and project documentation. Key characteristics of the case are presented in **Error! Reference source not found.**.

Table 1. Characteristics of the studied case.

Name	Contract	Cost	Location	Content
Sjogata Panorama	Design build	110 Million Norwegian kr.	Finnsnes, Norway	• Underground parking garage in concrete • Four separate apartment buildings made in wood

Yin [13] highlights the importance of gathering data from different perspectives. Therefore, data was collected through interviews, observations and a document study. The design manager and six designers were interviewed using an interview guide structured after the three research questions. The design manager and two of the designers were employed by the contractor. Four of the designers worked for design companies procured by the contractor. The interviews lasted from 45 to 60 minutes. Recordings from the interviews were transcribed and sent to the interviewees for quality assurance.

The first author conducted sixteen observations in total as a passive meeting participant, namely ten design meetings, two information meetings and four training meetings. The participation was as a researcher and not as an employee. Data from the observations were documented by taking chronological notes that later was structured similarly to the questions in the interview guide. An advantage of conducting observations as meeting participant is the possibility for in-depth understanding of the project circumstances [14].

The document study mainly included project execution plan, contract documents, descriptions of MMI used in the project, minutes from meetings and the BIM (DWG- and IFC-files). The documents were provided through access to the project database. The documents were used to supplement and confirm statements from interviewees and from the observations.

3. Theoretical background

3.1. Need for communication in design processes.

The design process consists of tasks with varying forms of dependencies [15]. Which type of dependence is decided by the complexity and need for communication between design members [5]. Design teams will experience tasks that could be described as iterative reciprocal works. This is highly demanding and require synchronous communication. Iterative reciprocal design differs from traditionally production process, which mainly consist of sequential works [5]. To manage these processes, understanding for the different forms for dependencies is key [16]. It is the design manager who is responsible for the success in design works [17]. Therefore, an important task of the design managers is to locate where iterative reciprocal design works occurs.

The transition from traditional design to BIM-based design has changed the way of communication. It is recommended that communication and information go through the BIM-model, and not separately between group members. This can lead to faster response between members, which will improve the interaction in the design [6]. To exploit the potential of BIM it is important that the design groups uses the same models [18]. This contributes to the reduction of unnecessary iterations and systematization of the process [19]. To secure successfully use of BIM its recommended that the management gives thoroughly instruction on how modelling should be conducted, and what it should contain [20].

3.2. Traditional planning and Last Planner System

To uncover needs for communication, one must schedule the process. Traditionally planning is done by dividing head tasks into work packages and structure them by dependencies. To do this one could use Work Breakdown Structure (WBS) [21], where the work is divided in packages with information about resources needed to solve the task [19]. After packages and order is decided, managers illustrate the workflow through schedules. Gantt charts is a schedule that illustrate the activities in a chronological order. This is described by sorting task throughout the y-axis, and task duration by the x-axis [22].

A challenge with traditionally design planning is the similarities to production planning [23]. The schedules are then based on sequential works instead of iterative works. Svalestuen et al. [8] recommend that the AEC industry learns from design processes in the Petroleum-industry. The design processes in the Petroleum-industry allow iterative works for a longer period than AEC. They manage this by planning design with lean philosophy and model maturity. An important part of lean is Last Planner System (LPS) [24]. LPS describes the potential of involving those who are going to execute the activities in the planning. The design managers can explain what should be done in a long-term master plan. Afterwards the designers can use their expertise to define what could be done within the available time in a design phase schedule and underlying lookahead schedules. By combining what should and what could be done, the design group could decide what will be done and when it must be done to fulfill the master plan [25].

Lean philosophy involves continuous improvement. A strategy to achieve this is Plan - Do - Check - Act (PCDA) [25], [26]. By using PDCA the design groups establish routines for controlling works against planned work, and re-planning is necessary if the schedule turns out to be unrealistic. Complex construction projects consist of continuous processes [5]. This means that delays in one phase of the project will cause delays later in the process. By avoiding checks and re-planning, error or delays would not be detected which could lead to unsuccessful projects.

