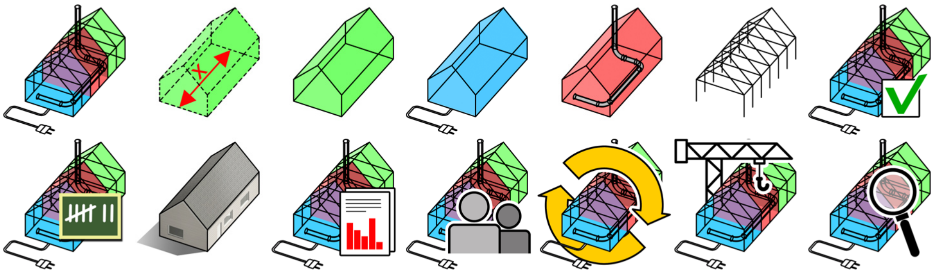
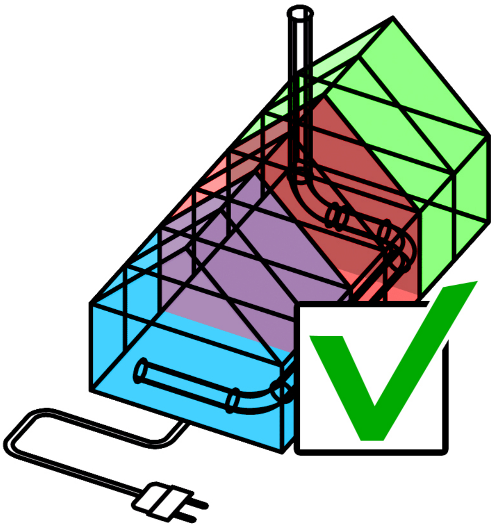


COBIM

Common BIM Requirements
2012

v 1.0



Series 6

Quality assurance

Table of Contents

Heikki Kulusjärvi

Foreword

The publication series “Common BIM Requirements 2012” is the result of a broad-based development project entitled *COBIM*. The need for these requirements arises from the rapidly growing use of building information modeling in the construction industry. During all phases of a construction project, the parties on the project have a need to define more precisely than before what is being modeled and how the modeling is done. “Common BIM Requirements 2012” is based on the previous instructions of the owner organizations and the user experiences derived from them, along with the thorough experience the writers of the instructions possess on model-based operations.

The parties to this project are: **Funding providers:** Aitta Oy, Larkas & Laine Architects Ltd, buildingSMART Finland, City of Espoo Technical and Environment Services, Future CAD Oy, City of Helsinki Housing Production Office, City of Helsinki Premises Centre, University of Helsinki, Helsingin Yliopistokiinteistöt Oy, HUS Kiinteistöt Oy, HUS Premises Centre, ISS Palvelut Oy, City of Kuopio Premises Centre, Lemminkäinen Talo Oy, Micro Aided Design Ltd. (M.A.D.), NCC companies, Sebicon Oy, Senate Properties, Skanska Oy, SRV Group Plc, Sweco PM Oy, City of Tampere, City of Vantaa Premises Centre, Ministry of the Environment. **Written by:** Finnmap Consulting Oy, Gravicon Oy, Olof Granlund Oy, Lemminkäinen Talo Oy, NCC companies, Pöyry CM Oy, Skanska Oyj/VTT Technical Research Centre of Finland, Solibri, Inc., SRV Rakennus Oy, Tietoa Finland Oy. **Management:** The Building Information Foundation RTS.

The requirements were approved by an executive group consisting of parties to the project. The executive group acted as committee TK 320 of the Building Information Foundation RTS, and as such, participated actively in developing the content of the requirements and asking for comments from the members of the executive group and from interest groups.

Parties to the © COBIM project.

Main objectives of building information modeling

Property and construction modeling aims to support a design and construction lifecycle process that is of high quality, efficient, safe and in compliance with sustainable development. Building information models are utilized throughout the building's life cycle, starting from initial design and continuing even during use and facility management (FM) after the construction project has concluded.

Building information models enable the following, for example:

- Provision of support to the investment decisions by comparing the functionality, scope and costs of the solutions.
- Energy, environment and lifecycle analyses for the purpose of comparing solutions, design and objectives of facility management follow-up.
- Design visualization and analysis of construction feasibility.
- Enhancement of quality-assurance and data exchange and making the design process more effective.
- Utilization of building project data during use and facility management activities.

To make modeling successful, project-specific priorities and objectives must be set for models and model utilization. Project-specific requirements will be defined and documented on the basis of the objectives and general requirements set in this publication series.

General objectives of building information modeling include, for example, the following:

- To provide support for the project's decision-making processes.
- To have the parties commit to the project objectives by means of using the building information model.
- To visualize design solutions.
- To assist in design and the coordination of designs
- To increase and secure the quality of the building process and the final product.
- To make the processes during construction more effective.
- To improve safety during construction and throughout the building's lifecycle.
- To support the cost and lifecycle analyses of the project.
- To support the transfer of project data into data management during operation.

"Common BIM Requirements 2012" covers targets for new construction and renovation, as well as the use and facility management of buildings. The minimum requirements for modeling and the information content of models are included in the modeling requirements. The minimum requirements are intended to be observed on all construction projects where the use of these requirements is advantageous. Besides the minimum requirements, additional requirements can be presented on a case-specific basis. Modeling requirements and content must be presented in all design contracts in a binding and consistent manner.

The publication series “Common BIM Requirements 2012” consists of the following documents:

1. General part
2. Modeling of the starting situation
3. Architectural design
4. MEP design
5. Structural design
6. Quality assurance
7. Quantity take-off
8. Use of models for visualization
9. Use of models in MEP analyses
10. Energy analyses
11. Management of a BIM project
12. Use of models during building use and facility management
13. Use of models in construction
14. Use of models in building supervision

In addition to the requirements in his or her field, each party to a building information modeling project must be acquainted at a minimum with the general part (Series 1) and the principles of quality assurance (Series 6). The person in charge of the project or the project's data management must have comprehensive command of the principles of building information modeling requirements.

1 Introduction

In this context Quality Assurance is focused on checking the quality of building designs according to what BIM-based design currently enables. It should be noted that depending on the field of design, quality assurance has many other tasks beyond what can be done with BIM.

The main goals of Quality Assurance are twofold: first, the quality of each designers own design work shall be improved and secondly, the exchange of information between the parties, thus also making the overall design process more effective.

Quality assurance of BIMs is a joint effort of the designers and the client, the purpose of which is to improve the quality of the design solutions, their conformance to the client’s needs and the predictability of the construction schedule and costs, to facilitate the construction stage, to reduce the amount of modification design required during construction, and to ensure a functional, high-quality building as the end result.

In this context, a Building Information Model (BIM) refers both to the original model that is in the native file format of the designer’s BIM Authoring Tool and to the IFC model (**Error! Reference source not found.**).

