White paper

Closing the gap with VDC and early involvement

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Abstract
MT Højgaard conducted in March 2016 this meta-analysis to combine the insight from our studies to uncover the larger context for increased productivity with the BIM-collaboration in Denmark. MT Højgaard had followed the maturation of Building Information Modelling (BIM) use on our projects, and documented practices with BIM in white papers and books and scientific dissertations based on empirical studies.

This white paper shows that BIM execution plans often do not provide for the data required by the contractors on projects where the contractors are not involved from the outset. In order to address this problem the client can require that:

I. The overall framework for digital collaboration requires that all parties must ensure that their digital production can be used by and together with other stakeholders in the project.

II. The collaboration shall at a minimum take place around an open industry standard as IFC (Industry Foundation Classes). The goal is that the project's BIM shall provide the client with a good basis for decision-making in terms of execution time, total cost of ownership and subsequent operation and maintenance.

III. The contractor must be involved as early as possible in order to realize the project. The first focus must be on the choice of solutions and 4D production planning that enhances project efficiency and reduces execution time by up to several weeks. The early involvement of the contractor will also contribute to a more effective production and the client will have high-quality buildings and infrastructure assets, among other things because project documents based on BIM results in less rework.

The client that translates these recommendations to the requirements contained by the project's BIM Execution Plan will ensure a framework for collaboration where the projects profitability is increasing and the stakeholder's exposure to risks and conflicts is reduced.

This white paper shows MT Højgaards findings starting from how ICT and BIM influence the design quality of projects in general. It shows our findings in regards to the impact the IFC format has on design quality and addresses the importance of the right framework for BIM collaboration. The development of the National Danish ICT regulations is discussed and their influence on the use of BIM and on the quality of projects and even how they significantly impact the use of classification. Finally the business benefits of using BIM and standardised frameworks are presented through what MT Højgaard calls Industrialised BIM.

Make the framework
The client can be a part of the change by looking at structures in and about the client's construction. Our analysis over the recent years reflect the industry practice and show a clear link between the client's choice of project type and the productivity and quality of the project. An effective cooperation on the project's BIM is a prerequisite for effective achievement of the client's objectives.

The analysis indicates that the key is that the client first develops a strategy for the use of BIM and Virtual Design and Construction (VDC) on the project. It frames how the overall objective and intermediate objectives can be achieved and what competencies should be present to complete the project. The following elements may be advantageously incorporated into the client's early framing of the project and the digital collaboration:

a. Early involvement of the contractor allows an early collection of data on the relevant building components and helps enrich the project's BIM with more information. Using the enriched BIM, the contractor can visualize and simulate the process and the built environment, based on the solutions selected, thus providing the client with a good basis for decision-making in terms of total cost of ownership and subsequent operation and maintenance.

b. The client sees that project changes are being handled more swiftly and prices are set at a realistic level relative to the changes because the contractor and the designers can use BIM to visualize, simulate and analyze the changes requested. The result of this is high-quality buildings or infrastructure assets delivered early because the contractor is able to optimize execution time by using 4D production planning. The 4D production planning feature enhances project efficiency and reduces execution time by up to several weeks, thus providing greater security that the project can be handed over to the client on time or earlier.

c. The use of BIM adds value to the project from the initial concept phase. Through visualization and clarification with BIM, the clients' requirements for ICT and BIM can be used as the platform for joint analysis and simulations.

d. Production becomes more effective when the project's BIM contributes to a faster clarification process. The client will be offered a visualization of the construction site and thereby greater insight into the project and the construction process. Moreover it contributes as a guarantee that the contractor takes into account an optimized construction process and health and safety at work. The client will have high-quality buildings and infrastructure assets, among other things because good BIM-based project documents results in less rework.

e. A common approach for the use of BIM on the project. This will ensure a common effort and alignment of expectations about common objectives that support the client's goals as well as achievement of the objectives of the individual project participants.

f. Benchmarks would be a facilitator for many reluctant actors to adopt the new work methods inherent in BIM and VDC and thereby to increase the productivity throughout the project life cycle together.

Getting close to the gap - The experience of current practice shows the way forward
The last years of research in particular in the form of white papers, books and articles shows

the client can achieve increased productivity on their project through an early involvement of the performing parties. This research also points to the importance of all performing parties involved in the project digitally.

