Collaborative Engineering with IFC: common practice in the Netherlands

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Abstract
The practical use of the open data standard IFC has been on debate for years. Many publications have presented limitations about the technology and software implementations. Only little research is done with users. In recent years the use of IFC in the Netherlands has increased rapidly. Users claim it is the only way to collaborate effectively in a BIM environment. However, discussions about the process and model quality seem to blind the debate. The goal of the research presented here was to find if there is a standardized workflow (and/or dataflow) for collaborative engineering with IFC. This was done by observations at organizations and interviews with users. The conclusion of the research is that there seems to be a standardized process and dataflow for collaboration with BIM, and that IFC is the most effective technology to support it. In this paper we present that process, explain the collaboration cycles and describe a 'typical' example. The authors feel this paper eliminates many myths and shows that inventive users are the driving force of innovation in our industry.

Keywords: BIM, IFC, Collaboration, process

1 Introduction

The 'Industry Foundation Classes' (IFC) is the main open data standard in the Architectural, Engineering and Construction (AEC) industry. The use and usefulness of IFC has been under a lot of pressure. In recent years the industry has discovered IFC as a reliable technology to collaborate. For some reason non-users are still reluctant to the use of IFCs and thereby obstruct an open discussion about it. In a risk avoiding industry, the potential of BIM is therefore limited. The debate is further hindered by discussions about 'Level of Detail/Development' and claims that the BIM process does not have the same steps as a traditional process. This paper examines the workflow of advanced BIM users to investigate if there is a common workflow for the industry.

2 Background

In 2012 the publication '*Collaborative Engineering with IFC: new insights and technology*' by Berlo et. al. suggested high usefulness of IFC for the industry. The concept of 'reference models' was introduced and claimed to be very effective when used in an specific workflow. That result was the base for BuildingSMART in the development of the Model View Definition (MVD) 'IFC Reference view'. Today the use of this concept in the Netherlands has advanced and evolved. This paper intents to bring an update of the publication from 2012.

In the Netherlands the discussion about the stability of IFC seems to be under less stress than a couple of years ago. Many conferences and workshops have shown that using IFC with the reference model concept is stable and effective. The reason why IFC is popular, in comparison to other (open) standards, might have something to do with the relatively high penetration of Solibri users. Solibri Model Checker is above average popular in the Netherlands and relies highly on IFC data. Recently Tekla BIMSight also seems to gain popularity. Both Solibri and Tekla BIMSight have the ability to exchange data about issues and topics in the 'BIM Collaboration Format' (BCF).

In the Netherlands there are different tender processes and contractual constructions. This has an effect on the composition of project teams. We try not to deal with these in this paper as it had little influence on the collaboration workflow.

Like many countries, in the Netherlands the debate about BIM is driven by top down policy makers. Many discussions about concept libraries, standardization and (lack of) software implementations have set the tone for years. The mindset of this approach was that BIM is far from 100% effective. Parallel on that effort, end-users have just started using the available tools and dealt with problems when they arise. This bottom up approach allowed them to harvest the usable technology as effective as possible at that moment. For many years the industry thought that, in time, the bottom up and top down approach would meet each other half way. However, more and more people seem to agree that both approaches are on different tracks. In respect to the conclusion of Miettinen & Paavola (2014) this research presented in this paper specifically reports the bottom up approach from (advanced) users.

3 Research

3.1 Research goals

The main goal of this research is to explore if there is a standardized collaboration workflow when using BIM. Originally there was no pre-requirement for the use of IFCs. The research looks at a process workflow over different stages of the project, and at workflow within a single stage. The hypotheses was that many organizations work in the same way but do not realize it yet. Base research questions were: 'Is there a standardized project phasing when working with BIM (and is that different for a traditional phasing)?'; 'How does the data flow between organizations in a collaboration process?' and 'what are the limitations for an effective collaboration process with BIM?'. During the interviews additional questions were asked depending on the answers.