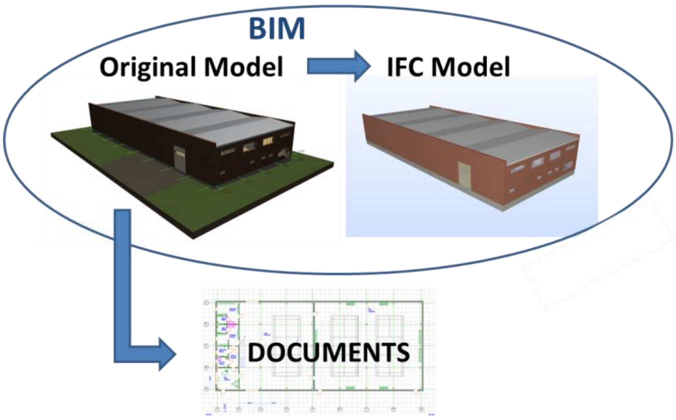


Figure 1. BIM Consists of Both Original and IFC Models

Quality assurance of BIM also improves the quality of documents produced from BIM.

This document focuses on the method of quality assurance, describing what kind of problems BIMs may typically involve, how to detect them, and how to correct them in the most convenient manner.

Detailed requirements for each design discipline will be found in design field specific guides.

Requirement

Design field specific requirements define what information the BIM file shall include and how the information is defined and introduced unambiguously. Quality assurance is meant to ensure that the BIM is built according to these requirements and therefore fits its intended purpose.

Instruction

The BIM quality assurance mainly refers to the validation of the IFC model, although the requirements also refer to other validation stages, the execution of which makes the work easier and, ultimately saves time for all parties.

In a traditional design process, 5–10% of the design information is systematically checked, whereas the use of an IFC model makes it possible to systematically check and analyze 40–60% of the information contained(e.g. in the architectural design).

Please note that this method does not measure the functionality or fitness for the purpose (e.g. structural analysis) or performance of architectural design.

There are three approaches to analyze IFC models and their content

- *Technical information content; has the BIM file been produced correctly from the authoring tool?*
- *Information included; is discipline specific information of the current phase of design included?*
- *Design content and quality analysis based on a BIM file; analyze the model comparing components of the model against each other (like consistency, clash detection) or against known requirements (like spatial requirements, deficiency detection, building code checking)*

The quality assurance of IFC models does not specifically concern the IFC file structure but instead focuses on the content and correct presentation of the design solution.

If there is a problem with the BIM authoring tool used that should support IFC standards to produce a suitable IFC file, the first option shall be to seek alternative ways to overcome the issue causing the problem. In case this does not work this shall be handled as a problem of the authoring tool (see also section 2.2.).

If any structural IFC problems emerge during the course of the project, the software supplier should be contacted for instructions. At the same time, the client, BIM quality assurance persons, and those using the information should be notified of the issues encountered, without delay.

1.1 Quality Assurance; Client View

From the client's point of view, monitoring the project progress and conformance to the requirements defined for the project are of primary importance.

Quality assurance as such is not a new thing, and the process should already be in place in conventional document-based design processes. In practice however, this has required considerable effort and attention to detail, in particular in the event of changes. This, in turn, has often led to situations where the problems are only detected and resolved when absolutely necessary – usually at the construction site. To rectify the situation, additional design will then be required, often on a very tight schedule, which results in significant change orders and additional costs incurring for all parties.

Instruction
One of the main objectives of a BIM-based process is to detect potential issues as early as possible and to correct any discrepancies and deficiencies before they turn into problems.
A BIM-based quality assurance process, including checking and analysis of the BIM file, provides a better overview of the building information at an earlier stage. The mere visual examination of the BIM file will make it easier to form an overall view of the project, not to mention the more detailed analyses that can be performed.

1.2 Quality Assurance; Designer View

For a designer the key finding is to adopt BIM as part of daily practice. The designer is responsible of the quality of design, including BIM files as one of the vehicles for passing design information to other parties.

Instruction
Information is interpreted by the reader from traditional document-based design. Annotations etc. are not passed or understood between software tools. On the contrary, information in BIM will be utilized as such by other software tools. Please note that the BIM process is a vehicle for information management and transfer, but it's not meant to substitute, at least not in the near future, official documents.

Double-team work, where design is done following a traditional document-based process and a separate team is producing a BIM "because the client asks for it" must be avoided. In practice, this kind of working doubles the design costs and quality assurance of the BIM files will hardly improve the design that is done separately.

Designers shall use the most recent buildingSMART certified IFC import/export modules available for their choice of BIM authoring tools. If there is a problem with the BIM authoring tool used that should support IFC standards to produce a suitable IFC file, the first option shall be to seek alternative ways to overcome the issue causing the problem. In case this does not work this shall be handled as a problem with the authoring tool. In cases of this kind the provider of the authoring tool shall be contacted and support should be requested. Also, the project participants in charge of the BIM quality assurance and coordination shall be informed immediately and a written note shall be made.

1.3 Quality Assurance; Designer Group

The group of designers typically is not collectively responsible for design, but when the group performs effectively the overall quality of the design will improve, and especially when the design as a whole gets better coordinated.

Instruction
When the information in BIM is managed from the beginning the communication within and during the project is easier throughout. As in practice some part of the design, especially in the beginning, is at its early stage searching for its final form, it is important to indicate to other parties in the design group the maturity of design. Preliminary, immature design might help other designers see where the design is going and identify and raise potential issues early on.

Before the actual design starts, designers shall check the working coordinates for each designer. This can be easily verified by merging first BIM drafts and checking that coordinates, including elevation have been set up correctly.

The design group shall list and record BIM authoring tools and versions to be used in the project. This will help solve some issues later in the project.

1.3.1 Recommended Meeting Practices

Instruction
It is recommended to arrange BIM coordination meetings for designers where BIM files are used to communicate the status of design and bring up the issues needing more attention. It is recommended to arrange such meetings before official project meetings that are typically more for making decisions on next actions.

Meeting procedures are agreed specifically for the project. BIM files in IFC format shall be delivered before the BIM coordination meetings. Delivery, at the level designs are at the current moment, will be made to the person in charge of the coordination.

BIM files will be merged and preliminary observations will be made. Each party will report the status of the BIM file.