The gap between the design documentation that the client needs and what is applied in practice was documented in 2014 with the white paper *Quality of Design in Denmark*:

> "*MT Højgaard has studied design documents of 100 Danish construction projects to assess the extent to which the use of Building Information Modelling (BIM) and ICT affects the quality of the design documents. The survey shows that 63% of covered projects are based on design documents in a quality that either requires a partial or complete redesign of the design documents, or makes it necessary to solve challenges that otherwise directly reduces productivity and the profit of the project. 37% of the projects are evaluated to have a high quality that creates a basis for making qualified decisions on the basis of design documents*".

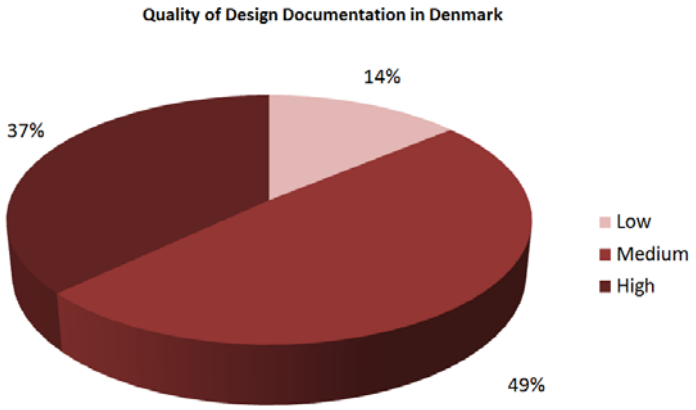

Figure 1 The qualitative distribution of design documents for projects (The Quality of Design Documents in Denmark, April 2014, page 4)

This point to the fact that many projects lack an effective framework for managing the design the client has paid for. This framework is also the optimal basis for constructability, economics and minimizing the risk and increase productivity.

> "The current regulations 118 and 119 include less requirements specifying how things should be done, but applies an increased focus on what aspects of ICT and BIM that must be done" (*Value drivers in the Danish national ICT*).

Simple framing changed the quality

As mentioned earlier our research points to the fact that the framework from the client involved in the digital collaboration has a major impact on the quality of the design that all the projects parties provide.

> "*A group of projects, that are subject to the ICT regulation and therefore per definition are prioritizing the use of ICT and BIM, is investigated to clarify if this condition has an effect on the design documents' quality. 23% of the projects in this group are based on design documents in a quality that requires a partial or complete redesign or necessitates to solve challenges that otherwise directly reduces productivity and the profit of the project. 77% of the projects subjected to the ICT regulation have design documents in high quality*" (*Quality of Design in Denmark*).

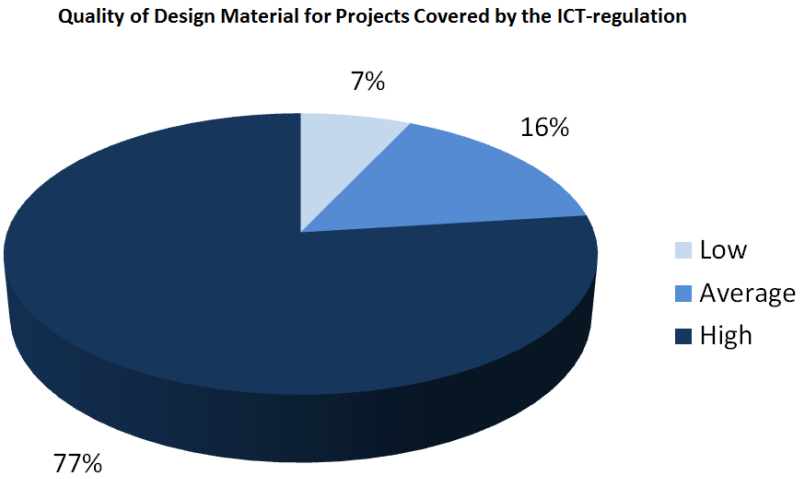

Figure 2 The distribution of the quality of design documents for projects covered by an ICT-regulation (*The Quality of Design Documents in Denmark*, April 2014, page 11)

The clients had with a simple framing for the digital collaboration changed the quality of project design from 37% and obtained 77% of the application of the ICT-regulation' requirements for a digital collaboration from concept to delivery, as shown in Figure 1 and 2.

The analysis from spring 2014 was elaborated late summer 2014 in the white paper *IFC - A driver for design quality in the AEC industry* in August 2014. The analysis was working with 153 projects design and concluded that:

> "*The research shows how the IFC format almost eliminates projects with a low design quality and that the use of IFC applied within the Danish ICT regulations 118/119 increases design quality with 45% compared to projects without IFC*".