3.2 Methodology

To answer the research questions two types of research were used: observations and interviews. Observations were done at Hendriks Bouw & Ontwikkeling (Oss) and VolkerWessels (Tilburg and Eindhoven). The BIM Managers from these organizations are also co-authors of this paper.

Interviews have been conducted with known advanced BIM users. Multiple organizations were interviewed. The interviews were qualitative and always with more than one representative from the organization.

Information was also gathered from daily practice of research organization TNO. The BIM team at TNO is involved in projects that have issues with BIM. These abnormalities bring detailed insight in collaboration processes at companies using BIM.

3.3 Delimitation of the research

This research is being done in the Netherlands. Although it aims to give an overview of the phases in a BIM process, the engineering phase had specific interest. The reason for this was because the use of BIM with suppliers has increased rapidly since the previous publication about reference models (Berlo et al, 2012). The questions during the interviews were specifically aimed at contractors and their collaboration with other team members (architect, MEP and suppliers). The authors believe it gives a good insight in this part of a BIM project, but more research is necessary to find if the dataflow is representative for the design stage.

4 Workflow & Dataflow

Several observations and interviews showed a generic pattern in the phases and data flow during a project that used BIM. This chapter describes the generic pattern. We start with the phases per project, followed by a description of the dataflow in one of the phases and finally present a typical example.

4.1 Project phases

The project phases are debated since the popularity of BIM technology. In the publication '*Creating the Dutch National BIM Levels of Development*' (Berlo et al, 2014) this was already described for the Dutch situation. Seven levels where introduced for results of each stage. The conclusion was drawn that the go/no-go moments in a project are basically the same whether BIM is used or not. The conclusions of the 2014 research have been only limited adopted by the industry. The research presented in this paper therefore had a closer look at the validity of the project phases.

Interviews and observations learned that the basics remain the same, but there is confusion about the naming of the phases. The phases found in this research are presented in Figure 1.

