# Testing 3D Building Modelling Framework In Building Renovation

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*The paper describes a process where digital measuring survey data is transferred into 3D building model to be used as a foundation for renovation design. The process and method is tested in a case study of an office building of 8 floors. Measuring survey data is more often documented to 2D plan drawings, whereas 3D-modelling was more preferable in the case project. The final aim of the case project is to further test building product model or building information model (BIM) based design methods in building renovation.*
*Product modelling is one emerging framework to manage building related information in contemporary design & construction. Model based methods are more commonly used in new buildings, whereas renovation is usually done with more traditional techniques.*
*Case project results underline the importance of measuring and modelling definition phase. Measuring and documenting objectives for 3D-model based design work are different than for traditional design work. Measuring survey has to be done under the coordination of the designer participants. Selecting and informing the proper and capable surveying partners is also important.*

***Keywords****: 3D modelling; product modelling; building information modelling BIM; renovation; measuring surveys.*

## Background

Extensive changes have altered both the social and physical working environments the architect currently operates in. The architectural "working table" has turned into digital and communicative aspects of the architectural profession have gained importance during the last 20-30 years. The changes within architectural profession have concerned very profoundly the tools which architects use as well as the working methods (Kalay, 2004). CAD-systems have become the main tool for the architects during the 1990s and working without CAD is hardly possible any more (Nordic, 2002).

While the majority of architectural work is currently documented in CAD-based 2D-documents - the trend which strengtehened during the 1990s - recent Finnish experiences from building information modelling (BIM) have encouraged the AEC-field to develop CAD-drawings towards more integrated virtual building information management. The evolutionary trend in developing digital CAD-drawings towards more advanced data management methods has expanded with accelerating pace during the last 10-15 years within western construction.

### Building product modelling

Building product modelling or also called building information modelling (BIM) is an integrated method for a future framework for the AEC-field to manage all design and building related information in digital form. The foundations to manage design and architectural data in computerized from were created already during the early 1960s (Sutherland, 1963/2003; Negroponte 1970). Foundations for building product modelling were strengthened during the 1980s and 1990s (Björk & Penttilä, 1989; Eastman, 1999). In Finland building product modelling has been formed to be a common national future goal for AEC-field informatics research and several national research programs - Ratas, Vera, Sara, Pro IT - have been realized to further develop modelling further since mid 1980s, essentially with active support by national public technology fund Tekes (Lieblich, 2002; Fischer & Kam, 2002; Penttilä, 2005). International efforts by the IAI-initiative to promote AEC-field information management and data exchange and neutral IFC-format have also been noticeable during the last 5-10 years (Tarandi, 2003).

Building product modelling framework has been under active research since the late 1980s. The research results have also been applied in real projects, lately in Finnish Pro IT -project, which has been a construction sector initiative. Since 2000 product modelling has been piloted in a handful of pilot projects. One important domain within modelling, has been the effort in publishing product modelling guidelines for the AEC-field (Pro IT 2006). Design by modelling is currently characterized by wide enthusiasm and vast expectations.

Model based methodology has been applied to actual design & construction process so far mainly concerning design integration, design-cost estimation chain, designing-to-build activities and so far mainly new constructions. Using modelling in renovation design nor actual re-use projects has not been tested extensively yet, despite the fact that renovation will be a growing area within construction in the future (Schink, 2004). In Finland the share of renovative projects compared to new building is currently 40-50% and the figures for renovation are constantly growing.

Essential strategic decisions in model based activities have been made by several major players on national AEC-field, namely constructors YIT and Skanska and also Senaatti Properties, the state-owned FM-operator, who all have publicly announced their strategies to develop and accept model based working methods and processes. Long time commitment to product modelling is currently significant in Finland.

## Objectives

The objective of this study is to test how building product model based methods suits to the early phases of building renovation design. The measurement data which is needed in architectural design, was transferred in this project to 3D product model format that supported later architectural renovation design.

An office building in Helsinki of 23 000 sqm in eight floors has been used as a real test case for the study. The case building has even been voted for the "ugliest building in Helsinki" by a local newspaper a few years ago (Figure 1).

The main objective of Senaatti Properties, the facility owner and manager, has been to test mod-

*Figure 1*
*Building modelling case study of an office-building in Helsinki to be measured and renovated.*

ern building measuring actions plus the following building data modelling phase. The aim has been to show how building measuring and documenting should be done to better support the following model based design activities. It has been important in the project to distinguish model based process from more traditional measuring plus measuring drawing activities.

The objectives did not include quantity take-offs nor guidelines for demolishing activities, but just ideal support for the actual architectural renovation design.

## Special characteristics of renovation ICT

The different character of renovation design compared with design of new buildings is evident. One of the most significant features is the unexpected nature of design. Design tasks the architect performs in the office have always to proceed with active interconnection with the site activities, demolition, reparation work and rebuilding. The existing but still constantly changing on-site status in renovation sites has often been difficult to present with CAD. Also typical non-orthogonal geometric forms and diversities in renovation have traditionally been more difficult and much slower to describe with CAD-systems, which seemingly suit better to working with planar and orthogonal forms.