Increased value of BIM during construction

At the end of 2014 an analysis of the importance of the client's early framing of the digital collaboration was conducted. The findings were documented in December 2014 in the white paper *Value drivers in the Danish national ICT regulations*. The main conclusion based on a systematic review of project execution was:

> "*Thus projects covered by the current ICT regulations shows a 44% increase in value compared to projects covered by ICT regulation 1381 and a 205% increase in value compared to projects covered by ICT regulation 1365*", see Figure 3.

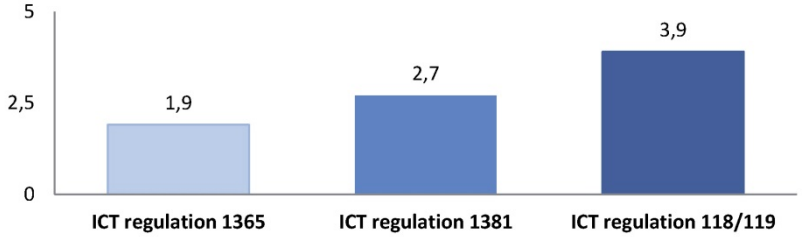

Figure 3 Value drivers in the Danish national ICT regulations, December 2014, page 2

For projects covered by ICT regulation 118, see Appendix A, or 119 the major BIM value contributors are:

> "*Structured use of quantity take-offs to control the changes of quantities in project material revisions; digital inspections for a better and mutual understanding of the project within the project team and clash detection tests for proactive identification of constructability issues*".

The industry can be seen as divided in relation to the standards and framework for effective collaboration. The national ICT regulations separate the industry in two (*Value drivers in the Danish national ICT regulations*):

1. "*There was one group advocating that standardization and national regulations constrain the choice of applications and methods for the individual participants, and that the requirement of using IFC ultimately create more work. However, it is argued that fewer requirements towards common standardisation will derive risks, since the digitalisation and possibility for exchanging models and valuable data will deteriorate along with the lack of a standard specification for data exchange formats.*

2. *The other group of participants was pro regulations and standardisation arguing that the requirements for using IFC propagate a frame for flexible data exchange within the value chain all the way from design to operations. Within this group some recognise how the ICT regulations provide a more structured application of BIM thus resulting in productivity gains and savings. Additionally some participants are requesting more standardisation from the ICT regulations in order to realise the full potential of process standardisation."*

Clear objectives for the collaboration

MT Højgaard has up to June 2015 analyzed 3.168.926 objects from 196 discipline specific BIM models and researched the use of classification in the Danish AEC industry. MT Højgaard found that SfB is the most common used classification system in Denmark, represented by 48% of the design discipline contributions, but 37% of the design discipline contributions don't use classification to any extent. The research not only yields results concerning the use of a specific Danish classification system but also reveals how the Danish ICT regulations have a considerable impact on the use of classification, and thus digital collaboration on the project. The white paper *Addressing classification in the Danish AEC industry* from June 2015 shows that the industry holds its own energy and readiness for change:

> "*Even though 64% of the projects don't explicitly require classification systems it is found that 63% of the discipline models contain classified objects to some extent*" (*Addressing classification in the Danish AEC industry*).

The ICT regulations 118 and 119 in Denmark has in many ways shown the value when client sets clear objectives for the cooperation, and even more can be achieved through earlier involvement by the contractor and the other designers, as evidenced by the following:

> "*The current Danish ICT regulations explicitly prescribe the use of classification, but leave the choice of classification systems open. Investigating if the ICT regulations are a driver for the use of classification, MT Højgaard has compared the use of classification on projects governed and not governed by the ICT regulations*" (*Addressing classification in the Danish AEC industry*).

The results are shown in Figure 4, and shows that the client's requirements has a significant impact on what is provided by the designers and the extent to which the project is given a real basis for increased productivity through digital collaboration on the project.

The category of projects where no requirements exist but the design disciplines use classification regardless shows a practice within the industry, which can be used as best practice focusing on digital collaboration and reuse of design data across the parties in the project.

> "*To have 31% applying classification even without requirements reflects a maturity-level in the industry, but without the governing effect of contractual requirements it is not feasible to base any activities on the classification in these cases. Without a guarantee that the classification will be maintained throughout the project it is too risky, and a lot of potential for the project is lost*". (*Addressing classification in the Danish AEC industry*).