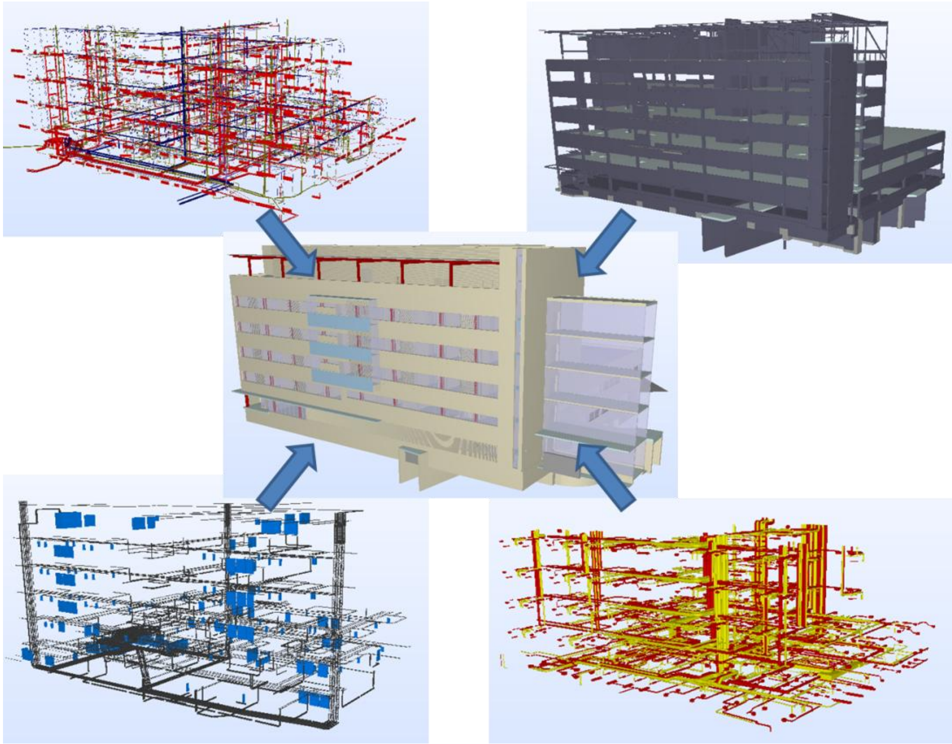


Figure 2. Merging BIM files

It is highly recommended that designers perform a self-test before the BIM coordination meeting, including at least:

- *Architect checking that spaces have been designed according to room schedule and that spaces are aligned with surrounding walls before delivering the model to other designers.*
- *Structural engineer checks that load bearing structures and openings in them match with corresponding components in the architectural model.*
- *MEP designers perform spatial coordination on their own field and clash detection between systems they have designed themselves.*
- *Chief Architect to assure spatial coordination, lead the clash detection process, and coordinate issue resolution.*

1.3.2 Manage Changes

Instruction
The general idea is that each designer informs other designers of the changes done by him/herself. When the design process is moving forward to the more final stage it is recommended that each designer checks models received from other designers to find out any changes made in more detail.

This enables designers to focus on and react to the most relevant changes affecting their own design. Furthermore, designers should check changes made to their own deliverables before sending them out to other designers. This is to avoid unintended changes flowing forward to other designers.

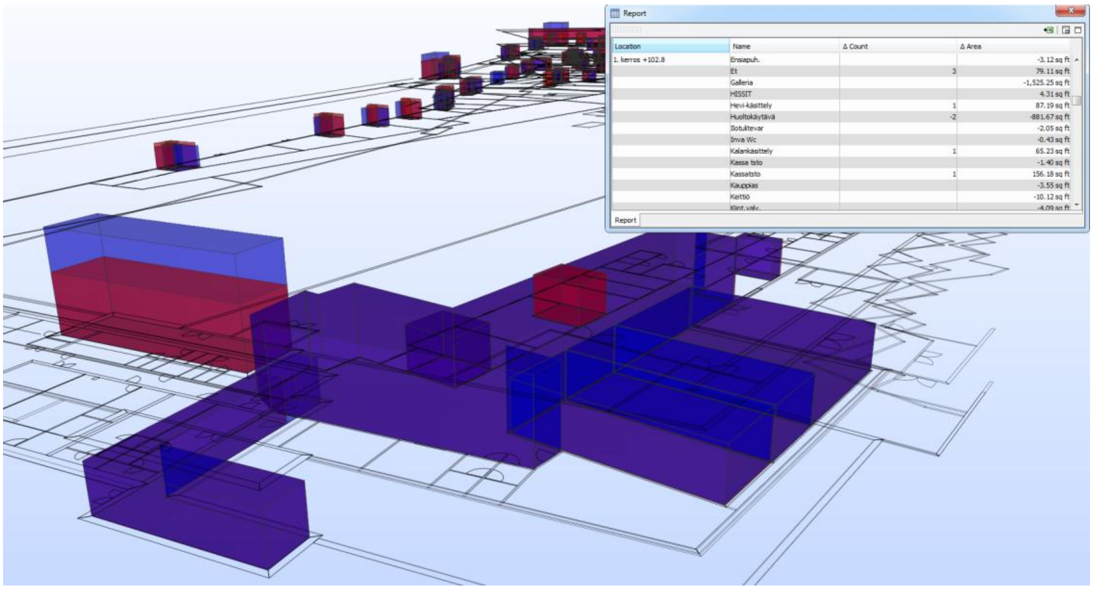


Figure 3. Visualizing changes between two versions of design

1.3.3 Improving Communication Between Designers

BIM files in IFC format make it possible to pass significantly more and better quality information between parties than traditional document-based design. By utilizing information the design process is more effective and the risk of misinterpretation is lower. At the same time, this does require more emphasis on the correctness of the information.

1.4 Transparency of the Process to all Parties

Checking and analyzing of design information utilizing IFC files gives a clear view of the progress of design and how client and user requirements are to be fulfilled.

As a positive side effect more people are able to follow how design is progressing and observe potential issues. This kind of transparency leads to better client satisfaction.

2 Quality Assurance

2.1 Managing and Maintaining the Quality the Designs

Making high quality design is easier when quality is taken care of constantly.

Requirement
Each designer shall perform quality assurance for their own design regularly according to their own quality assurance procedure.

Instruction

It is proven to be challenging to significantly improve the quality of design by performing ”clash detection” kinds of checks at the late stage of design. This easily leads to a situation where design coordination will be “done later” and preferably by “someone else” who is responsible for the task. Then suddenly the designs have surprisingly much to be fixed and in a tight schedule it is almost impossible to get everything fixed. This occurs especially when changes in one design create changes in other designs.

In addition, it shall be noted that there are discipline-specific quality standards, regulations, and laws that are not covered in these BIM requirements.

2.2 Checkpoints and What is Included

Quality assurance at checkpoints is a task with several steps including self-check done by the designer, check coordinated by the designers as a group, and clients (or subcontracted by client) quality assurance. All of these have a specific purpose.

Instruction
The quality assurance process consists of three main tasks done by individual designer, designers as a group, and client.

	Regularly	For meetings	Checkpoints
Designer (Self Check)	X	X	X
Designers Group (Quality Assurance)		X	X
Quality Assurance of the Client			X

Figure 4. Checkpoints of Quality Assurance in Principal

The internal quality assurance of the designer is solely the designer's responsibility and this document will only recommend some best practices for the quality assurance of what is reasonable with BIM files. If the designer uses a significantly different approach for quality assurance than what is described here, this method shall be described to the client and project team and have written approval from the client.

Checkpoints are agreed on a project by project basis. The more comprehensive quality assurance is done at agreed checkpoints (e.g. before producing concept phase documents, before final concept, next level, next level). A checkpoint is also required when design results are to be delivered (e.g. as inventory model). Checkpoints shall be part of normal scheduling and enough time including possible correction rounds shall be reserved.

