White paper:
Critical clashes in the 3D design

23. February 2017
Revision: 1

Version 1 – February 2017

Summary
For more than four years, MT Højgaard has systematically uncovered the scope of critical clashes in the 3D design that we as contractor receive in connection with calls for tenders etc. as these clashes may drive up costs and delay production on site.

This white paper analyses the scope and nature of critical clashes in the 3D design on projects that together have more than 2.4 digital building components and which have been put out to tender in 2016 and at the beginning of 2017. The analysis gives a picture of a practice where:

- the contractors receive projects with up to 33,000 critical clashes;
- there is an average of 98 critical clashes per 1,000 m^3 in the 3D design;
- there are more than 42% of all critical clashes in the interdisciplinary clash detection.

The analysis thus shows that the interdisciplinary clash detections performed before the contractor is involved do not reduce the scope of critical clashes sufficiently from a buildability perspective (see Figure 1). Failure to involve the contractor and inadequate clash detection may be connected with the temporal and financial problems on construction projects. The white paper presents a possible solution to the industry in the form of early involvement of the contractors in an effective digital collaboration using Virtual Design and Construction (VDC).

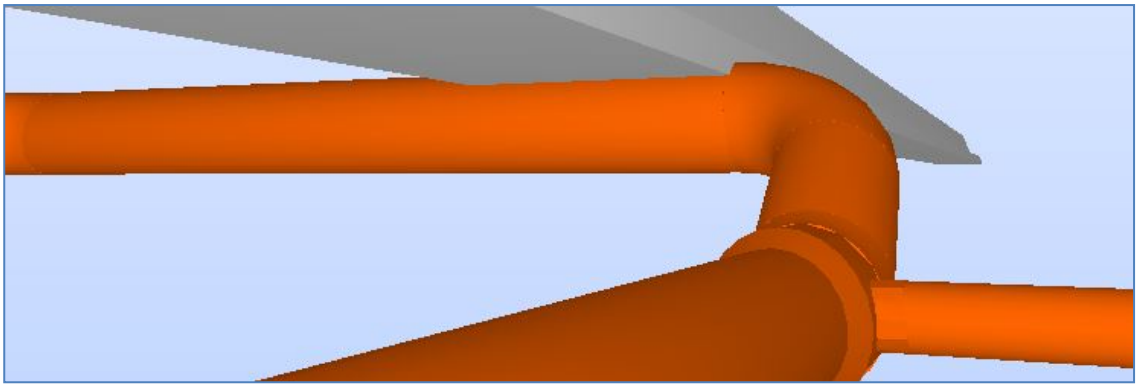

Figure 1 Examples of critical clashes which are either impossible to implement or which require extra works

Critical clashes cause problems in our industry, both nationally and internationally
In April 2014, MT Højgaard published a white paper entitled *The Quality of Design Material in Denmark* (in Danish) and subsequently in August 2015 a white paper entitled *IFC - A driver for design quality in the AEC industry* (in English) which received the bSI Award 2014 recognition *Heroes of Interoperability Award* from the buildingSMART International (bSI) in Toronto in October the same year.

The white paper entitled *The Quality of Design Material in Denmark* from April 2014 showed "*that it is right to demand and focus particularly on ICT coordination to ensure a well-coordinated and strong design material".* One of the things that was emphasised was that the

use of Building Information Modeling (BIM) "*enhances the possibility of coordinating design material prepared by different disciplines by testing the discipline models against each other and identifying defects and deficiencies in coordination. This can form a platform for better execution of the project which will contain fewer errors in case of coordination failures, miscommunication, ambiguities etc. But the potential of better design information quality remains largely unexploited in the Danish construction industry*".

Both white papers were based on an analysis of the 3D design of 153 projects in the period 2013 and 2014 and had two main conclusions on the quality of the 3D design:

- The use of the IFC format improves the quality of the 3D design – "*The results show a 33% increase in the quality of the design material when projects include IFC as a part of the design material*" (see the white paper entitled *IFC – A driver for design quality in the AEC industry*).
- There is a great potential in working with the quality of the 3D design provided to the contractors on a project - the white paper entitled *The Quality of Design Material in Denmark* showed that "*in 56% of all projects internal collision and clash detection reveals material deficiencies that require additional coordination and planning of the design material. Moreover, the analysis shows that in 67% of all cases, collision and clash detection performed when the discipline models are compounded also gives rise to additional coordination and planning of the design material*".

