

## Senate Properties: BIM Requirements 2007 Volume 7: Quantity take-off



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# 1 Main Objectives of Senate Properties' Building Information Model Requirements

The modeling of construction projects is not an end itself; instead, with the help of three-dimensional assessment of design solutions, it aims at improving quality and the information exchange between the parties, reducing the number of design errors, increasing the efficiency of the design process and ensuring that the end result conforms to the objectives. The modeling requirements concern both new and renovation construction projects. The use and information content of the models will be binding requirements in design agreements.

The mandatory part is limited to modeling and visualization of the starting situation and architectural design, as well as to the monitoring of the scope and costs based on the models. In the architectural design, modeling will be applied throughout the process, starting with the presentation of alternatives based on a spatial model and ending with the tender documents for the contracting stage and updating them during the construction process to match the final building.

The main emphasis of the modeling is in making the design process more effective and providing support for investment decisions by comparing in particular the practicality and scope of the alternatives and, to the extent possible, their costs and life cycle characteristics.

Efforts will be made to secure the energy budget of properties by simulating the energy consumption of the building prior to making any major decisions and by harnessing these results in monitoring the energy consumption of the building during its occupation stage. The modeling of structural and MEP systems is also intended to be performed as early as possible, but the requirement for these models will be decided on a case-by-case basis.

The use of models involves quality management as its integral part. Its principal objective is to improve the quality of design solutions and the exchange of information between the parties, thus also making the overall design process more effective. This requires cooperation between the designers, project management and the client. However, the responsibility for quality cannot be solely attributed to quality assurance; instead, each party is responsible for their own work.

The entire set of "Senate Properties' Building Information Model Requirements 2007" consists of the following documents:

- Volume 1. General part
- Volume 2. Modeling of the starting situation
- Volume 3. Architectural design
- Volume 4. MEP design
- Volume 5. Structural design
- Volume 6. Quality assurance and merging of models
- Volume 7. Quantity take-off
- Volume 8. Use of models for visualization purposes
- Volume 9. Use of models in MEP analyses

In addition to the requirements pertaining to their respective domain, each party must become familiar with at least the general part and the principles of quality assurance. The person in charge of the project or project information management must master the principles of building information model requirements completely.

## 2 Introduction

Through the utilization of BIM it is possible to considerably increase the efficiency of the quantity take-off process. The laborious and error prone process of measuring quantities from drawings, paper or digital, is replaced by automated take-off from a BIM. However, increasing efficiency should not be the only goal. Increased efficiency makes it possible to use quantity take-off in new ways, with the final goal being a streamlined design process and better design solutions.

A BIM does not solve all quantity take-off related issues and not all quantities of a project can be taken off from a BIM. Even though a software application can take care of most manual work in a matter of seconds, the professional knowledge of a quantity surveyor is still needed at least for assessing the validity of the input information, ensuring the coverage of the take-off, proposing alternative solutions and organizing the results for presentation to decision-makers.

This document does not contain any rules or guidelines for how quantities must be taken off from a BIM. The purpose of this document is to provide the reader with an understanding of what is meant by BIM based quantity take-off and what kinds of BIMs are created by the designers at different stages of a project. Based on this information it is possible to plan how to carry out the actual quantity take-off and to assess the resources required for performing the necessary tasks.

Chapter 3 of this document covers the process of BIM based quantity take-off and its dependencies in relation to other processes in a project. Chapter 4 enumerates on a generic level the different alternatives for using BIM for quantity take-off. Chapter 5 deals with how BIMs of different granularity can be used. The chapter is tightly connected to the requirements for different design disciplines, which define in detail what kind of BIMs must be created by each designer at different stages of a project.

This document covers only quantity take-off from BIMs. It does not cover how to use the resulting quantities for calculating investment and lifecycle costs, environmental impact assessment, scheduling, etc.

### 2.1 Client's motivation

The investment cost of a building is calculated based on the quantities produced by quantity take-off. The client's goal is to always be aware of the building's investment cost because it is an important criterion when the client makes decisions about, for example, the scope, massing or materials of the building. For decision making, it is important that the information on which decisions are based is reliable and available when needed. As the most important decisions are made at the beginning of a project, it is especially important to increase the level of cost awareness in the early design stages. The BIM based quantity take-off process provides excellent opportunities for achieving this goal. The target is to change the process in such a way that instead of only using quantity take-off at major decision points it is used for constant real time tracking of the investment cost.