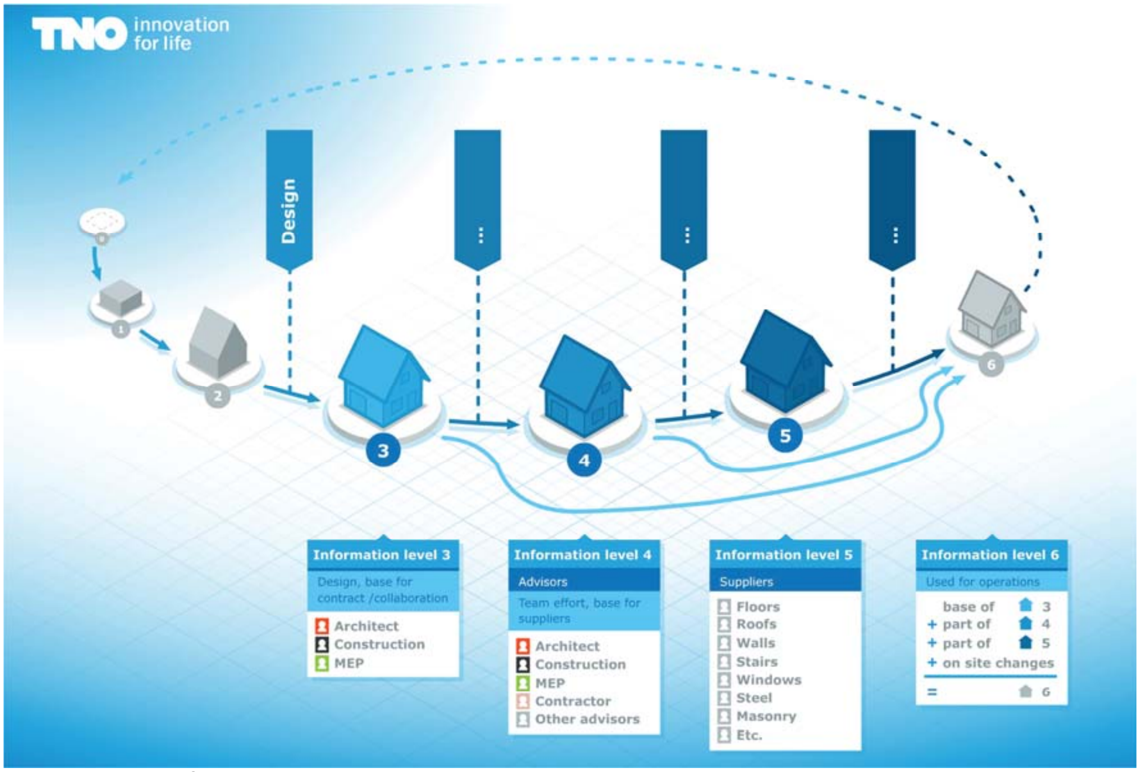

Figure 1: Process flow / project phases

Everyone seems to agree that there is a design phase (with several go/no-go moments). This model (on Dutch information level 3) is a collection of discipline models (or aspect models) created by (usually) the architect, the construction engineer and the MEP engineer/advisor.

The model that results from the design phase needs to be upgraded in the next phase. Most people agree that this phase is called 'engineering' but there is no unanimity on this. During this phase extra advisors take part in the team. In most cases this is the contractor and advisors on important parts of the building (for example a façade supplier when the façade is a big part of the project and design). During this phase the model is upgraded to a higher reliability. Tolerances are defined in the model; slope of the floors might be modeled; extra properties are added in case the team works with suppliers that needs extra details about objects; etc. In this phase the contractor might also model scaffolding, the crane, etc. This information is not always exchanged with others so of lower importance for the topic of this paper. In this phase constant checking is done between the mutual discipline models and aspect models. In the next chapter 'data flow' this is explained in detail. The result of this phase is a collection of discipline models (aspect models) from the architect, construction engineer, MEP engineer, contractor and other advisors. This model is a model on level 4 of the Dutch information level standard and the base to send to suppliers.

In the next phase the suppliers are the main modelers. Suppliers receive the data from the model at level 4. Sometimes they receive all the data, sometimes only from the objects that concerns them. The suppliers are requested to reply with a model that replaces the objects in the original model from level 4. The contractor usually checks if the objects received from suppliers match the plan and principles of the original designed objects. This is done with Solibri Model Checker in most cases. Interviewed teams showed advanced custom-made Solibri rules to check model integrity.

The name of this phase is debated the most and doesn't seem to converge to a consensus. The result is a set of aspect models from every supplier that (in total) could replace the model from level 4. Not all objects from the original model are replaced. Only the ones that are provided by suppliers. Typical objects like masonry and tiling remain from the architect and cast in situ remains in the model from the construction engineer.

Then starts the construction phase (also 'build' phase is a popular term for this phase). During the construction several models are used to control the construction. The use of A3 drawings created on the fly on site, as described by van Berlo and Natrop (2014) is experienced as a potential valuable concept for the use of BIM in this phase. After the construction phase data is gathered from several sources. Usually the original design model from level 3 is the base, complemented with objects and properties from the models from level 4 and 5. Changes during the construction phase are also processed. The result is a new model with the label 'level 6'. In some cases (with lesser experienced clients) this is one model (file) on request of the client. Advanced clients however set specific quality restrictions that the model from level 6 has to comply with. COBie is gaining interest from the Dutch industry to use during the operational phase of a building. The actual appearance of the level 6 models may therefor vary. This research didn't focus in detail on the operational phase (and models from level 6). This part of the Dutch situation doesn't seem to be mature enough for conclusions at this point in time.

4.2 Data flow

In every phase of the project an intense collaboration effort is required. The number of involved partners is increasing during the project and the amount of data also increases. This chapter describes the generic collaboration process and dataflow that goes on during every phase, but specifically in working towards level 4 and 5. It might also represent the phase that works towards a design model on level 3, but more research is needed to conclude this.

The collaboration workflow and dataflow are described in Figure 2.