2.2.1 Tasks of the Designer at Checkpoints

The designer is in a key role as his/her task is to bring the quality of designs, especially BIM files, to fulfill the design field specific requirements. The designer alone is responsible for this; no one is doing this for him/her.

Requirement
The detailed requirements as defined project by project according to the following instructions:

Instruction
Tasks on principal level are:

- *The designer's task is to first perform a quality check of the original model utilizing the features available in the BIM authoring tool. Potential issues will be corrected in the original model. By this manner many basic problems can be fixed and potentially one round of checking the IFC files can be avoided.*
- *During the next phase an IFC file shall be exported and the exported IFC files shall be checked. Please note that the IFC file should be made with the mutually agreed upon version of IFC. It shall be verified that all components required at the given phase are included in the model. At the same time it shall*

be verified that the model does not contain any extra or unintended components.

- *The designer shall check both the original model and the IFC file (self-check). It is recommended that another designer at the designer's office or a person at the office dedicated to quality assurance checks the IFC model (control check). However, it is up to the designer office how to organize this. Any issues found shall be corrected in the original model with a BIM authoring tool.*
- *A report according to examples attached to this document as appendices shall be produced based on the checking of the IFC file. This report shall be delivered along with the checked IFC file to the project data bank, etc. agreed for the project.*
- *In addition, an auditing report will be produced, including findings identified during the check, status information, etc. (things that clarify the status of the model to the receiver).*

Please note that in addition to the tasks above, all design specific tasks, standards, and laws shall be followed.

2.2.2 Tasks of the Designers Group

The group of designers should focus on merging and coordinating individual models already checked by designers and report potential change requests. This might be a task lead by the Chief Architect.

Instruction
It should be noted that it's not the task of the group to fix designs of individual designers, rather the task is to seek solutions to potential problems and point out what the designer(s) should be fixing.

Typical tasks of the group are:

Collecting designers IFC models into one or more merged BIM files (e.g. utilizing software tools listed in appendix 2).

Making sure that individual models are of the same version and phase and in this sense comparable. Filenames and dates shall be written down.

Viewing auditing reports made by designers

Verifying correct location (coordinate points) of separate IFC files

Comparing architectural and structural models against each others and verify that load bearing structures and openings are equally located.

Performing clash detection between MEP and architectural models. Here the main emphasis is on spatial coordination.

Performing clash detection between MEP and structural models. Here the main emphasis is on clashes between structures and MEP components including voids required

Required fixes shall be done by designers to the native model and then the previous quality assurance steps shall be repeated.

The last step is to check documents produced from the original BIM models, especially when documents are to be delivered to the project data bank. In case *documents need corrections and information is coming from original models the corresponding corrections shall be made to original BIM models.*

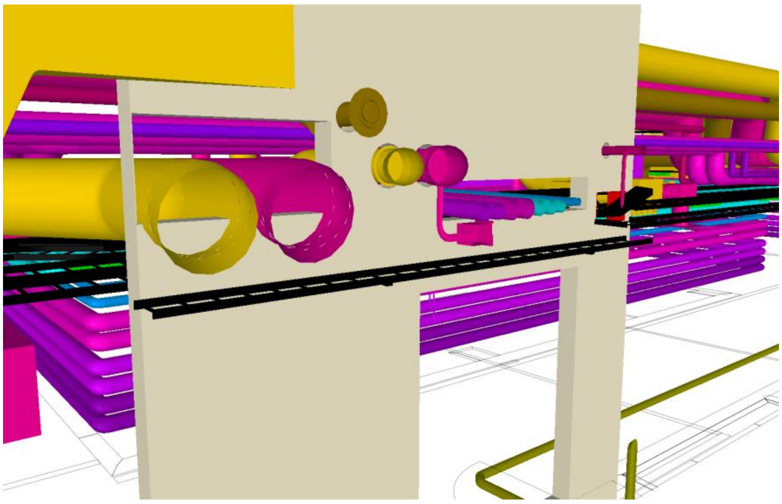


Figure 5. Clash detection between MEP and Structural models

2.2.3 Tasks of the Client

The client shall receive designs of high quality. Any problems in quality will inevitably be a cost for the client unless it is a clear design flaw that according to agreements will be compensated by the designer. Also, problems that were not detected during design may result in schedule delays or even increased operational costs for many years in the future.

These reasons alone should be enough to assure the quality of BIM files also by the client.

Instruction
Quality assurance may be done by the client or the client may hire a BIM consultant with knowhow and tools for the task. When quality assurance is done by the client, problems are only reported (not to be solved by client) to the Designers Group or in clear cases to the individual designer.

Quality assurance is most efficient when the software tools listed in appendix 2 are used. While using these software tools it is important to use knowledge from the construction field and reasoning based on the type of building project to sort out reports produced by software tools and report relevant problems to be fixed.

BIM files shall be published only after quality assurance and client's approval.

In all cases designers are responsible for the quality of BIM files delivered. Even if the client has approved files the full responsibility remains with the designer. In other words, the responsibility is on the person who made the mistake not on the one not finding it.

2.3 Quality Assurance Methods

There are two principal methods used for BIM quality assurance. The methods fall into two main categories: checking and analysis.

2.3.1 Checking

Checking refers to a method whereby the correctness of the information contained in a BIM file is verified. To determine the correctness of any information, it must be possible to compare or measure it against some reference information.

Instruction
When checking the room area in the model it can be compared to the room schedule made for the project. Similarly, checking of the modeling of spaces (and room area) can be verified comparing the space object in the model to the surrounding walls.

Checking is done programmatically utilizing so-called rules that systematically browse complete BIM files or parts of them. "Clash Detection" is one typical example of this. Other rule examples include "Deficiency Detection", "Accessibility Rules", "Comparing Design Versions" etc.

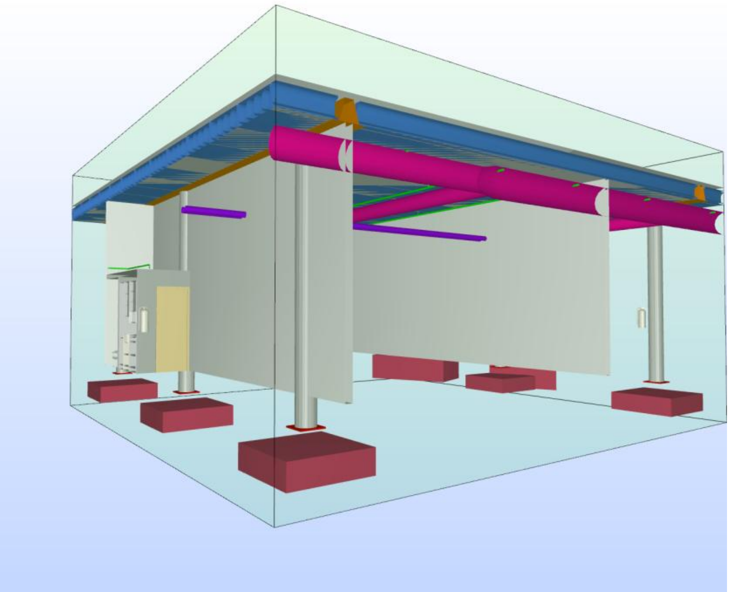


Figure 6. Deficiency Detection shows that columns do not reach the foundation elements

One form of checking is **visual review**. This is carried out by comparing the items, usually geometry, that are visible in the BIM against the viewer's concept of 'what is correct'. The most efficient approach for this is to use "technical visualization" described in Series 8. Technical visualization is focused on identifying components, not how components would look in reality.