### 2.2 Quantity professional's motivation

BIM based quantity take-off changes the day-to-day work of a quantity surveyor dramatically; the traditional routine work almost disappears and the requirement for more advanced skills increases. The quantity surveyor becomes a 'quantity

professional'. In the traditional sense the workload diminishes considerably but at the same time new possibilities appear. The shift to BIM based quantity take-off creates the opportunity to develop and expand the quantity take-off business to deliver more value to the client.

## 2.3 Designer's motivation

Investment cost is a frequently used justification for decisions in a project. According to the current process, the investment cost is calculated infrequently and the results are difficult to explain and visualize. Cost overruns are often noticed when the design is already advanced far, correcting the situation is difficult, and the reason for the cost overrun often cannot be clearly identified. This typically triggers a design cycle for reducing the investment cost, which is mentally tiring and leads to compromises that reduce the overall value of the design.

The BIM based quantity take-off and cost estimating process helps in managing the investment cost aspect of the project and, when it works well, eliminates the need for cost reduction design cycles. The causes of the investment cost can be presented more transparently, which means that, for example, cost increases due to a rise in the market price of steel cannot be claimed to be the result of anything other than the decision to use steel as the frame material. It becomes possible to discuss what effect different design solutions have on the investment cost early enough, based on facts and in an understandable way, which is also in the best interests of the designers.

# 3 The process of BIM-based quantity take-off

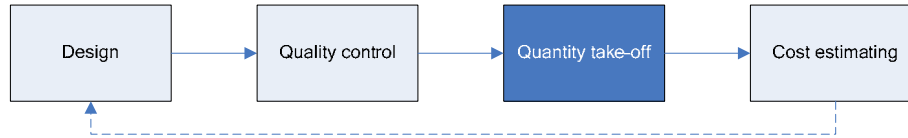
The BIM-based process for quantity take-off is in many ways different from the traditional document-based process. But just as in the traditional process, the quality of the quantities produced by the process always depends on the quality of the input information and the skills of the quantity professional. Not just anybody can produce useful quantities from any BIM. This chapter introduces a process that creates the conditions for successful BIM-based quantity take-off in a project.

## 3.1 Quantity take-off in the context of a project

Because of its effectiveness, BIM-based quantity take-off gives the possibility to take off quantities more often and to explore more alternatives. The decision in a project about when and how often quantities are taken off and how many alternatives are explored is naturally decided based on the needs of each project. However, to make offers for carrying out quantity take-off in a project and to allocate the necessary resources, the main principles of how to utilize quantity take-off in a project must be known already before the project starts.

It is also highly advisable to ensure beforehand that the software application intended to be used for quantity take-off in a project is capable of utilizing the BIMs produced in the project.

### 3.2 Relationship to other processes in a project



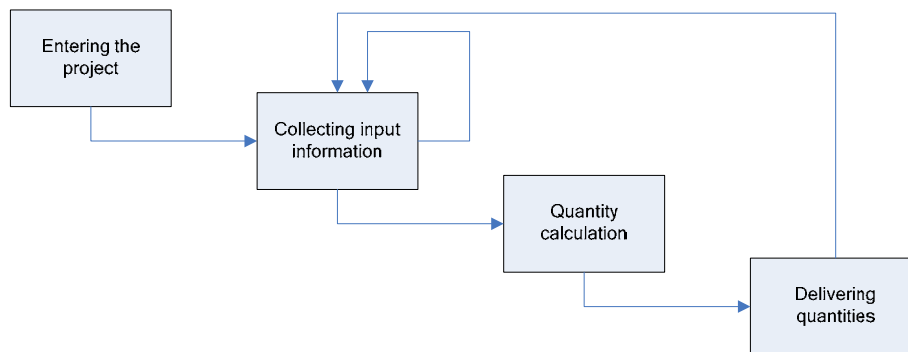
The input information from design is the documentation of the design solution, which from the viewpoint of quantity take-off includes the BIM, building specification, BIM specification and other material relevant to quantity take-off.

Quality control checks that it is possible to produce reliable quantity information from the BIMs intended for quantity take-off.

In quantity take-off, quantities with the appropriate scope and accuracy are produced based on the material received from the designers.

Based on the quantity information, the process of cost estimating produces cost information that can be used in decision making and as feedback to the designers.

### 3.3 The process of quantity take-off



#### 3.3.1 Entering the project

Entering the project is done once before the first quantity calculation. At this stage the quantity professional gets familiar with the project. Through a BIM the scope and other characteristics of the design are easier to comprehend. In addition to the BIM, it is advisable to study also all other relevant material, such as the building specification, and to discuss the design with the designers.

#### 3.3.2 Collecting input information

Before each time quantities are taken off, the input information for quantity take-off must be collected. Furthermore, it must be verified that the quantity professional has the correct version of each relevant file.