In the period following the publication of the two white papers, there were throughout the industry various initiatives to create a common understanding that some clashes in a 3D design are irrelevant to the production on site whereas other clashes have different and more profound implications for the construction project and may cause several weeks' delay and very large sums to handle rework, procurement and production of specific building components.

From 2015, several clients began to include analyses of the scope and nature of clashes in the 3D design in their overall project charter when they invited tenders for construction projects. In September 2016, the Danish trade organisation *bips* converted this best practice within the industry into the *C402 Consistency Checking in Building Models (in Danish: C402 Konsistenskontrol af bygningsmodeller)* standard providing guidance on quality assurance of 3D design in the industry. As stated on page 11 of *C402 Consistency Checking in Building Models*, the purpose of clash detection is to "*eliminate critical clashes within the individual discipline and across disciplines that have financial and temporal implications for the project*". In *C402 Consistency Checking in Building Models*, clashes in the 3D design are divided into three categories depending on the importance to the project where "*C*" refers to "*Criticality*":

C1. Low severity
C2. Moderate severity
C3. Critical severity.

The critical clashes (C3) include all clashes that "*are deemed to have a great impact on the execution of the project and/or great financial implications*". *C402 Consistency Checking in Building Models* further states that critical clashes "*are clashes that have no documented solution*".

Three years later the scope of critical clashes is still too large
MT Højgaard has analysed the critical clashes in the 3D design of projects that involve a total of more than 2.4 million digital building components distributed across architectural, engineering, ventilation, electricity and HVS models.

Despite many years of working with the IFC format within the industry and digital tools that effectively contribute to the coordination and handling of the 3D design between the project designers, we have as contractor received projects with up to 33,000 critical clashes in 2016.

The interdisciplinary clash detection is a key element in any good digital collaboration on a construction project. The scope of critical clashes in the 3D design which is three years later illustrated in Figure 2 more than indicates that there is room for improvement in the way the industry coordinates and collaborates on the digital platform for projects. In 2014 the white paper entitled *The Quality of Design Material in Denmark* described one of the problems faced in terms of the quality of 3D design coordination: "*When different disciplines develop discipline models, it is necessary for them to coordinate with each other as otherwise it will not be possible to compound the models to make an overall assessment of the project. The analysis shows that on 20% of the projects, the coordinates are not the same in the discipline models, which makes it difficult to use the models throughout the project"* and the current analysis shows that industry practice has not improved in this area.

The analysis forms a picture of an average 3D design in 2016 and the beginning of 2017 that has 98 critical clashes per 1,000 m^3, of which 42.61% of the critical clashes are detected in the interdisciplinary clash detection. The distribution of the critical clashes is shown in Figure 2:

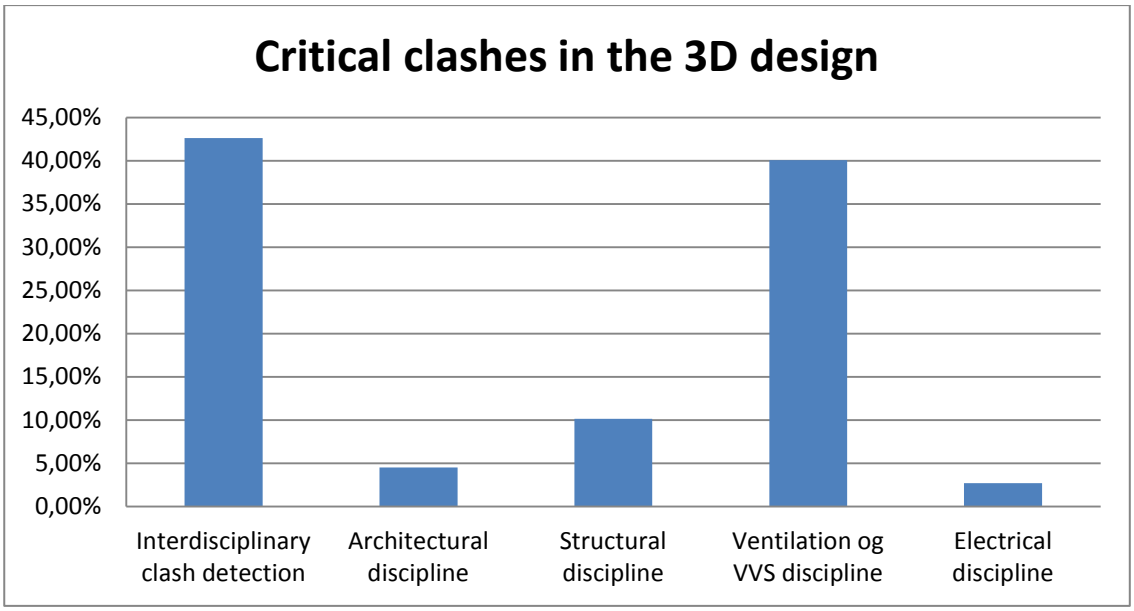

Figure 2 Critical clashes in the 3D design provided to contractors in 2016 and 2017

If we look only at projects with more than 100,000 building components in the 3D design, there is an average of 104 critical clashes per 1,000 m^3, of which more than 48% of the critical clashes are detected in the interdisciplinary clash detection. There is a large spread in the quality of 3D design, ranging from 20 to 300 critical clashes per 1,000 m^3, which may indicate

that some of the designers deliver a 3D design that supports a well-coordinated implementation of the project.

The large scope of critical clashes is not expedient for the project parties. Analyses and initiatives in the period from 2014 to 2016 have shown that the critical clashes pose an unnecessary temporal and financial risk to the client and the contractors, but no analyses have shown which initiatives the client can bring into play on a project to reduce the scope of critical clashes.

Interdisciplinary clash detection methods
Today the industry has a common conceptual framework for the quality of the 3D design with a concept such as critical severity regarding clashes. Critical clashes in the 3D design can be uncovered systematically and handled in the interdisciplinary clash detection and coordination using analysis tools such as Autodesk Navisworks and Solibri Model Checker (see Figure 3).

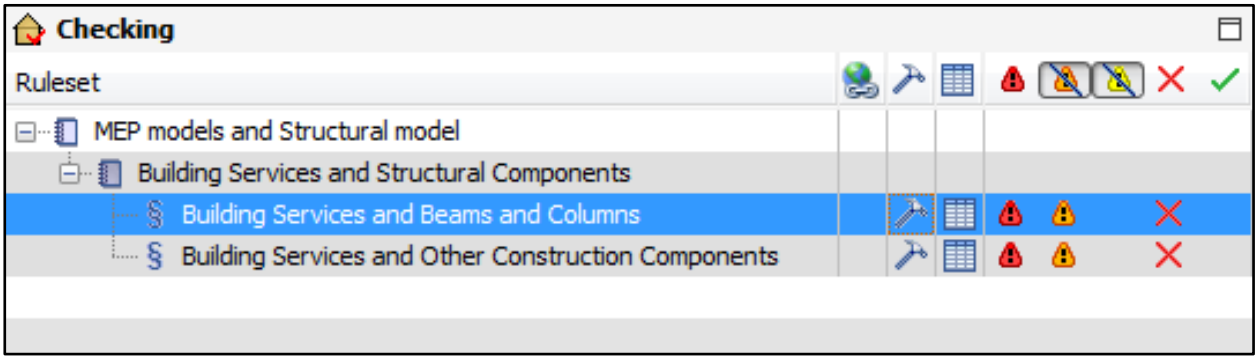

Figure 3 Example of the application of rules in the analysis tool Solibri focusing on critical clashes (C3) between discipline models (marked red) and where Moderate severity (C2) and Low severity (C1) (marked orange and yellow respectively) have been deselected

It means that approaches to improving the quality of the 3D design can become concrete and measurable (see Appendix A providing an example of benchmarking of e.g. critical clashes in the 3D design of the discipline models (*Internal Clash Detection*) and the interdisciplinary clash detection (*Interdisciplinary Clash Detection*). Benchmarking on critical clashes gives the project parties a real opportunity to show and follow up on the quality of the digital deliverables from all parties. In that way, the industry can achieve a new good practice that drives up productivity when rework, wait times, etc. on site are limited.