Figure 2: Collaboration workflow (with IFC and BCF)

The process starts on the left with the green (MEP), black (construction engineer) and orange (architect) models. Every team member models data in their own native BIM softwaretool. Popular tools in the Netherlands are ArchiCAD, Tekla, MagiCAD, DDS and Revit. Team members are getting paid to model their knowledge and experience in a BIM. They are not getting paid to use a specific software tool. Free choice of tools is seen as a valuable freedom and contribution to effective work in a BIM environment. Without good tools for the actual team members, good collaboration is impossible.

Part of the native model is exported to IFC. Be aware that only part of the data is put into an IFC file. Not all data have to be shared with others and experience learned that this only diverts from the focus. The fact that not every object is represented in IFC is therefore not an issue.

The IFC data are shared with team members. Depending on the phase of the project and intensity of the collaboration this is done, at regular frequency, bilateral or as a whole team every week or month. The IFC data are viewed and coordinated in relation to each other. In most cases Solibri Model Checker or Tekla BIMSight is used for this. Notable is that the IFC data are not fused into one file or central database, but are being kept separate while viewing all the data at once. For the user this creates a seemingly integrated model while different disciplines are still nicely separated. Most users call this an 'aggregated model'. Some projects use BIM specific repositories like BIMserver (Beetz et al, 2011) for this, but most use generic tools like dropbox, projectplace or alfresco. In many cases the revisions are maintained so the project team can go back to previous versions.

In the one-to-one interaction between partners there are examples where different partners receive different structured IFCs from the same native model. Since IFC is a standard to transport data the same data can be structured differently without breaking the semantic meaning. An electrical engineer might get an IFC file from the architect that is exported with different settings than the one send to the plumbing engineer. Effective collaboration is also about supplying custom data per project partner instead of just dumping everything over the fence to the others.

Users also see a link with the 'Level of Detail/Development' (LOD) discussion. It doesn't matter to them what information is in the model, but what matters is what they can do with that information (Figure 3). Maybe information is in the model to perform an engineering task, but the status of the model might not be final enough to start that work. Maybe the model doesn't show many geometric details, but all the information is in there to perform a cost calculation. This is in line with the publication about the Dutch information levels and the Level of Development Specification from BIMForum.org (2014).

Figure 3: Education about the difference between LOD and usefulness

The 'aggregated model' (central presented model in Figure 2) is used for analyses. In most case Solibri Model Checker is used in an advanced way to check several quality rules. During the design phase an example is the check if all structural columns occur duplicate in the model and exactly the same. This check is used between architects and construction engineers to make sure the collaboration about the (location of the) structural columns was successful. When the structural columns in the model from the architect are the same as the ones in the model from the construction engineer the collaboration was successful. This check is done every time the discipline models are combined. In a later phase the suppliers models are being checked against the original design. For this also specific rulesets are created. More common checks like collision detection, cost calculation, energy efficiency, program of requirements, etc. are also performed with this model.

The results of these analyses form a to-do list for the project team. This list is constructed by the project manager (sometimes referred to as 'BIM coordinator' or 'BIM manager'). The todo list used to be send to the project partners by e-mail and excel. More recently the use of BCF has gained popularity, probably due to stable implementations in Solibri and Tekla BIMSight. In some cases BCF issues are not e-mailed, but communicated via a central dashboard as described by van Berlo and Krijnen (2014).

The todo lists are processed by the modelers in their own native BIM software tool. This triggers a new iteration of the workflow.

Basically Figure 2 shows the collaboration process and data flow of a BIM project. On the left the modeling takes place, in the middle coordination and on the right the conclusions. Conclusions are communicated with the modelers. Important to notice is that the IFC data flows only downstream. A new iteration starts with new export of IFC from the native model. Team members and modelers process results from the iteration loop.

The new BCF 2.0 brings functionality to import IFC snippets to native models. Interviewees noted this could be a potential useful technology.

4.3 Example

To give more insight in the generically described process, an example is provided in this chapter. The authors present the 'PLUS ULTRA' project. A project from contracter Hendriks Bouw & Ontwikkeling. This project seems representative for many BIM projects in the Netherlands and holds several good examples to show the concept of collaboration with IFC.