- It must be determined if quantity take-off is done from the BIMs of one design discipline or several. If several BIMs are used, it must be decided which quantities are taken off from each of the BIMs. For example, if the load bearing structure is taken off from the Structural BIM and doors and windows from the Architectural BIM.
- It must be determined if the BIM of some design discipline has been broken up into several partial BIMs.

- It must be determined if the take-off should be done from the original BIM or from an IFC file (or IFC data) exported from the original BIM.
- If take-off is done from the original BIM, it must be ensured that the delivered material contains all necessary library elements and external references and that the BIM can be opened without problems in the software application used by the quantity professional. For example, it may be necessary to update the reference paths of external references. If the BIM is a collection of multiple files, it must be determined which files are used in the take-off and which files are reference files.
- The scope of quantities to be taken off the BIM must be determined, i.e. which quantities can be taken off the BIM and which have to be taken off using other methods. Chapter 5 of this document lists references to the sections in the various designer requirements, which define the scope of information captured in the different types of BIMs produced by the different designers.
- It must be determined if the whole BIM is modeled to the same level of detail and if quantities are to be taken off the whole BIM or only part of the BIM. The BIM may, for example, contain objects that are not intended for take-off, such as furniture used by the architect for designing the dimensions of spaces. In such cases it must be determined how the objects excluded from the take-off can be identified, for example, by using layer combinations. Detailed information about each BIM can be found in the BIM specification created by the author of the BIM.
- With regards to the building specification, it must be determined if its information is consistent with the BIM, for example, that both use the same construction types for building elements. All changes agreed by the design team must be captured in the building specification, because it cannot be expected that the quantity professional collects such information from, for example, the minutes of design meetings.
- The main changes relative to the last version used for quantity take-off must be determined.

The shortcomings of the BIM and related material relative to the requirements are mainly caught in the quality control process and documented in the BIM validation report produced during quality control. Resolving the internal conflicts of the source material is the responsibility of the principal designer or other person appointed by the client. Certain shortcomings can be accepted as long as the quantity professional is aware of them before the take-off is started. The quantity professional may also express an opinion as to whether take-off with the intended scope is meaningful from the provided material. If there are too many shortcomings, it is advisable to postpone the quantity take-off.

The version management of the input information is the responsibility of the designers and the principal designer. It must be safe for the quantity professional to assume that the delivered input information contains the correct versions of all files. Designers are responsible for versioning their own files, while the principal designer – or another person appointed by the client – is responsible for collecting, versioning and publishing the file package delivered to quantity take-off. However, the quantity professional must always notify a representative of the client if there is any doubt about having correct versions of all files.

### 3.3.3 Quantity take-off

BIM-based quantity take-off is done using a suitable software application. The capabilities of the software application used have a major impact on the reliability and efficiency of the take-off process, for example, when a new version of the design is taken off or the task is to make a number of alternative take-offs from the same BIM. This document does not define how quantity take-off is carried out, nor does it comment on or enumerate the commercial software applications available for the task.

### 3.3.4 Delivering quantities

The deliverable from quantity take-off is a bill of quantities, which is delivered for cost estimating as well as used for other purposes specified by the client. Traditionally, a bill of quantities is a human-interpretable list of quantity information, but it can also be exchanged in a computer-interpretable format, for example, as a proXML file, which is a quantity information format defined by the Finnish construction industry. In addition, BIM-based quantity take-off provides new possibilities for visualizing quantity information. It is easy to produce static documents from a BIM for visualizing different aspects of quantity information. In a more advanced process quantities are linked dynamically to the BIM from which they were calculated. This makes it possible to visualize the objects used for calculating the quantity of each assembly or item in the take-off.

It is important to note that all quantity take-off results and reports are valid only in the context of the 'input information package' from which they were taken off. All results must be clearly associated with this package, because taken alone or when associated with a different package they no longer provide correct information about the design solution.

## 4 Taking quantities off a BIM

This chapter covers the basics of BIM-based quantity take-off. The goal is to give the reader an overview of the possibilities the BIM approach provides for quantity take-off. The level on which these possibilities are used in projects is determined by the BIMs created by the designers, the data exchange solutions used, the software application used by the quantity professional and, naturally, the skill level and know-how of all participants of the project.

### 4.1 Quantity take-off related requirements for a BIM

#### 4.1.1 Consistency

For quantity take-off the most important characteristic of a BIM is consistency. All building elements must be modeled as agreed and the modeling style must be documented. It is problematic when the same thing is modeled differently in different parts of the building.