This form of checking is easily mastered and often remarkably effective, but it is also prone to human error and requires care to enable comprehensive checking. Numerical data or larger quantities of information are also difficult to process using this method.

Definite conclusions cannot always be reached in the checks, because construction often involves exceptional situations. In such situations, the nature of the potential problem must be recorded and the required further action must be agreed between the parties.

Figure 7. Visual Inspection

2.3.2 Analysis

Analysis, on the other hand, produces information refined from the BIM, making it easier to interpret and assess the quality and correctness of the information.

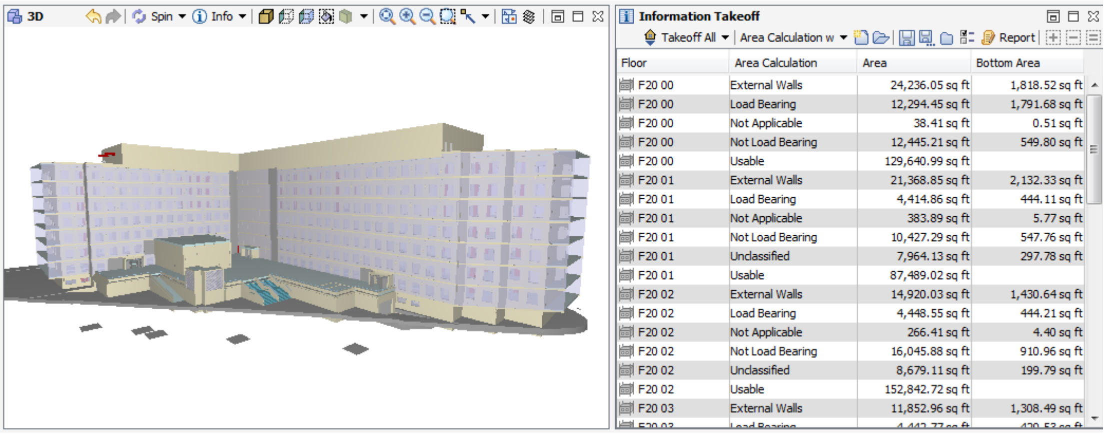
Instruction
An example of analyzing an architectural model is the area calculation as it makes it possible to comprehend how the current status of design corresponds to the set target.

Any significant differences and the underlying reasons must be examined, to determine whether the difference refers to a problem that requires further action. Energy and cost analyses are not discussed in this document, because they have been described in other documents and will be performed after the completion of the checking and analysis performed at this stage.

It is usually most practical to perform the analyses after the checking tasks have been completed. This way, the analysis will provide more reliable results.

The purpose of the analysis is often to depict a larger whole and to process the building information as a whole from a specific perspective.

An analysis usually does not provide a ‘correct or incorrect’ solution but instead reveals order of magnitude level problems, the reasons for which must then be examined in more detail on a case-specific basis.



Floor	Area Calculation	Area	Bottom Area
F20 00	External Walls	24,236.05 sq ft	1,818.52 sq ft
F20 00	Load Bearing	12,294.45 sq ft	1,791.68 sq ft
F20 00	Not Applicable	38.41 sq ft	0.51 sq ft
F20 00	Not Load Bearing	12,445.21 sq ft	549.80 sq ft
F20 00	Usable	129,640.99 sq ft	
F20 01	External Walls	21,368.85 sq ft	2,132.33 sq ft
F20 01	Load Bearing	4,414.86 sq ft	444.11 sq ft
F20 01	Not Applicable	383.89 sq ft	5.77 sq ft
F20 01	Not Load Bearing	10,427.29 sq ft	547.76 sq ft
F20 01	Unclassified	7,964.13 sq ft	297.78 sq ft
F20 01	Usable	87,489.02 sq ft	
F20 02	External Walls	14,920.03 sq ft	1,430.64 sq ft
F20 02	Load Bearing	4,448.55 sq ft	444.21 sq ft
F20 02	Not Applicable	266.41 sq ft	4.40 sq ft
F20 02	Not Load Bearing	16,045.88 sq ft	910.96 sq ft
F20 02	Unclassified	8,679.11 sq ft	199.79 sq ft
F20 02	Usable	152,842.72 sq ft	
F20 03	External Walls	11,852.96 sq ft	1,308.49 sq ft

Area Calculation

Chief Architect

Floor	Usable	Not Load Bearing	Circulation	Total Usable	Technical	Stairs	Load Bearing	External Walls	Floor Area	Efficiency
F20 01	18 450	548	6 915	25 913	385	391	444	2 030	29 163	1,58
F20 02	14 813	885	5 157	20 855	790	386	444	1 409	23 885	1,61
F20 03	16 302	902	5 790	22 993	1 104	386	430	1 308	26 221	1,61
F20 04	17 173	895	5 790	23 858	1 104	386	419	1 325	27 092	1,58
F20 05	17 100	939	5 790	23 829	493	386	400	1 322	26 430	1,55
F20 06	17 100	680	5 790	23 570	493	386	398	1 323	26 170	1,53
F20 07	17 100	939	5 790	23 829	493	386	406	1 547	26 661	1,56
F20 08	3 479	324	1 300	5 103	10 282	89	86	3 497	19 057	5,48
Total	**153 277**	**6 662**	**44 701**	**204 641**	**15 141**	**2 796**	**4 819**	**15 581**	**242 978**	**1,59**

Figure 8. Area information of the model in the picture above is collected in a spreadsheet below

3 BIM Files to be Checked

The BIM quality assurance involves five levels of different extent and purpose. The following are to be checked as IFC models (when in scope):

- Inventory BIM
- Spatial BIM
- Building Element BIM (architectural and structural)
- System BIM (MEP)
- Merged BIM

Instruction

The IFC file format is of crucial importance in terms of quality assurance, because it can be checked and analyzed independently without the BIM authoring software. Furthermore IFC models are utilized with downstream applications for multiple purposes.

As a rule, the object of the quality assurance is the domain-specific BIM requirements and their compliance. The required level of accuracy and information content is described in more detail in those documents.

3.1 Inventory BIM

Instruction

The minimum checklist of Inventory BIM:

- *Space names and areas correspond to the measurement documents*
- *Spaces shall be visually inspected. The most recommended method is to use different colors for spaces of different categories. This makes it easier to identify*

the grouping of spaces and, for example, the placement of stairs and shafts from one story to another.

- *The spaces must not cross each other horizontally or vertically.*

A checklist for Inventory BIMs is provided in Appendix 1.