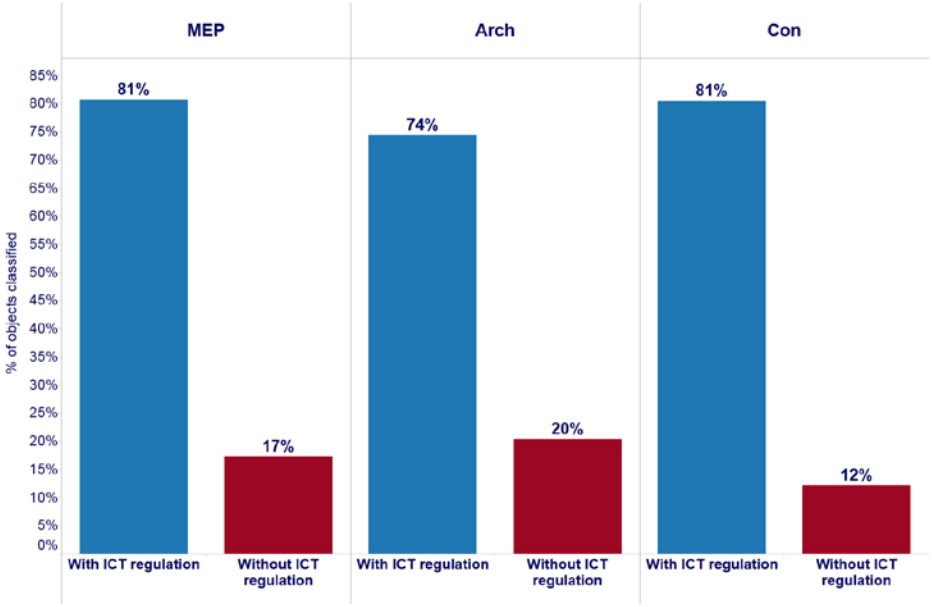

Figure 4 The figure displays the percentage of classified objects for each discipline when contributing to a project either governed - or not governed by the ICT regulations. (Addressing classification in the Danish AEC industry, June 2015, page 5)

The client can benefit from a clear framework prescribing the use of classification throughout the project, and thereby obtain a change from 12% to 81%, as shown in Figure 4. This will include facilitating critical project activities such as faster iteration in the tender phase, model-based procurement and the subsequent operation with BIM for Facility Management (FM). These benchmarks would be a facilitator for many reluctant actors to adopt the new work methods inherent in both BIM and VDC and thereby to increase the productivity throughout the project life cycle together.

The client can ensure that the project is based on productivity-enhancing data that is based on the collaboration and dialogue. It is often seen that BIM execution plans do not provide the data required for the contractors on the projects where the contractors are not involved from the outset. These projects impose unnecessary costs on the contractor because of the lack of

productivity. These costs ultimately end up with the client in the form of higher bid and higher unit prices.

> "*It is MT Højgaard's experience that standardization through governmental legislation is not an organisational constraint but actually an industry opportunity to align interfaces between trade disciplines and drive productivity together*". (*Value drivers in the Danish national ICT regulations*).

Ways to close to the gap

We may as industry become more productive when we to a larger degree systematically collect, share and use our common learning and experience from our projects. This provides an ongoing accumulation of experience which allows efficient use of BIM in the projects and consequently increased productivity. The client will see better cooperation where all of the parties are able to meet the requirements made and execute the ICT and BIM execution plan.

It is documented in the white paper *Industrialized BIM - using data to drive productivity* from October 2015:

> "*Utilising data from projects is a methodology that is applied both internally in MT Højgaard and externally, since many projects are relying on an effective data flow between companies and different trade disciplines*".

We see that performance measurement is a necessary element when addressing productivity in the construction industry. The clients can create projects that can overcome current challenges in the construction industry by similarly focusing on the possibility of increasing productivity on its own project. Our experience today is that BIM and VDC makes it possible to create simulations that give the client a better basis for making decisions.