However, the BIM may contain parts that are modeled to a different level of detail than other parts of the same BIM, for example, when a design solution is first experimented with in one part of a building. Such cases are documented in the BIM specification and the quantity professional must take this into account during the take-off.

#### 4.1.2 Identifying objects

It must be possible to identify all objects from the viewpoint of quantity take-off, for example, different types of walls must be identified because wall quantities are calculated by summing the quantities of individual walls of the same type. The clearest identification method is the construction type, but any appropriate information, such as the height of a wall, may be used for identification. For example, timber frame walls of different heights may be 'of the same type' from the architectural viewpoint, but 'of a different type' for quantity take-off because the internal composition of the wall changes once its height exceeds a certain limit.

Appendix 3 lists all objects typically found in architectural design software and the relevant identification information for each object type. The identification may be a separate data field, encoded inside a data field or accessible through the value of a data field. For example, the fire rating of a wall could be defined in a data field dedicated to this information or be a part of the definition of a construction type. In the latter case, the actual fire rating can be found in the definition of the construction type, which again can be found through the construction type name of the wall object. The identification system for each object type must be agreed on and clearly documented in each project,

#### 4.1.3 Quantity information of objects

The recipes used in quantity take-off are built so that they require a specific measure or quantity information. For example, windows can be taken off by count or by area, but it is not allowed to use the window count in an area-based recipe for windows. Quantity take-off typically uses the following quantity information:

- Count
- Length measure
  - Length
  - Perimeter
  - Height
- Area measure
  - Net area
  - Gross area
  - Many objects have special areas, such as the net area of the left side of a wall, or for a space, the net area of a wall below the low ceiling.
- Volume measure
  - Net volume
  - Gross volume
- Weight

For quantity take-off it is essential that BIMs are created using objects which provide the quantity information required by quantity take-off. The most straight forward solution for satisfying this requirement is to model each building element using the modeling tool for that specific building element, for example, modeling walls with the wall tool. If a building element is modeled using a tool that is incompatible with the requirements of quantity take-off, the quantity for that building element cannot be taken off automatically. This can occur when design software does not have a specific tool for the building element in question, for example, when modeling the curb of a driveway. Appendix 1 of this document

lists the typical modeling tools of architectural design software and the quantity information available from objects created by each tool. Appendix 3 lists cases which are typically problematic for quantity take-off from BIMs created by current architectural design software.

The data exchange solution used in a project and the software application used for quantity take-off have a major impact on the quantity information available for quantity take-off and on the reliability of this information. It is also worth noting that the level of detail of a BIM determines the level of detail of the quantities taken off from that BIM. For example, it would be unrealistic to assume that accurate quantities for pre-cast concrete elements could be taken off from a Preliminary Building Element BIM.

The quantities extracted from the BIM are fed into production recipes. Here it is important to note that the BIM provides the real quantities of the building elements. In manual take-off, for example, in digitizing, simplified quantities are often used for speeding up the take-off. The projection area could, for example, be used instead of the real area, because it is faster to measure the projection area from plan drawings. If the internal calculation rules of the production recipe are built to compensate for such simplifications, it is advisable to adjust the production recipes for use with BIM.

## 4.2 Methods of quantity take-off

It is possible to carry out quantity take-off on many different levels of detail by applying different quantity take-off methods. The highest level of detail, i.e. the best available method, always depends on the level of detail of the BIM. It is possible to use several different methods for the same BIM. For example, it is possible to combine a space-based take-off with a building-element-based take-off for the facades. In different phases of a project an appropriate quantity take-off method, or combination of methods, must be used. The following is a list of available methods sorted by their level of detail.

### 4.2.1 Key figures

Information about the size of the building, for example, its total volume and facade area, is extracted from the BIM. Based on such information, key figures such as the ratio of volume and facade area are calculated. Using key figures it is possible to assess the efficiency of the design on a rough level.

A Space Group BIM is the minimum requirement for using the key figures method.

### 4.2.2 Space-based take-off

The area of programmed spaces, such as offices, and optionally also spaces outside the space program, such as corridors, are extracted from the BIM and summed by space type. The calculated areas can be validated against the space program and a cost estimate can be made based on the unit cost (€/m<sup>2</sup>) of the different space types.

A Space BIM is the minimum requirement for using the space-based take-off method.

#### 4.2.3 Building element take-off

The quantities of building elements are extracted from the BIM based on the building element objects in the BIM. For example, the length of a foundation beam can be extracted from the length of a foundation beam object. The extracted quantities can be used in the context of a traditional bill of quantities and used for determining quantity changes between design solutions and for cost estimating.