3.2 Spatial BIM

Instruction
The minimum checklist of Spatial BIM:

- *Space names and areas correspond (order of magnitude) to the space program*
- *The story-specific gross area component of the Spatial BIM is compared against the sum total of the areas of the story in question, and if a deviation significantly exceeding the normal area of walls and other similar structures is detected, the reason for this deviation must be determined.*
- *Spaces shall be visually inspected. The most recommended method is to use different colors for spaces of different categories. This makes it easier to identify the grouping of spaces and, for example, the placement of stairs and shafts from one story to another.*
- *The spaces must not cross each other horizontally or vertically.*

Special attention should be paid to the visual examination of the spatial reservations for MEP systems, such as shafts and horizontal routes (usually the spaces above the suspended ceilings).

A checklist for Spatial BIMs is provided in Appendix 1.

3.3 Building Element BIM

Instruction
The building elements defined in a Building Element BIM must be reliably identifiable. This is of primary importance for nearly all BIM utilization purposes.

In document-based design, a drawing layer system is used for classifying building elements. In an IFC model, the identification of components is based on the tool used for creating the object (component class) and on the type definition.

If it is necessary to construct structures or objects that cannot be generated using the logically correct tool, this must be agreed upon and documented on a project-specific basis so that the deviations are known by all parties on the project.

The consistency of types of information can be verified by, for example, defining different types of walls with different colors and then examining visually where the color of the walls (i.e. the wall type) changes.

Building Element BIMs include:

- *Architectural BIM*
- *Structural BIM*

3.3.1 Architect’s Building Element BIM

Instruction
Spaces

Spaces must be directly adjacent to other space components, surrounding walls and to the floor below (floor slab or ground floor slab). These components can be used for reliably determining whether the area and volume of a space are consistent with the surrounding structures. Overlaps are not allowed, and there must not be any gaps between components.

Depending of the authoring software, the checking is performed in the original model by, for example, selecting the spaces into 3D view to enable a better view of the heights and levels of the spaces. Displaying the spaces belonging to different categories with different colors makes the checking easier.

The analysis of spaces compared with the floor gross area component makes the detection of potential problems easier. In addition, the areas of stories must be compared with each other. The sum total of the areas of individual spaces and the foot print of walls and columns must be near the area of the gross area component.

Spaces must also be compared to the space program the same way as when checking the Spatial BIM. Space IDs and names must correspond with the space program, because it would otherwise be difficult to compare the design solution against the set space requirements.

The naming of building elements shall be consistent. This shall be verified by checking the IFC model produced from authoring tool.

Component overlaps

Overlapping building elements will cause incorrect results in the quantity takeoff and cost estimation, as well as most likely causing problems in energy calculation. Walls and slabs, as well as overlaps between them, are items that most frequently cause problems.

If the authoring tool contains clash detection features or removal of overlaps, these should definitely be used.

When performing software-based checking, typically a large number of minor overlaps between building elements can be found. These often result from the deficient capability of the BIM authoring software to clean up the joints between walls, slabs, etc. In practical terms, however, this does not cause problems (for, e.g., quantity takeoff or energy calculation).

By using a software-based analysis, the volume quantity of all component overlaps can be determined and a type-specific report can be generated, providing an overview of the order of magnitude of the number of overlaps. Based on this, the quantity surveyor can make a corresponding adjustment to the early stage quantity takeoff according to his/her discretion.

Minor wall overlaps at corners, for example, may be allowed if they do not have any major impact on wall quantities.

A checklist for Architectural BIMs is provided in Appendix 1.

3.3.2 Structural BIM

As regards Structural BIMs, the quality assurance process will focus on checking the so-called design model.

Instruction

The analysis model for structural design can only be checked using BIM authoring software.

A software-based and visual examination will be performed on the structural design, as well as by comparing the load-bearing structures and their openings with the corresponding structures and openings in the Architectural BIM. All significant deviations must be reported and processed together with the architect. This will also ensure that the system of coordinates and possible angles of rotation used in the architectural and structural design correspond with each other.

Special attention must be paid to the correct definition of the basic building elements of structural components, such as slab, column and beam. Conversely, it is equally important that the structure types have been correctly defined. These must be verified by examining the IFC model generated from the BIM authoring tool.

A checklist for Structural BIMs is provided in Appendix 1.

3.4 System BIM

The Architectural BIM and Structural BIM, received as input information, are used as reference in the quality assurance of MEP BIMs.

During the advancement of the design process, the merging of System BIMs with the Architectural and Structural BIMs makes it possible to view the placement of components and the crossings of main routes in more detail.

Instruction
Internal clash detection for MEP systems must be performed using the means provided by the BIM authoring software whenever possible. In addition, the checking should also be performed outside of the BIM authoring software using a BIM consolidation and validation software.

The subsystems of System BIMs must be modeled as separate components, usually in the same BIM, and their naming must be consistent.

The requirements concerning MEP BIMs are defined in more detail in Series 4 of the BIM requirements: "Building services technology design".

3.4.1 MEP System BIM

Instruction
In the BIM, sewers and other systems for which a downward slope is designed must be presented according to Series 4. The presentation of the downward slope is important when examining the BIMs of different domains of design together and performing clash detection for systems and building elements. Conversely, when this information is used in penetration and reservation design, the penetrations and reservations will be assigned to correct locations.

A checklist for MEP System BIMs is provided in Appendix 1.

3.4.2 Electrical System BIM

Instruction
As regards electrical systems, the most essential items to check are the division of electrical systems into stories and the clashes of cable racks and other cable routes in relation to HVAC and building elements.

A checklist for Electrical System BIMs is provided in Appendix 1.

3.5 Merged BIM

3.5.1 Objective

The merging of BIMs is needed so that the BIMs of different domains of design can be reviewed together to investigate their compatibility. This will substantially facilitate managing the design and presenting it to the client.

Several problems that are traditionally finally detected at the construction site can be discovered earlier, during the design stage. The merged BIMs are also helpful at the construction site, since they make it possible to visualize challenging installations and possible design solutions.

Requirement
Responsibility and Leadership

The merging and checking of BIMs is performed under the leadership and responsibility of the Chief Architect or other person in charge as defined in the agreements and together with the Designers Group. Each designer is responsible for updating their own BIMs if changes are detected in the joint review.

Merging

The merging of BIMs is primarily carried out using IFC files.

IFC files will be prepared of the BIMs of different design disciplines, which will be checked by the designers in accordance with the quality assurance process specified in section 2.

NOTE! The required corrections must always be implemented in the original models.

3.5.2 MEP Clash and Route Detection

Requirements
The clash detection between MEP systems, such as pipework, ducts and cable carriers, must be performed in the BIM authoring tool when a clash detection feature is available. More detailed requirements are defined in Series 4

Instruction
The person performing quality assurance shall have domain expertise and careful reasoning while reporting flaws. Some typical examples are:

- *Software-based clash detection often results in multiple issues concerning clashes between partition walls and pipes, some which do not require any action to be taken. For example, a perpendicular clash of a ventilation duct with a gypsum board wall is hardly ever an actual problem since it is easy to place voids into correct positions at the work site.*
- *A clash with a load-bearing wall in an architectural BIM is in principle a problem, but because voids are usually not presented in the architectural design, unnecessary issues will be identified for these as well.*
- *A clash in which a pipe clashes parallel with a wall in Architectural or Structural BIM is usually a problem, unless the pipe is specifically intended to run inside the wall.*

For the reasons presented above, it is more practical to perform the clash detection with both Structural and Architectural BIMs.