3.3. The model maturity index used for planning the design process

MMI is a framework for communication, planning and control of BIM development [9]. MMI is different from Level of Development (LoD). MMI describes maturity of the whole BIM, while LoD describes maturity of individual objects [6], [27], [28]. Some consider LoD too orientated towards development of objects instead of creating value for the design process [6], [29]. MMI has five standard levels describing model maturity:

- MMI100 – Sketch. Conceptual solutions are proposed, while objects are sketch suggestions. This means solutions can be changed and major changes of objects can be done.
- MMI200 – Established conceptual solutions. The objects are proposed based on conceptual solutions. Major changes in conceptual solutions that affects other disciplines are not allowed at this level.
- MMI300 – Ready for control against other disciplines. Objects should be coordinated within individual disciplines. Objects at this level have correct geometry and placement.
- MMI350 – Completed coordination against other disciplines. The coordination is iterative, and objects are not mature to this level before collision control is completed.
- MMI400 – Production ready. The objects are controlled and accepted for construction. Any conflicts or suggested changes should be reviewed by actual disciplines. When approved, the objects are ready for production.
- MMI500 – As built. As-Built documentation is provided.

The first thing that should be done while planning MMI is to arrange a start-up meeting. The project objectives and each designer's role should be clarified. An important step is to map the BIM skills and earlier knowledge of MMI. This may do it easier to decide how detailed the MMI-framework should be practiced [10].

The Norwegian MMI manual recommends to adapt the standard levels describing model maturity to each project [9], [30]. Studies shows that Norwegian contractors have created supplementary index levels to the standard framework. The reason was the need for sub-levels between the standard levels [7], [30]. Garcia et al. [11] explains that the project participants must be acquainted with the specific MMI framework, as they may have perceptions of MMI from previous projects. When creating supplementary index levels the designers should be involved, and the number of levels should be restricted to a necessary minimum [10].

To control the BIM maturity development the project should be divided into geographical zones [9]. These zones can be a floor, room, story or a building [7], [10]. Then the design deliveries for each zone can be described and scheduled according to the overall plan for BIM maturity development. Garcia et al. [11] suggest technical systems as an alternative to geographical zones. Examples of technical systems are heating, ventilation, air condition (HVAC), plumbing, electrical, steering systems etc.

Designers should create delivery lists for each zone or system. Delivery lists contain the design deliveries the zone or system need to reach the next BIM maturity level [9], [10]. The design delivery is a single or multiple BIM objects provided by the delivery list owner. Experiences from LoD show that detailed descriptions of single objects may lead to a too detailed framework [6], [7], [30]. All BIM objects do not need to reach the maximum maturity level to be built [11]. To decide the necessary level of maturity for each object it is important to involve the designers [10].

Scheduling of design with MMI is recommended illustrated with post-it-note plans [10]. Each note represents a maturity level milestone for the disciplines' BIM-models. The order of milestones and the duration is decided by using the information from the delivery lists. Scheduling and planning give the opportunities to do routine checks on progress. Styrvold et al. [10] describe how to check amount of completed work against planned work. Mejlænder-Larsen [31] describes a similar checking with measuring the percent plan completed (PPC) to discover lack of deliveries. PPC is recommended to measure maturity at each design meeting to continuously track if BIM maturity development is according to plan [32]. A design manager that discovers lack of deliveries should aid the suffering designer to re-plan.

4. Findings

4.1. RQ1: How is the model maturity index used?

It was used a selection of the standardized *model maturity indexes* on the case project. More specific only MMI200, 300, 350 and 400 were applied. The reason for avoiding MMI100 and 500 were that the design managers considered these indexes as inadequate and unnecessary design steps for project. Architectural concepts were determined, and the management presumed no need for sketches from other disciplines, which led to neglection of MMI100. MMI500 were neglected due to the limited value for the contractor after the production and no requirement from the client.