A Preliminary Building Element BIM is the minimum requirement for using the building element take-off method. In a Preliminary Building Element BIM the quantity professional makes assumptions about the exact type of the building elements. In the Building Element BIM more precise types of information are accessible through the BIM and the quantity professional makes less assumptions.

#### 4.2.4 Enhanced building element take-off

The quantities of building elements are extracted from the BIM based on the building element objects in the BIM, but the quantities of items can be also be extracted from the BIM if needed. For example, in addition to the length of a foundation beam it is possible to also extract the volume of the foundation beam from the BIM. This means that the quantity for the concrete item does not have to be calculated in the traditional way using formulas or factors. The objects in the BIM are still building elements, meaning, for example, that a wall is modeled as one object and not using a separate object for each wall layer.

The minimum requirements for the BIM are the same as for building element take-off.

#### 4.2.5 Item take-off

Quantities of items are extracted from the BIM based on the objects in the BIM. For example, the quantity for rebar (kg) can be either derived from the volume (m<sup>3</sup>) of a foundation beam (kg/m<sup>3</sup>) or extracted directly from rebar objects in the BIM.

The minimum requirements for the BIM are the same as for building element take-off. However, item take-off is typically used only at the late stages of a project. Item take-off is often done from the Structural BIM.

#### 4.2.6 Quantity take-off by location

Any method based on building elements or items can be used for taking off quantities by location. Locations that are used often include sub-project, section, building storey, space group/zone and space. Quantity take-off by location is typically used for taking off procurement quantities and for producing input information for scheduling.

The minimum requirements for the BIM are the same as for building element take-off, with the additional requirement that locations must be modeled. Assigning the objects in a BIM to locations of different types usually requires additional work, even though all objects by default have a geometric location,

### 4.3 Using information in a BIM for quantity take-off

The information captured in a BIM can be used in several different ways for quantity take-off. The best available way is determined by the data exchange solution used in the project and the software used by the quantity professional. Even if the designer produces valid and useful information, this information can be lost during data exchange or the data may not be accessible in the software application used for quantity take-off. Incomplete or inaccurate documentation of what information a BIM contains (BIM specification) also reduces the usefulness of the BIMs. On the other hand, the quantity take-off software application may provide tools for adding new information to the BIM or for re-creating data lost during data exchange. Such changes do not constitute design work, in other words, any changes to the BIM are made only for use in quantity take-off.

There are three main levels of using a BIM for quantity take-off

1. **Object quantities.** The objects in the BIM are reported with the properties provided by the designer, for example, they are grouped by construction type. This corresponds to the tools found in virtually all BIM authoring tools for creating lists, or reporting information from an IFC BIM to Excel, for example. The relationship between building elements and what is reported is 1:1.
2. **Estimate item quantities.** Based on the information in a BIM, the quantities for items in an estimate are taken off. For example, the quantity of walls of type 'EW-1' may be used as the quantity for the estimate item 'External brick wall.' Several types from the BIM may be combined into one item in the estimate, or one type in the BIM may produce quantities to many items in the estimate, meaning that the relationship of building element and estimate item is n:n.
3. **Production recipe quantities.** This is otherwise identical to estimate item quantities, but the estimate item has a production recipe behind it, which calculates the quantities of sub items or resources based on the quantities of the item using formulas and factors. This type of take-off produces quantities on a resource level, which makes it possible to take into account and analyze resource level changes in labor, material prices and the like during a project.

In the following sections, the main alternatives for how software applications can take off quantities from a BIM are listed. Each alternative below can be combined with any level listed above.

#### 4.3.1 Automated take-off

The objects in the BIM can be identified from the viewpoint of quantity take-off and the quantity information needed by quantity take-off can be extracted from the objects. This alternative makes optimal use of the BIM approach. Quantities can be taken off efficiently and reliably. It is possible to visualize the quantities using the BIM. There is no need for the quantity professional to modify the BIM, which means that updating the quantities after design changes is efficient.

#### 4.3.2 Derived take-off

The BIM does not directly contain the quantity information needed by quantity take-off, but this information can be derived from the BIM. For example, the length of the foundation beams can be taken off quite reliably using the length of the load bearing walls of the bottommost floor. Quantities can be taken off efficiently and quite reliably, but it is only possible to visualize the objects in the BIM from which the quantity was derived. In the example above the quantity of the foundation beams could be visualized only through the walls from which the quantity was actually taken off. There is no need for the quantity professional to modify the BIM, which means that updating the quantities after design changes is efficient.