To integrate the surroundings of the buildings early in the project can in many ways enrich the project. Already at the early stages of the project, the BIM may be used to give the client and the other parties a good insight into the overall urban interaction between buildings. Moreover it may, if coupled with information on the individual components of the buildings or infrastructure assets, be used to simulate and analyze an operating environment with focus on the occupants and users of the buildings. The book "*A practical guide to BIM in construction and infrastructure projects*" from September 2015, provides examples of how the client can achieve this:

> "*Early involvement of the contractor allows an early collection of data on the relevant building components and helps enrich the project's BIM with more information. Using the enriched BIM, the contractor can visualize and simulate the process and the built environment, based on the solutions selected, thus providing the client with a good basis for decision-making in terms of total cost of ownership and subsequent operation and maintenance*".

The client should start by setting a clear goal for the digital collaboration on the project, which could also contribute to increased productivity similarly as described in the book *A practical guide to BIM in construction and infrastructure projects*:

> "*For cooperation on the project's BIM to add most value to the project participants, it is necessary to define the objective for the use of BIM on the project. This will ensure a common effort and alignment of expectations about common objectives that support the client's goals as well as achievement of the objectives of the individual project participants*".

This may lead to:

> "*The use of BIM adds value to the project from the initial concept phase through visualization and clarification with BIM, the clients' requirements for ICT and BIM are being used as the platform for our joint analysis and simulations. Here the consequences of choices made regarding design of the building or the civil work asset and the subsequent execution can be clarified and tested*" (*A practical guide to BIM in construction and infrastructure projects*).

This means that:

> "*The client sees that project changes are being handled more swiftly and prices set at a realistic level relative to the changes because the contractor and the designers can use BIM to visualize, simulate and analyze the changes requested. The benefit to the client is high-quality buildings or infrastructure assets delivered early because the contractor is able to optimize execution time by using 4D production planning. The 4D production planning feature enhances project efficiency and reduces execution time by up to several weeks, thus providing greater security that the project can be handed over to the client early or on time*" (*A practical guide to BIM in construction and infrastructure projects*).

Precisely the early involvement of the contractor also helps the client to secure the correct and desired realization of the project by:

> "*Production becomes more effective when the project's BIM contributes to a faster clarification process. The client will be offered a visualization of the construction site and thereby greater insight into the project and the construction process as well as a guarantee that the contractor takes into account an optimised construction process and health and safety at work. The client will have high-quality buildings and infrastructure assets, among other things because good BIM-based project documents results in less rework*" (*A practical guide to BIM in construction and infrastructure projects*).

Early involvement of the contractor and other projects parties in the project are the primary change clients must adapt and practice. This will together with the right framework for digital cooperation allow that the potential of VDC-collaboration is realized on the client's project.

References:

- *A practical guide to BIM in construction and infrastructure projects*, September 2015
- White paper entitled *Industrialised BIM - using data to drive productivity*, October 2015
- White paper entitled *Addressing classification in the Danish AEC industry*, June 2015
- White paper entitled *Value drivers in the Danish national ICT regulations*, December 2014
- White paper entitled *IFC – A driver for design quality in the AEC industry*, August 2014
- White paper entitled *Quality of Design in Denmark*, April 2014.

Appendix A, ICT Regulation 118

Regulation concerning the use of information and communication technology (ICT) in public construction.

Pursuant to Section 2(1), Section 5(1), Section 8 and Section 8a of the Danish Act on Public Construction Activities, cf. Consolidated Act no. 1712 of 16 December 2010, as amended by Act no. 623 of 14 July 2011, the following is laid down:

Area of application

1.-(1) The Regulation applies to the construction of buildings, the conversion and extension of buildings, the renovation and maintenance of buildings, and facilities related to such buildings with regard to:

1) Construction with the Danish State as the Client for an estimated contract sum of DKK 5 million excluding VAT, or higher.

2) Construction for an estimated contract sum of DKK 5 million excluding VAT, or higher, of which at least 50 per cent is financed in full or in part by State loans or subsidies.

3) Construction for an estimated contract sum of DKK 5 million excluding VAT, or higher, for the use of institutions of which the operation is paid by the State, when the subsidy constitutes at least 50 per cent of the operational expenses.

4) Construction with a region or municipality as the Client for an estimated contract sum of DKK 20 million excluding VAT, or higher.

5) Construction for an estimated contract sum of DKK 20 million excluding VAT, or higher, which is financed in full or in part by loans or subsidies of at least 50 per cent from regions and municipalities.

6) Construction for an estimated contract sum of DKK 20 million excluding VAT, or higher, for the use of institutions of which the operation is paid by regions and municipalities, when the subsidy constitutes at least 50 per cent of the operational expenses.