The project was sectioned into *geographical zones,* based on how the production was divided in zones. The first zone was *Ground and Foundation,* the second *Parking Garage* and the third *Apartment Buildings*. Design managers used zoning to achieve analytical interfaces to provide easier design works.

It was planned to use *delivery lists* on the project, but inadequate involvement of designers and poor commitment from the design managers led to meeting-based planning instead. In these meetings designers were involved by communicating their information needs to further evolve own design. These needs of information where then classified as task for the informative designer.

There were not made any *schedules* describing progression of design works or model maturity. Through interviews it emerged that MMI-related schedules were intended to be generated, but the lack of early involvement of designers made it challenging to achieve this.

Studies showed that design tasks from different zones were instead *followed up* in design meetings, where design managers successively review each zone to obtain an updated status on the design and maturity, resulting in completed task being clarified and need of information communicated. It was not established MMI-related milestones on the project due to the lack of scheduling. Therefore, controls of maturity on BIM-models were not done properly. Designers instead declared upgraded maturity on BIM-models sporadically based on when they reach it and design managers did not execute internal control of declared maturity except for MMI350. This because MMI350 was achieved after collision controls which were facilitated by design managers.

4.2. RQ2: What are the strengths / weaknesses of using model maturity index?

In general, the design group was pleased with the selected maturity indexes. The descriptions of indexes appear to be easily understood and it is intuitive to understand when to use various indexes. A deficiency was that the process between MMI300 and MMI350 is poorly described.

The zone sectioning can be used as a structure for design meetings, and it made involvement of correct designers in discussions and to clarify problems easier. It was observed an increasing need for special meetings concerning different systems in respective zones. The reason for this was that design members considered descriptions of zones to be too general, focusing too much on interfaces between zones, instead of describing interfaces within the zones. The zones were also considered too large. Especially the *Parking Garage* and the *Apartment Buildings* consist of many smaller technical systems. Designers had BIM-objects in different systems in the zones, and the different systems had varying degrees of maturity. A weakness was therefore that maturity descriptions on zones led to incorrectly descriptions of maturity for internal systems within that zone.

One of the first involved designers were asked to create a delivery list, entailing which deliverables this design discipline had regarding the MMI system. This list is a useful input in the planning process, while it also makes the designer self-conscious on own tasks and needs. Therefore, a weakness identified in the case project's MMI application was the lack of usage of such delivery lists. This, as well as the lack of delivery plans led to weekly task planning in design meetings.

Studies showed that the lack of scheduling and delivery planning result in short-term overview, which in the long run led to re-design. This is considered as a weakness. It was not addressed any strengths with the planning strategy on the case project.

It is categorized as a weakness that managers did not control declaration of model maturity, but entirely relied on the design discipline's self-assessment. Also, when wrong declarations were discovered, the management did not demand changes in BIM-models maturity description. Designer appreciated the confirmation of MMI350 through clash detections and communicated that measurable index declarations were favorable. Because of lack of scheduling there were not any checkpoints to control that progress was maintained. This is considered a weakness and designers believed that this usage is not compatible with re-planning.

4.3. RQ3: How should model maturity index be used in future projects?

Some designers suggested more specific descriptions of the phase between MMI300 and MMI350, which could be achieved by creating new maturity indexes which describes that BIM-models are in a coordination process with other BIM-models.

To increase the utility of project sectioning, zones should be further detailed. It is suggested that geographical zones should be detailed by technical subsystems. By this approach, designers believed that the various interfaces inside of zones could be uncovered. These technical subsystems should be described with the different BIM-models that belongs to the system. This is believed to create easier checks and controls of the systems.

In future project it is suggested that delivery lists should be used more in design planning with MMI. It is a general opinion that delivery lists would make it possible to predict dependencies between disciplines. Also, it could be used to predict duration of tasks which could be combined with scheduling.