#### 4.3.3 Enhancing the BIM

The BIM does not directly contain the information needed by quantity take-off, but the quantity professional can model this information based on objects that exist in the BIM. For example, the rain gutter on a roof could be modeled to the edge of a roof object using the wall tool. Quantities can be taken off quite efficiently and quite reliably. It is possible to visualize the quantities using the BIM. The quantity professional modifies the BIM, which means that the same changes have to be redone or copied every time the designer makes a new version of the BIM. For example, the rain gutter modeled to the edge of the roof does not automatically update when the designer changes the geometry of the roof, and the wall object (which was used for representing the rain gutter) must be updated manually.

#### 4.3.4 On-screen take-off

The quantity take-off software cannot use the BIM directly, but quantities can be taken off manually from the objects in the BIM. This is similar to digitizing from paper drawings. Quantity take-off is slow and error prone, meaning that it is unreliable and quantities cannot be visualized using the BIM. Quantities must be recalculated after each design change.

### 4.4 The scope of BIM-based quantity take-off

#### 4.4.1 The whole building is modeled to the same level of detail

When the whole building is modeled to the same level of detail, the situation is clear and the whole building can be taken off using the same method. However, in some cases different systems in the building can be taken off using different methods, for example, by combining the building-element-based take-off of facades to an otherwise space-based take-off.

#### 4.4.2 Part of the building is modeled in more detail

Sometimes, it makes sense to model part of the building in more detail than other parts of the same building, or to test proposed design changes first in only one part of the building. In this case, quantities could be taken off from only the part which is modeled in more detail and then use factors to calculate the total quantities of the building. For example, in a building with five identical floors partition walls could first be modeled only on one of the floors, and then a factor of 5 could be

used to calculate the total quantity of the partition walls. The quantities for the building frame could be calculated from the same BIM normally without a factor.

If such an approach is used, it is of utmost importance that the detailed modeling or testing of a solution is done in an agreed and well-defined area. This must be documented in writing in the BIM specification. Otherwise, the quantity professional does not know how to use the BIM correctly.

#### 4.5 Alternative quantity take-offs from the same BIM

It is possible to make several alternative quantity take-offs from the same BIM. Using an early-stage BIM, the cost effect of several alternative facade solutions (pre-cast, cast-in-place, masonry, etc.) could be examined. This is done by linking the same BIM objects to different production recipes during quantity take-off. In this approach it is important to consider the ripple effects of, for example, the facade solution on the dimensions of the foundation. The assumptions used in the different alternative take-offs must be documented and the results connected to the file package used as input information for the quantity take-off.

When examining different alternatives is part of a larger process, it is important to coordinate the alternatives between different disciplines. Different facade solutions could, for example, be examined for their investment cost, their effect on energy consumption and using photorealistic renderings. In this case, all disciplines must use the same file package as input information. The principal designer must coordinate which alternatives are being examined and combine the results from the different analysis for presenting them to decision makers.

## 5 Quantity take-off from different types of BIM

This chapter enumerates the different types of BIMs and how each type can be used in quantity take-off. The BIM requirements for the different design disciplines define the information content required from the designers at different stages of the project using the 'Extended Talo2000' classification system. Some of the items are mandatory in all projects, while others are decided on a project-by-project basis.

The scope for quantity take-off covers the building section and the extensions of the 'Talo2000' classification system.

Quantities are taken off BIMs separately according to each design discipline, not from a combined BIM.

### 5.1 Spatial Group BIM

#### 5.1.1 Designers

- Volume 3: Architectural design – chapter 3.4

#### 5.1.2 Use in quantity take-off

- Key figures
- In part of the building, such as facades, it may be possible to use building element take-off

## 5.2 Spatial BIM

### 5.2.1 Designers

- Volume 3: Architectural design – chapter 3.5

### 5.2.2 Use in quantity take-off

- Key figures
- Space based take-off
- In part of the building, such as facades, it may be possible to use building element take-off

## 5.3 Preliminary Building Element BIM

### 5.3.1 Designers

- Volume 3: Architectural design – chapter 3.6
- Volume 5: Structural design – chapter 6

### 5.3.2 Use in quantity take-off

- Key figures
- Building element take-off

## 5.4 Building Element BIM

### 5.4.1 Designers

- Volume 3: Architectural design – chapter 3.7
- Volume 5: Structural design – chapter 7
- Volume 4: MEP design – chapters 5 and 6 (System BIM)

### 5.4.2 Use in quantity take-off

- Building element take-off
- Enhanced building element take-off
- Item take-off (from the Structural BIM)

## Appendix 1: Typical modeling tools in architectural design software

The modeling software used for architectural design has different modeling tools. In many cases the choice of tool does not require any special consideration (walls are modeled using the wall tool), but all buildings have parts for which the choice of tool must be thought out (which tool to use for modeling the curb of a driveway?). Not all cases have a tool that is specifically designed for that case, and in such cases other tools have to be applied.