3.6 Checking of Design Documents

The design documents are checked the same way as has been done before. These requirements do not take a stand on their checking except for noting that through the BIM quality assurance, the quality and feasibility of the design document is also improved.

3.7 Future Opportunities of BIM checking

3.7.1 Accessibility and Egress Analysis

The conformance with regulations of accessibility and egress routes of a building can already be checked using BIMs. Checks of this kind can be assumed to be included in the quality assurance process in the near future.

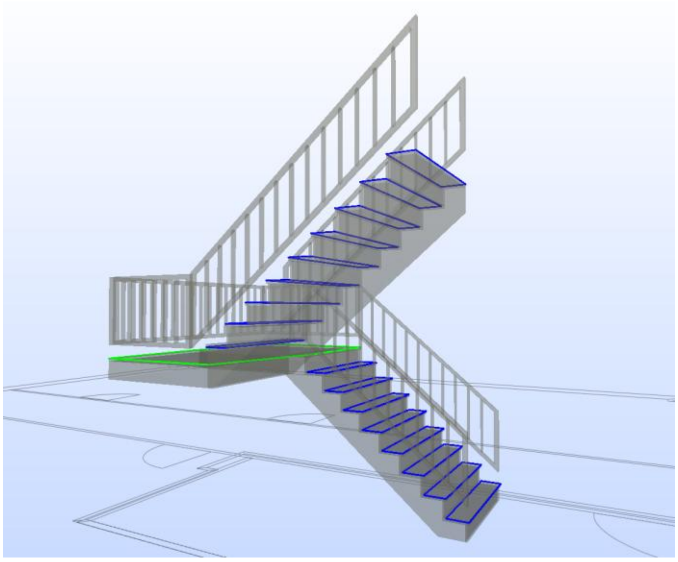


Figure 9. Accessibility analysis; here the step height exceeds the requirements.

4 Responsibilities

The designers are responsible for the quality of the BIMs they produce and also fixing them. BIM files shall be checked after fixes according to agreements and verified that flaws and defects have been fixed.

4.1 Appoint Person to be Accountable

Instruction
The quality assurance task must have a person responsible for it and if this person is not able to do the work a substitute person. Accountable parties may be for example the Chief Architect, construction consultant or other specialist authorized by the client.

Each design agency must also assign a person responsible for their internal BIM quality assurance.

4.1.1 Reporting the Quality Assurance

Requirement

The inspection form presented in Appendix 1 must be filled in for the checking performed by the designer. The minimum requirement is that all items of the form are reviewed and the situation is noted for each item. The detailed instructions specific to each domain of design are to be given the first priority. Any other observations must also be recorded.

Quality assurance of the Designers Group shall be reported at the project meeting in a form, as agreed by the group.

A report will be prepared for project specific official checkpoints, describing the most essential issues that require correction or further specification. The items listed in the inspection forms are the minimum requirement. The report must be prepared so the designer or the Designers Group can locate the problems as easily as possible, so the situations can be resolved as efficiently as possible.

Appendix 1: Checklists

Paikka:	
Aika:	
Tarkastaja:	
Kohde:	
Versio:	
Version päiväys:	

Lähtötietomallin tarkastuslomake	Kunnossa	Puutteita	Ei relevantti	Kommentit
Tietomalliselostus				
Mallit sovittuina tiedostoformaatteina (IFC ja muut sovitut tiedostot)				
Mittaustulokset vastaavat mitattua rakennusta				
Malli vastaa mittausdokumentteja (pistokoe)				
Koordinaatisto on sovitun mukainen				
Sovittuja kuvatasoja on käytetty				
Kerrokset on määritetty				
Rakennusosat ja tilat on määritelty kerroksittain				
Sovitut/vaatimusten mukaiset tilat ja rakennusosat on mallinnettu (Osa 2, Liite X)				
Rakennusosat on mallinnettu oikeilla työkaluilla				
Sovittuja rakennusosatyyppejä on käytetty				
Mallissa ei ole ylimääräisiä rakennusosia				
Mallissa ei ole sisäkkäisiä tai tuplarakennusosia				
Mallissa ei ole merkittäviä komponenttien välisiä leikkauksia				
Huonetilat seinät ja pilarit kattavat kerroksittain bruttoalan				
Tilojen korkeus on mallinnusvaatimusten mukainen				
Tilat kohtaavat ympäröivät seinät ja muut objektit				
Tiloja ei ole päällekkäin				
Sovitunmukaisia tilatunnisteita on käytetty				

Allekirjoitus:

Paikka:				
Aika:				
Tarkastaja:				
Kohde:				
Versio:				
Version päiväys:				
Arkkitehtimallin tarkastuslomake	Kunnossa	Puutteita	Ei relevantti	Kommentit
Tietomalliselostus				
Mallit sovittuina tiedostoformaatteina (IFC ja muut sovitut tiedostot)				
Sovittuja kuvatasoja on käytetty				
Koordinaatisto on sovitun mukainen				
Kerrokset on määritetty				
Rakennusosat ja tilat on määritelty kerroksittain				
Sovitut/vaatimusten mukaiset tilat ja rakennusosat on mallinnettu				
Rakennusosat on mallinnettu oikeilla työkaluilla				
Sovittuja rakennusosatyyppejä on käytetty				
Mallissa ei ole ylimääräisiä rakennusosia				
Mallissa ei ole sisäkkäisiä tai tuplarakennusosia				
Mallissa ei ole merkittäviä rakennusosien välisiä leikkauksia				
Bruttoala- ja muut laajuutta kuvaavat komponentit on mallinnettu				
Laajuutta kuvaavien komponenttien nimet ja tyypit ovat sovitun mukaiset				
Sovitunmukaisia tilatunnisteita on käytetty				
Huonetilat vastaavat tilaohjelmaa				
Huonetilat, seinät ja pilarit kattavat kerroksittain bruttoalan				
Tilavaraukset talotekniikalle on tehty				
Tilojen korkeus on mallinnusvaatimusten mukainen				
Tilat kohtaavat ympäröivät seinät ja muut komponentit				
Tiloja ei ole päällekkäin				
Allekirjoitus:				