A result of this study is that scheduling should be done in further projects with MMI. This is explained by the fact that MMI is a framework to guide planning and control of the design process. Therefore, it is crucial for anchoring of MMI that schedules are made. Designers recommended that in future projects, schedules are created to show maturity development towards each individual discipline.

Designers suggested that design managers closer monitor maturity development in future projects, reducing errors from wrong declared maturity. To be able to control maturity development it is important to establish checkpoint dates or milestones for achieved maturity. Delivery list could be used as measurable checklist for maturity developing task between indexes.

5. Discussion and conclusion

The standard *MMI* framework was used without project specific adaptions as suggested by Garcia et al. [11] and without introducing more maturity levels in the index as suggested by Nøklebye et al. [7]. Findings showed that designers were happy with the standard model maturity index, but that they missed descriptions of the iterative processes between MMI300 and MMI350 sufficiently. The tailor-made BIM-manual of Statsbygg [30] provides extra maturity levels that could have helped describing this iterations if integrated in the standardized MMI framework. The complexity caused by iterative design between MMI300 and MMI350 is illustrated in fig. 1.

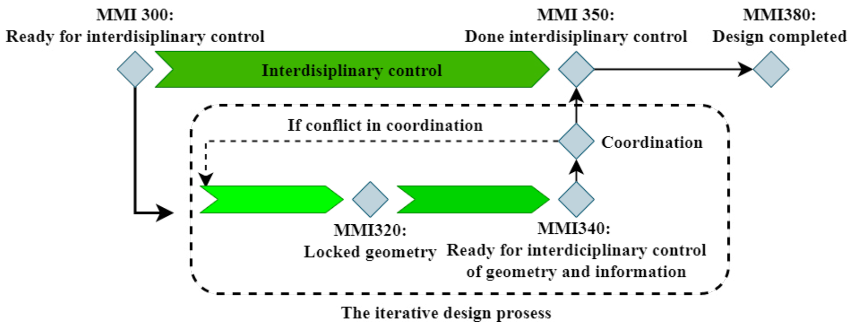

Fig. 1. Design processes – with repeated iterations (lock, control, coordination loops) – between MMI300 and MMI350 causes complexity.

Iterative design processes occured after model coordination had revealed model clashes. During coordination engineers were checking and discussing clashes. Some clashes had significant impact on design. Afterwards affected disciplines had to adjust geometry and information in their respective BIM. New geometry and information could affect even more disciplines, and therefore the iterative design processes needed to move from MMI300 to MMI350 became complex in the investigated case.

Geographical zones were used to split the project in manageable design parts. This aligns with the description in the Norwegian MMI-manual [9]. The zones used in the studied case were too large for practical use of MMI. The zones consisted of several technical systems, each with different maturity development. When describing maturity of a zone, some systems in the zone were constantly described with wrong maturity. Despite this, the chosen geographical zone sectioning was suitable for structuring design meetings. A problem with the sectioning was that it focused on geographical interfaces instead of technical systems. For some of the discipline designers, the technical systems required more attention than the geographical zones. Systemic sectioning as described by Garcia et al. [11] could probably have solved the problem caused by many technically systems distributed geographically in the building. However, applied alone systematic sectioning could have led to chaotic identification of systems and their mutual dependencies. It would have been easier to describe dependencies between systems in a limited geographical zone. Therefore, geographical and systematic sectioning should have been combined in the studied case. A combinational sectioning would use the structural idea of a WBS with the total project on top split in geographical zones, the zones split in technical systems and finally the technical systems split in discipline models. To put it the other way around: when merging all discipline models (number 1.1.1-model m.2.n) the project got the complete BIM (BIM of the underground parking garage, two three story apartment buildings and one four story apartment building). The combinational sectioning hierarchy of discipline models is illustrated in fig. 2.