This appendix lists the modeling tools that are typically found in architectural modeling software and the quantity information available from objects created using each tool. The tools are categorized into BIM and non-BIM tools. Tools in the latter category cannot usually be exchanged using, for example, IFCs. If the description of the tool contains special cases, it must be possible to identify these cases in quantity take-off. The availability of quantity information in each special case must be verified separately.

### BIM tools

Tool	Description	Quantity information
Wall	Defined usually through a baseline. It is possible to define layers (material and thickness). Software automatically cleans up wall intersections. Special cases include curved, clipped, variable thickness, variable profile, slanted, geometric additions and subtractions as well as any combination of the above.	Count, thickness, length, height (may vary), left and right net and gross areas, footprint area, net and gross volume.
Curtain wall	A grid with transparent or solid cells. The cells may contain windows, doors, equipment, etc.	Typically count and gross area. More detailed quantity take-off must be done mainly manually. An alternative way to model curtain walls is to use wall, door, or window objects and the like, which would enable quantity take-off from these objects.
Window	Inserted into a wall. It is possible to define many parameters which control the geometry and other properties of the window. Special cases are windows in special walls (see wall special cases), corner windows, windows belonging to more than one wall and windows partially outside a wall.	Count, width, height, perimeter and gross area. It may be possible to get information from the parameters (e.g. glazing area) but this must be verified case by case.
Skylight	A window in a slab or roof	See Window
Door	Inserted into a wall. It is possible to define many parameters which control the geometry and other properties of the door. Special cases are doors in special walls (see wall special cases) and doors partially outside a wall.	Count, width, height, frame length and gross area. It may be possible to get information from the parameters (e.g. glazing area) but this must be verified case by case.
Opening	Opening in a wall. Special cases are openings in special walls (see wall special cases), openings belonging to more than one wall and openings partially outside a wall.	Count, width, height, perimeter and gross area.
Recess	Recess in a wall	<i>Is typically associated with quantity take-off done through a space object.</i>
Slab	Usually defined through a perimeter, may contain openings. It is possible to define layers (material and thickness). Special cases are variable thickness, slanted, geometric additions or subtractions and any	Count, thickness, perimeter, net and gross area, side areas (perimeter and openings), net and gross volume.

Tool	Description	Quantity information
	combination of the above.	
Roof slab	Defined usually by perimeter, roof line and slope. May contain openings. It is possible to define layers (material and thickness). Special cases are variable thickness, geometric additions and subtractions (e.g., profiled edges) and any combination of the above.	See slab. Has also projection area.
Roof	Typically a composition of roof slabs. Defined by selecting a roof type (pitched, dome, etc.) and providing parameter values specific to the selected roof type.	Can be used mainly as reference geometry. More information may be accessible if the roof is exploded to roof slabs (see roof slab).
Column	Typically defined by insertion point, profile and height. Special cases are variable profile, slanted, geometric additions and subtractions and any combination of the above.	Count, height, profile perimeter and area, volume.
Beam	Typically defined using a baseline. May contain holes. Special cases are variable profile, slanted, geometric additions and subtractions and any combination of the above.	Count, length, profile perimeter and area, net and gross side area, top and bottom area, net and gross volume.
Stair	Usually defined by selecting a stair type (straight, L, spiral) and providing parameter values specific to the selected stair type.	In many cases only the count. The quantities for steps, risers, landings, railings, etc. may be available in some cases.
Railing	Typically defined using a baseline.	Length and height (may vary)
Space	Defined typically through a perimeter, which may contain holes, and height. Software can often associate the bounding elements of a space to the space. Special cases are multi storey, curved and slanted sides, variable height, lowered ceiling and any combination of the above.	Count, perimeter, height (may vary), side areas and volume. Often spaces have only one footprint area, which can either be the space program area or the physical area (area for floor material). Sometimes it is possible to get the net and gross areas of the bounding walls, net perimeter (doors deducted), roof and lowered ceiling areas and the walls areas above and below the lowered ceiling.
Parametric object	An object for which the geometry and other properties can be controlled by setting parameter values. May represent anything related to the building. May contain a rich set of data.	Count and bounding box dimensions. It may be also possible to get other quantity information, but each object must be dealt with separately and the availability and reliability of the information is unpredictable.