The goal is not zero clashes, but zero critical clashes
In recent years, MT Højgaard has, together with designers, taken an effective approach on several projects to ensure a 3D design which supports an efficient production on site. The common approach shows that working with 3D design can be improved in two essential respects:

- The early involvement of the contractors in terms of both on-site and off-site production for the project.
- A close collaboration between the designers and the contractors which is supported by a systematic application of tools for the 3D design. It is not merely a common application of information and communication technology (ICT) focusing on project BIM, but it is a VDC collaboration where the project is designed and executed in a virtual environment. This through a process management ensuring that ICT and BIM help reduce the number of critical clashes by way of a systematic interdisciplinary coordi-

nation. In this way, we boost the quality of the production basis for the contractors on the project.

Zero clashes in the 3D design are not the goal to be focused on by the industry parties to begin with. However, zero critical clashes in the 3D design is both a reasonable and realistic goal and imperative for an efficient digital collaboration.

Through VDC collaboration with the client and the designers, MT Højgaard succeeded in achieving measurable results. One of the important elements of the VDC collaboration is the common review and update of the project 3D design in the VDC Lab in which both the designers and the contractors participate. Practice shows that the client will gain most from the VDC efforts when VDC is incorporated in the client's framework for the digital collaboration as early as possible. This is supported by the white paper entitled *Closing the gap with VDC and early involvement* from March 2016 which shows that the systematic benchmarking increases the project parties' focus on reducing the scope of critical clashes.

Final summary and recommendation

In recent years, steps have been taken to optimise the digital collaboration on construction projects. The parties involved in the 3D design have the expertise on good digital collaboration in place, but it is necessary to focus on continuous benchmarking of the interdisciplinary coordination of the 3D design. It does not require much time to demand, execute and apply a systematic benchmarking of the scope of critical clashes if the work is based on *C402 Consistency Checking in Building Models*, which should be standard practice.

In MT Højgaard, our efforts have in this respect been based on Virtual Design and Construction (VDC) which has made designers and contractors work together to continuously improve the quality of the 3D design through a coherent approach to the construction project. In this way, we have succeeded in reducing the number of critical clashes and consequently the risk associated with the project.

References:

- C402 Consistency Checking of Building Models (in Danish: C402 Konsistenskontrol af bygningsmodeller), bips, September 2016
- White paper entitled Closing the Gap with VDC and Early Involvement, March 2016
- White paper entitled IFC – A driver for design quality in the AEC industry, August 2014
- White paper entitled The Quality of Design Material in Denmark, April 2014

Appendix A – Example of benchmarking of critical clashes in the 3D Design.

Extract of MT Højgaard's benchmarking of critical clashes in a 3D design:

Internal Clash Detection

Internal clash detection is made for disciplines in scope and disciplines out of scope (if there is). If the disciplines within scope are not coordinated, this can affect QTO and the models might not serve as a good basis for production. If the disciplines out of scope are not coordinated, this might result in project changes.

Architectural discipline			
	Critical Severity	**Moderate Severity**	**Low Severity**
Issue Count	241	5	262
Issue Density	7.8	0.16	8.5
Structural discipline			
	Critical Severity	**Moderate Severity**	**Low Severity**
Issue Count	24	44	0
Issue Density	0.78	1.4	0
Ventilation and VVS discipline			
	Critical Severity	**Moderate Severity**	**Low Severity**
Issue Count	1548	2256	0
Issue Density	50	73	0

Interdisciplinary Clash detection

Interdisciplinary clash detection is made between disciplines. If the disciplines are not coordinated, this will result in project changes and changes in quantities.

Interdisciplinary clash detection	**All disciplines**
Total number of checked objects	47287
Total number of objects with mistakes	8274
Total number of clashes	3941
Severe clashes (issues per 1000 m^3)	1069 (35)
Moderate clashes (issues per 1000 m^3)	1952 (63)
Low clashes (issues per 1000 m^3)	920 (30)