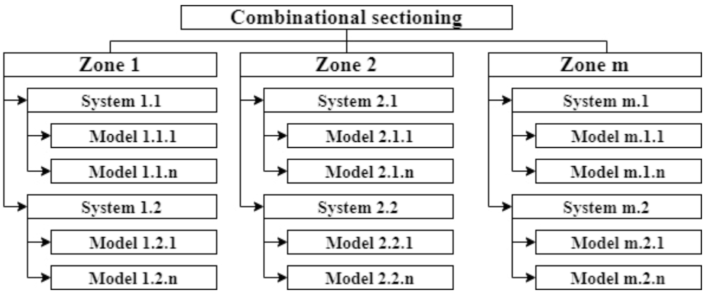

Fig. 2. Combinational sectioning, with sectioning in geographical zones split in technical systems that are split in discipline models.

Delivery lists describing when the defined zones were to reach the different maturity levels were unfortunately not used in the examined case project. The delivery lists were replaced with ad hoc task planning during design meetings. A consequence was that designers did not acquire the overview of the tasks and their mutual dependencies needed to apply MMI as described in the Norwegian MMI-manual [9]. This manual recommends creation of delivery lists to all discipline models with tasks, the tasks' duration and a description of how to achieve the different maturity levels. The designers should apply both LPS and WBS when preparing the delivery lists with planned maturity levels for geographical zones, systems, and models. Delivery lists with descriptions of tasks that must be completed to achieve each maturity level should be created for every single discipline model.

Despite crystal clear recommendations in literature, no *schedules* for the design - except from setting a completion date for the complete BIM – were made at start. It could be considered as a weakness for the studied project that design progress was planned between meetings on an ad hoc basis. The project lacked long-term overview of the design process. Lack of overview created risk for missing out on necessary tasks and unnecessary iterations especially between MMI300 and MMI350. A first step to mitigate the consequences could have been to create MMI-related schedules. It is established that this should be done by creating post-it note plans [10]. Each discipline model should have defined milestones for when to reach the different maturity levels. To put it in other words, there should be one post-it note for each of the milestones for every discipline model in the post-it note plan. Just setting milestones for the geographical zones alone would not lay sufficient grounds for measuring maturity, because technical systems at various maturity levels are located across these zones. Schedules should therefore be created with superior milestones for technical systems, while the milestones for each underlying discipline model should be reached before the milestone for the system can be reached. Zones could be declared as completed when every system in a zone has reached MMI 380 – Design completed. The design manager and the designers realized that despite lacking a schedule specified down to each discipline model, the design process benefitted from the designers' consciousness of the hierarchical structure of geographical zones, technical zones and discipline BIMs. However, the benefits would have increased with a properly detailed schedule.

Design progress was monitored in the weekly design meetings where the designers declared maturity development of their respective discipline models. The developments were not coordinated against any MMI-related schedule – since such a schedule did not exist – despite clear recommendations from for example Styrvold et al. [10]. The lack of coordination led to lack of control on maturity development. Wrongly declared maturity from designers that did not want to reveal they were lagging behind were not corrected. A lack of re-planning when maturity development for individual discipline models lagged behind probably enforced the lack of control in the studied case. The designers should have made delivery lists with measurable plans for maturity development, so that for example measurement of the percent plan complete (PPC) described by Belsvik et al. [32] could have been for each discipline model. With PPC, the design manager could have adapted Plan-Do-Check-Aca (PDCA) to reveal need of re-planning.

To sum up the conclusions, the MMI framework should have been used more in detail in the studied case to balance the maturity development out in time. A more balanced development would have prevented the model maturity for the complete BIM to go directly from MMI100 to MMI380 in one step. The leap from MMI100 directly to MMI380 caused a lot of clashes and caused many costly re-iterations for the designers that could have been avoided with stepwise maturity development.

Future case studies documenting experiences from full implementation of the MMI framework – with delivery lists and schedules for each discipline model are needed. Especially there is a need to study sectioning in both geographical zones and technical systems. There is also a need for a more detailed description in the MMI framework of the design iterations when the design moves from maturity level MMI300 to MMI350, i.e. when removing the clashes arising when merging the discipline models into the full BIM.

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