### Non-BIM tools

Area object	A horizontal 2D object with hatch and color. Typically defined through a perimeter, may contain holes.	Count, perimeter, net and gross area.
Surface object	Object for modeling 3D surfaces. May contain holes. Typically defined through a grid of 3D points within a specified area.	Count, net and gross area.
Mass/volume object	Object for modeling 3D masses. Typically defined by combining basic geometric objects (boolean operations), defining 3D points or exploding a parametric object.	Count and volume



## Appendix 3: Known problems in BIM-based quantity take-off

This appendix lists typical known problems in using BIMs for quantity take-off. The list is not exhaustive, but it provides an idea of what kind of situations require special attention when taking quantities off from BIMs created by designers. In all cases the minimum requirement for the BIM is the possibility to tell which parts of the BIM can be taken off reliably and which parts may be problematic. When the problematic cases have been identified they can be solved; only unnoticed problems cause errors to the result of quantity take-off.

### Take-off from multiple BIMs

Even when done properly, the BIMs from different design disciplines (architectural, structural and MEP) overlap. The Architectural BIM contains many of the same structural elements as the Structural BIM. The Architectural BIM also often contains terminals of MEP systems (sinks, light fixtures, etc.), which are also found in the MEP BIM. When multiple BIMs are used, such overlaps must be identified and it must be decided from which BIM each quantity is taken off. As a rule of thumb the structural and MEP BIMs contain more accurate information of the overlapping objects than the Architectural BIM, in which these objects mainly serve as placeholders.

### Space surfaces

Current architectural modeling software usually has inadequate tools for modeling space surfaces. Space surfaces are typically not modeled as separate objects but are derived from space objects. In the early design stages this is often accurate enough, but at later stages partial surfaces especially cause problems. There are also significant differences in how BIM authoring applications are able to associate spaces to their bounding elements. For example, when two spaces are directly adjacent to each other (no wall between the spaces) some applications report a space surface also between such spaces. The take-off of floor areas may also be problematic, if the application reports the program space area and not the real physical space area.

### Roofs

Architectural design software typically has tools for modeling complex roofs as one component. From the viewpoint of design this offers superior possibilities for controlling and editing roof shapes. For quantity take-off this is problematic, because the roof object does not contain any information needed by quantity take-off. It may be possible to take-off some quantities by exploding the roof into roof slabs and taking off the quantities of the roof slabs. However, even in this case it is not possible to automatically take off the quantities of, for example, rain gutters.

### Stairs

When stairs are simply counted the current BIMs are adequate. However, the take-off of stair components such as railings, landings and steps is problematic.

### Curtain walls

Architectural design software typically has tools for modeling complex curtain walls as one component. Taking off quantities from such components may be impossible, because the curtain wall tools are currently focused on the geometry and not the information content. Modeling curtain walls using tools for walls, doors, windows, and so on would be better for quantity take-off but much more cumbersome for the designer.

### **Parametric objects**

Most architectural modeling software give the user the possibility to create user-defined objects, where the scope and subjects of such objects is not defined or constrained in any way by the software. These objects are parametric, which means they contain parameters that can be used for creating many alternatives within the same object. For example, a table object may contain parameters for length and number of legs. In this case the same object could be configured to represent a 120-cm-long table with four legs, or a 200-cm-long table with six legs. Parametric objects can also represent large compositions, such as a bathroom or a whole building. Creating these objects is development work for the designers and aims at significantly increasing the efficiency of creating drawings and reacting to design changes.

For quantity take-off, however, parametric objects are problematic on several levels. The identification of even simple objects is difficult, because the name of the object does not reveal the detailed content of the object, for example, the dimensions or properties of a table. This detailed information is captured in the parameters of the object, but each object is structured differently and even the names of the parameters are not standardized. Consequently each parametric object must be dealt with individually.

When a parametric object has been identified it is possible to take off the count of objects such as furniture. Often a count is not enough and quantity take-off requires, for example, areas. Parametric objects can be built so that they report lengths, areas, volumes, weights, and so on, but the reliability of such information depends on the author of the object. Consequently the reliability of each measure value in each parametric object must be verified individually,

The most challenging parametric objects for quantity take-off are the ones that represent large compositions. It may, for example, be impossible to take off the parts of balconies from a parametric object representing a stack of balconies. In such cases the option is to create a production recipe for the whole composition and take off the count of the parametric objects. Creating a meaningful production recipe may, however, be very difficult, because the parametric object may contain many parameters that control the materials and others aspects of the composition.

### **Special cases of objects**

Unconventional shapes in a building are often significant for quantity take-off and cost estimating. Such cases include curved or slanted building elements containing non-standard openings and geometric additions and subtractions. It is often difficult to take off reliable quantities in such cases, but on the other hand such cases require in any case special attention from the quantity professional. Even if the material quantities could be taken off, it is of equal importance to select a suitable production method for each case.