Plus Ultra is an 8.000m2 project to be constructed in Wageningen. It has 5 storeys and an estimated building cost of 8.7 million euros. The client is Kadans Vastgoed. The handover is expected at the end of 2015. Hendriks is working with BIM since 2009. Since early 2014 every project is developed with BIM.

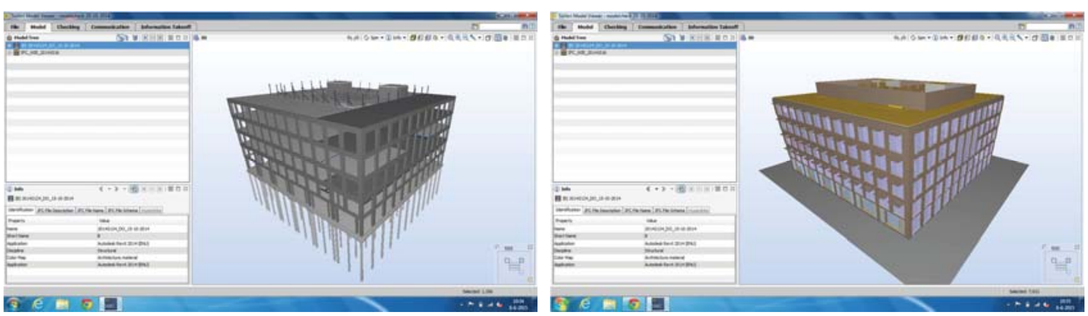

Figure 4: The models from the Construction engineer (left) and architect (right)

De starting situation for this project from the perspective of the contractor was after the design phase (model on level 3) after winning the tender. At this moment there was only a Construction model and Architectural model in BIM. The MEP engineer didn't have BIM data.

In the engineering phase (working from level 3 to level 4) the architect was involved to detail the model, but also other modelers from the contractor were involved.

In this phase the iterative collaboration process described in chapter 4.2 (and shown in Figure 2) was on a weekly base. In similar projects we found one-to-one collaboration in a cycle of every two days. It occurs that, when possible, in this one-to-one communication native BIM data is shared between partners (so not in IFC format). There is no religion about IFC or native data exchange found within this project nor with any of the interviewed users. Team members make sure they can collaborate effectively to get their job done.

Every Friday the discipline models were checked in Solibri Model Checker. The found issues are communicated with BCF (via e-mail). This process took place from October 2014 till March 2015. Experience learns that most projects are on the level 4 BIM within 8 to 12 weeks.

The process each week is: 1. Evaluating BCF issues received from project manager, 2. Modeling changes in the BIM, 3. Exporting IFC (or multiple IFC's depending on the collaboration team), 4.

Sending IFC to project manager, 5, checking the model (by manager), 6. Discussing issues with the project team. The responsibility from the project manager at the contractor is to make sure he receives updated IFC data, checks it in Solibri model checker and sends out the BCF list to the team.