Paikka:				
Aika:				
Tarkastaja:				
Kohde:				
Versiot:				
Versioiden päiväykset:				
LVI-mallin tarkastuslomake	Kunnossa	Puutteita	Ei relevantti	Kommentit
Tietomalliselostus				
Mallit sovittuina tiedostoformaatteina (IFC ja muut sovitut tiedostot)				
Kerrokset on määritetty				
Komponentit on määritelty kerroksittain				
Sovitut/vaatimusten mukaiset komponentit on mallinnettu				
Komponentit on mallinnettu oikeilla työkaluilla				
Komponenteille on määritelty järjestelmät				
Järjestelmien nimet ovat sovitunmukaiset				
Järjestelmien värit ovat sovitunmukaiset				
Mallissa ei ole ylimääräisiä komponentteja				
Mallissa ei ole sisäkkäisiä tai tuplakomponentteja				
Mallissa ei ole merkittäviä komponenttien välisiä leikkauksia				
IV-koneet on mallinnettu				
Komponentit eivät leikkaa merkittävästi sähkömallin komponenttien kanssa				
Komponentit eivät törmää merkittävästi rakenteiden kanssa				
Komponenteilla on vain sovitunlaisia törmäyksiä arkkitehtirakenneosien kanssa				
Järjestelmissä on laskentatietoa (vähintään tilavuusvirta ja painetasotieto)				
Komponenteilla on tunnustiedot osa 4/liite 4 mukaisesti				
Allekirjoitus:				

Paikka:				
Aika:				
Tarkastaja:				
Kohde:				
Versio:				
Version päiväys:				
Sähkömallin tarkastuslomake	Kunnossa	Puutteita	Ei relevantti	Kommentit
Tietomalliselostus				
Malli(t) sovittuina tiedostoformaatteina (IFC ja muut sovitut tiedostot)				
Kerrokset on määritetty				
Komponentit on määritelty kerroksittain				
Sovitut/vaatimusten mukaiset komponentit on mallinnettu				
Komponentit on mallinnettu oikeilla työkaluilla				
Mallissa ei ole ylimääräisiä komponentteja				
Mallissa ei ole sisäkkäisiä tai tuplakomponentteja				
Mallissa ei ole merkittäviä komponenttien välisiä leikkauksia				
Komponentit eivät leikkaa merkittävästi LVI-mallin komponenttien kanssa				
Komponentit eivät törmää merkittävästi rakenteiden kanssa				
Komponenteilla on vain sovitunlaisia törmäyksiä arkkitehtirakenneosien kanssa				
Komponenteilla on positio- ja tunnustiedot osa 4/liite 4 mukaisesti				
Allekirjoitus:				

Paikka:	
Aika:	
Tarkastaja:	
Kohde:	
Versio:	
Version päiväys:	

Rakennemallin tarkastuslomake	Kunnossa	Puutteita	Ei relevantti	Kommentit
Tietomalliselostus				
Mallit sovittuina tiedostoformaatteina (IFC ja muut sovitut tiedostot)				
Koordinaatisto on sovitun mukainen				
Mallia kohden on (pääsääntöisesti) yksi rakennus				
Kerrokset on määritetty				
Rakennusosat on määritelty kerroksittain				
Rakennusosat on numeroitu yksilöllisesti				
Sovitut/vaatimusten mukaiset rakennusosat on mallinnettu (Osa 5 -				
Rakennusosat on mallinnettu oikeilla työkaluilla				
Rakenteet on nimetty sovitulla tavalla				
Mallissa ei ole ylimääräisiä rakennusosia				
Mallissa ei ole sisäkkäisiä tai tuplarakennusosia				
Mallissa ei ole merkittäviä rakennusosien välisiä leikkauksia				
Rakenne- ja arkkitehtimallin rakenteet vastaavat toisiaan				
Rakenne- ja arkkitehtimallin aukot ovat vastaavilla kohdilla				
Rakenteet ovat tuettuja				
Kantaviin rakenteisiin on siirretty TATE-suunnittelijoiden varaukset				
Allekirjoitus:				

Paikka:				
Aika:				
Tarkastaja:				
Kohde:				
Versiot:				
Versioiden päiväykset:				
Yhdistetyn mallin tarkastuslomake	Kunnossa	Puutteita	Ei relevantti	Kommentit
Sovitut tietomallit ovat käytettävissä				
Malleista on toisiaan vastaavat versiot				
Mallit ovat kohdistettu oikein keskenään				
TATE mahtuu pystykuiluihin ilman törmäyksiä				
TATE mahtuu vaakareiteille ilman törmäyksiä				
TATE-järjestelmillä ei ole keskinäisiä leikkauksia				
Alaslasketut katot suhteessa TATE:an ovat kunnossa				
TATE ei törmää pilareiden kanssa				
TATE ei törmää palkkien kanssa				
TATE ei törmää muiden rakenteiden kanssa				
Laatoissa on aukot pystykuilujen kohdalla				
Rakenne- ja arkkitehtimallin rakenteet vastaavat toisiaan				
Rakenne- ja arkkitehtimallin aukot ovat vastaavilla kohdilla				
Allekirjoitus:				

Appendix 2: Validation Programs

There are a number of different tools available for quality assurance: design, viewing and rule-based validation software applications. There are also some add-ons that can be used for examining or processing the information models.

L2.1 Validation Using the Features of the BIM Authoring Software

BIM authoring software refers to the software with which the design is originally made. The systems often contain features that can be used for examining component overlaps, performing clash detections and reporting the quantities of spaces or building elements. The utilization of the capabilities of the BIM authoring software should always be given the first priority, because the problems detected are easiest to correct with them and this can be done immediately by the designer. The 3D viewing features should also be made use of for the same reason.

In connection with this, it shall be checked that original model employs a logical drawing layer grouping (or some other logical method) as part of the building information model, describing which drawing layers and/or components are included in the BIM and which are not. Before delivering the original model to the client, the unnecessary drawing layers, groupings and components that are not part of the actual design must be deleted from the BIM.

The quantity take-off performed using the original model, as well as other similar reports, can be used for examining, for example, whether a structure type has been defined for all building elements.

L2.2 Validation Using BIM Viewing Software

Viewing programs facilitate the visual examination of BIMs. With them it can be reviewed whether all building elements are included in the IFC model and whether all essential building elements are in the correct positions. There are viewing programs designed for viewing the original file and others designed for viewing IFC files. The use of viewing programs is not always necessary when using advanced BIM authoring software that also contains a viewing feature, but there are several programs available for viewing IFC files in particular. The IFCwiki web page contains a set of software tools available for free download:
http://www.ifcwiki.org/ifcwiki/index.php/Free_Software

L2.3 Software for BIM Merging and Viewing

Advanced commercial software packages are capable of merging multiple BIM files from different design disciplines. This makes it possible to perform visual review and integration between of BIMs. The programs also contain clash detection features that can be used for examining clashes between building elements. There are both free and commercial software tools available.

L2.4 Rule-Based Validation and Analysis Software

Dedicated applications for validation and analysis of BIMs are used for actual quality assurance. In addition what has been listed earlier these programs are able to find design flaws, defections, and other problems.

Validation with a rule-based validation program is performed by using a set of rules that has been specified in accordance with the BIM requirements. Any problems detected will be reported and presented to the validator, and the validator or the designer will make the final decisions on the measures to be taken. The programs can also calculate key figures for the building, which can be used for analyzing the quality of the BIM and the design. Currently even automated building code checking features are available. These tools are also capable of merging files and perform clash detection.