(2) The Regulation does not apply to construction for which public support is granted pursuant to the Danish Act on Public Housing, etc., the Danish Act on Private Care Dwellings and the Danish Act on Urban Renewal and Urban Development.

2.-(1) In conjunction with construction projects concerning renovation and maintenance, the Client may waive fulfilment of one or more of the Regulation's requirements if the costs of the fulfilment of the requirement(s) in question do not match the benefits.

(2) Nonetheless, the Client may not waive the regulations in Section 8 concerning digital invitations to tender and bids via a digital system.

ICT coordination

3. The Client must ensure that throughout the construction project there is coordination of the overall use of ICT between all of the parties involved.

Handling of digital construction objects

4.-(1) The Client must require that throughout the construction project digital construction objects are structured, classified, named, coded and identified on a uniform basis and to a specific degree of detail. In this respect the Client must require that the construction objects are provided with the information and characteristics that are of relevance to the subsequent management, operation and maintenance.

(2) The Client must ensure that guidelines are laid down for the handling of digital construction objects throughout the course of the construction project.

Digital communication and projectweb, etc.

5.-(1) The Client must require that a system be used for digital communication and archiving of all relevant information during the course of a construction project.

(2) The Client must ensure:

1) that a plan is drawn up concerning which parties are to make which information available in the system, and at which times;

2) that information can be obtained from the system and transferred to other systems, and that the plan that is drawn up includes specification of which transfers are required during the course of the project and on the completion of the construction work, cf. Section 10;

3) that the system includes access control, notifications and logs;

4) that it is determined which file formats are to be used; and

5) that it is determined which meta data is to be connected to the individual file types.

Use of digital construction models

6.-(1) As part of the competitive element of competition-based bidding rounds, the Client must require that the proposals received include digital, object-based construction models, as well as visualisations made on the basis of these models. Construction models and visualisations must document the proposals' architectural, functional and technical conditions at a specified information level.

(2) The Client must ensure:

1) that the competition programme outlines requirements of the models' structure and information content, cf. Section 4, based on the size, nature and complexity of the competition;

2) that the number and location of visualisations are determined on the basis of the size, nature and complexity of the competition; and

3) that object-based construction models are provided in IFC format.

7.-(1) During project design and execution the Client must require that object-based construction modelling be used.

(2) The Client must ensure:

1) that agreement is reached concerning which discipline and shared models are to be prepared;

2) that each of the parties with responsibility for models prepares the necessary discipline models, of which the content and use are specified in relation to the service provided by the individual party;

3) that discipline models are coordinated via one or several shared models for the purpose of simulation, clash detection, bill of quantities, drawings and specifications; and

4) that the models are made available in IFC format.

Digital invitations to tender and bids

8. The Client must require that for invitations to tender for construction works digital invitations to tender and bids are applied, by using a digital system. The tender documents must be drawn up so that, to a relevant extent, the documents can be used digitally by the bidders in conjunction with their submission of bids, and so that bids are structured in accordance with the structure otherwise used in the construction project, cf. Section 4.

9. To the extent that the tender includes bill of quantities, the Client must ensure:

1) that bill of quantities are included in the tender documents;
2) that the tender documents for each contract include bills of quantities as well as relevant digital, object-based construction models from which quantities can be extracted;
3) that models are made available to the bidder in IFC format; and
4) that the tender documents show the basis on which the quantities are calculated, including the measurement rules and/or measurement methods that are used.

Digital delivery on handing over the construction project

10.-(1) In consultation with the Contractor, the Client must set requirements concerning the digital submission of the information that is deemed to be relevant for:

1) documentation of the construction work;

2) documentation of the construction project;

3) operation and maintenance; and

4) the future management of the property.

(2) The Client must ensure:

1) that digital delivery on the handover of the construction project is included in the agreements with advisers, contractors and suppliers;

2) that the agreements include the handover's extent, structure, classification, identification and formats; and

3) that object-based construction models are provided in IFC format.

Digital information concerning defects

11. The Client must ensure that digital lists of defects are used, which describe the registered defects in accordance with the structure determined for the project, cf. Section 4.

Entry into force and transitional provisions

12.-(1) The Regulation enters into force on 1 April 2013 and applies to construction projects that are initiated as from and including this date.

(2) Regulation no. 1381 of 13 December 2010 concerning requirements of the use of information and communication technology in construction projects is repealed as of 1 April 2013. However, the Regulation will continue to apply to construction projects that are initiated before 1 April 2013.