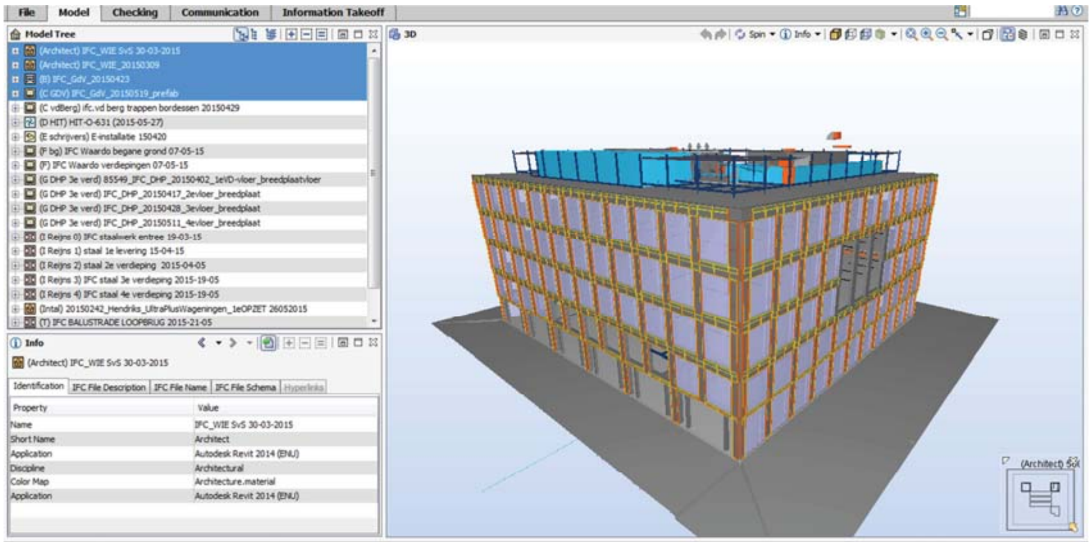

Figure 5: the discipline models from the suppliers viewed as an 'aggregated model'. This is a model on level 5.

In the interviews, and specifically in this Plus Ultra project, users stated that they have been trying to develop a generic '*BIM Execution plan*' (in the Netherlands also called '*BIM Protocol*') for all their projects. Advanced users unanimously claimed it is impossible to create a standard BIM execution plan. Collaboration is not about standardizing a dataflow or process, but about connecting to other team members, listening to their needs and requirements and adapting to that in the project. More experienced users state that it is not desirable to standardize a BIM execution plan because each project has different team members, different (BIM related) goals and different output requirements. The 'BIM Execution plan generator' is trying to address this problem with a solution. This tool identified preferred working methods and integrated them in a (concept) BIM execution plan that identified pitfalls and advantages before the start of the project. The BIM execution plan generator tool is being tested in some projects but not enough to draw conclusions yet.

After the aggregation phase (engineering phase) Hendriks describes to have a '*clean order*' moment. At this moment the BIM model has the necessary quality to start the collaboration process with suppliers. At this moment the BIM is at level 4.

The name of the phase where the BIM gets from level 4 to level 5 is under heavy debate. At this stage the contractor asks suppliers to replace objects from the level 4 model with their own objects. This request is done by sending IFC data (in most cases custom datasets for each suppliers) accompanied with PDF and sometimes DWG data to the suppliers. The suppliers are requested to respond with IFC aspect models. The dataflow iteration from chapter 4.2 (and shown in Figure 2) starts all over again. In this phase the checks from Solibri are different and more focused on checking if the suppliers meets the original requirements from the level 4 model.

The authors have seen advanced use of Solibri Model Checker with custom-made rule sets that make effective collaboration very efficient. At the Plus Ultra project checks were done to see if there were objects modeled inside other objects (these don't clash in a collision detection). Another important step was also to check if load-bearing floors were resting on load-bearing walls (and vise versa). A tolerance check was introduced to make sure there was a 9mm gap between the wood carpentry walls and the aluminum windows (as agreed on at the start of the phase). A very visual check was done between floor slabs and MEP to check if the piping had enough space from the reinforcement bars. Some examples are shown in Figure 6.

In this phase it is important that suppliers deliver high quality IFC data. This is guaranteed by working with intense test sessions before the start of the phase. Small models are being exchanged to make sure that classifications, IFC export, origin points are ok, and other agreements are being met. This is easier with trusted and regular partners.

In this phase it is known to have daily communications and checks with Solibri Model Checker. The number of files (aspect models) is much higher that in the previous phase. The contractor is coordinating and in the Plus Ultra situation the models are shared on Google Drive.

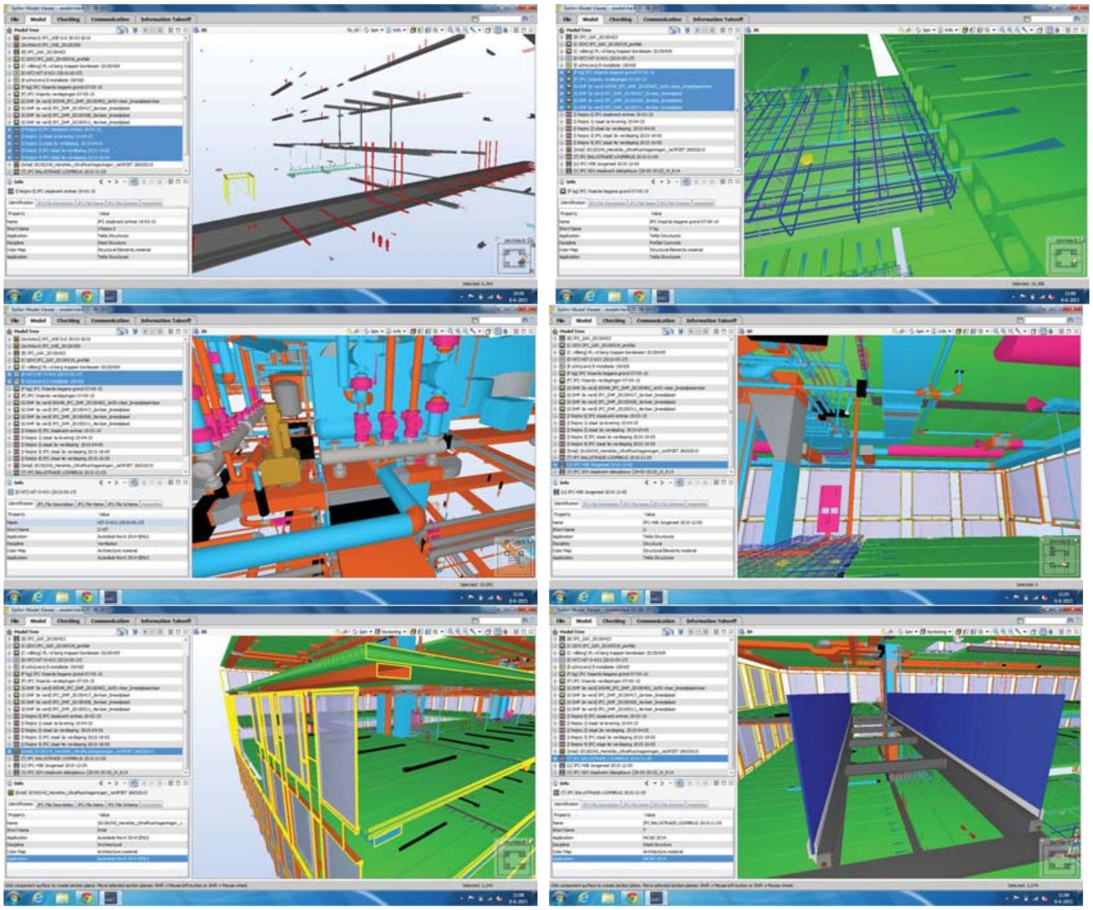

Figure 6: Examples of advanced checks between the discipline models from the suppliers (level 5) and original engineering models (level 4) with Solibri Model Checker.

In the Plus Ultra project the steelwork came from a supplier that modeled data in Tekla. In this case the supplier's sends data from Tekla to the machine park to produce the steel elements directly from BIM. Tekla was found to be used by over 90% of the steel suppliers. The limestone supplier's models in ACEdraw. The floor supplier of this project in Revit Architecture; the wood carpentry walls in HSBCAD. The hollow core floors came from a supplier using Allplan or another supplier using Tekla. The wooden mounting frame for the windows came out of Tekla. Aluminum windows were modeled in Revit. Railing and fences came out of HiCAD 2014. Over half of all suppliers use the BIM data to drive and control production. BIM and IFC make it possible to use the same data for production as for communication and coordination. For the communication with the client in this phase Hendriks uses Tekla BIMSight. The project manager on site also uses Tekla BIMSight during construction of the project.

All these modeling software tools have IFC as an export option. IFC is the only data format this can bring the different models in relation with each other. The accords between the contractor and the supplier ("definitive for production") were all based on the IFC data.

The use of BCF for issue management was experienced as very valuable in this project. An issue with an assigned user means that there needs to be a follow up. Management of issues is much more effective and transparent in this way.

5 Conclusions

This research has come up with some tentative conclusions. It seems valid to conclude that IFC works in daily practice in the Netherlands. Experienced users have found an effective way to collaborate in a BIM environment by using IFC.

The found process phasing and data flow seem to be a valid representation of the practical procedures in the Netherlands. This cannot be guaranteed due to the nature of this research (limited interviews and observations cannot be generalized into a generic concept).

Users unanimously agree that there are too many myths about BIM in general and IFC in specific. The legal issues of working with BIM seem to remain the same as before BIM, data are being kept separated between project partners (no central model in a repository), there is no data loss because there is no round tripping attempt with IFC (and not even a wish for that), and IFC can be exported in a proper way when users actually know what they are doing. In the industry inexperienced users still seem to stick to the myth that there are problems with all of the above statements. These negative rumors are strong and make it difficult for advanced users to partner with inexperienced users. New users first need to be talked out of disbelieve before the actual education can begin.

A noticeable conclusion is that none of the interviews users strives towards a perfect BIM. BIM is for them a way to effectively create a perfect building. They don't always need a theoretically perfect BIM for that.

The authors also conclude that the names of the project phases leads to unnecessary disputes about the process. Discussions have been observed where several team members didn't agree on the process just because they had a different semantic perception with some of the phase names. When asking what the tasks and goals should be in a phase they agreed that it was actually the same, but they named it differently.

There seems to be a sentiment that a standardized 'BIM Execution plan' is not possible and not desirable. This sentiment is not validated but also seen in other research and might be interesting for further investigation.

6 Recommendations and future work

The results and conclusions from this research have led to recommendations. In this chapter we present them:

1. The research finding support the conclusion from Miettinen & Paavola (2014): top down policy makers and bottom up users don't seem to meet in the middle. A recommendation is done to the top down policy makers to take knowledge of the rising movement of advanced and experienced users.

2. There are many myths and ignorance towards actual working solutions. We recommend increasing the priority of high quality BIM education. This might also increase the adoption of BIM in general because the risk for organizations would be lowered. This is why we also recommend software vendors to actively support education initiatives from the industry.

3. Concept libraries are not mentioned by users as an important part of the described process, but classifications are an important part of the dataflow. It is unclear how users value the difference between concept libraries and classifications. Further research on this is advised.

4. The naming of the phases should be defined and published. Since this is about standardization we recommend standardization organizations to take the lead on this.

We also see future work coming from this research. Using BIM during the construction phase is neglected during this research. How on-site changes should be integrated in the model and coordinated with the team is underexposed at this moment. More research on the phase leading up to a model on level 6 is needed.

The model checks are now done with Solibri in most cases. We see future applications for automated online BIM services (BIM Bots) like the ones presented in Global Perspectives on BIM: The Netherlands (Berlo, 2014).

7 Reflection

Due to the nature of the research (observations and interviews) it is difficult to generalize the conclusions for the whole (Dutch) industry.

This research focused on the phases between design and on-site construction. It is difficult to claim that the dataflow presented in Figure 2 is also valid for the other phases of a project.

Many of the projects use Solibri Model Checker very intense. It might be that the interviewed group is influenced by the use of Solibri in their judgment and preference for about the described workflow and IFC.

Acknowledgements

This paper was not possible without the kind help of many contributions from the Dutch AEC Industry. Special thanks go to the companies that opened their internal processes in order to get clear insight for this research. Without their open and honest attitude this publication was not possible. This publication is part of the Dutch National BIM Guidelines initiative and the authors thank the team for using and translating the infographics. Upfront gratitude to those who redistribute this paper and contribute to sharing knowledge.

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