The importance of non-geometric information related to demolished and renovative building objects is also typical to renovation information architecture. Written descriptions, even currently expressed just in oral form, often contain essential data of the renovation domain, and that data is often impossible to express in CAD-drawings. Photographs and images are likewise separate documents which have been difficult to link digitally to the renovation objects. Electronic document management systems (EDMS) and project webs (Hjelt & Björk, 2006) have recently offered proper tools to master and manage this diversity, also within renovation data and documents.

## Modelling process

Performed building measuring and modelling process in the case building is described step by step.

### 1st phase - Definition of measuring and modelling tasks

The measuring task was due to be performed by a professional building survey & measuring company. The following modelling task was then to be performed by another company, who were experienced in architectural CAD-modelling.

The starting point for this case project was the proper definition of wanted measuring activities which were needed to support the followed building modelling tasks. First definition of measuring points (Figure 2) was not appropriate for model based needs, hence the definitions had to be negotiated and altered to fit better for further modelling needs.

It was very essential to define the actual modellable objects and also non-modellable parts before the actual measuring phase. Tolerances were also agreed in the beginning. Measuring tolerance were defined to be 7 to 15mm and CAD-modelling tolerances in documenting the results were agreed to be 10 mm.

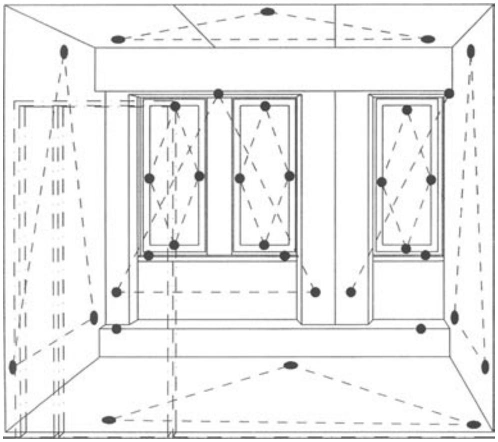
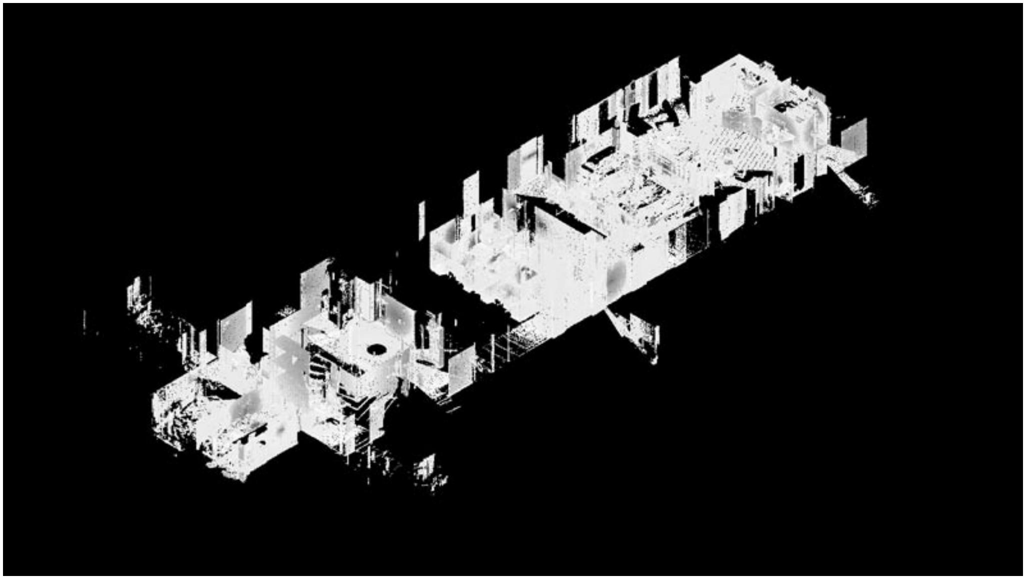


*Figure 2*
*Original measuring & modelling definition by project owner and project manager. Too many points were originally required to be modelled, whereas the 2nd definition limited measuring just to the most essential objects & points.*

Figure 3
*Point cloud of part of one measured floor included 50 scanning points.*



## 2nd phase - First measuring round

The first measuring round was done using laser scanning technology and it took about 440 man hours to perform. Measuring objective was to be accurate, meaning that walls, columns and surfaces were to be measured with 3 points each. The required accuracy could have resulted in roughly 2500 measured points per floor using traditional measuring methods. When using laser scanning technology about 50 different scanning points were defined and used per floor, which finally resulted 250 million measured points per floor. The volume of the measured data for the whole building was about 50 GB, meaning that the data had to be transferred from measurer to modeller with a hard-drive. Web-based transfer methods were impossible to use.

## 3rd phase - Second measuring round after demolition works

The second measuring survey round was done after the demolition works, because just then essential hidden objects could be measured. The second round focused also to unmeasured objects which were forgotten to be measured during the first round.

Second measuring took about 220 man hours to perform, hence, the total volume of performed measuring work in the project was about 660 man hours.

## 4th phase - Modelling of major components

The 3D CAD-modelling task was a rather simple one, including modelling of bearing frame components (floor slabs, columns, beams, bearing walls and external walls) and the objects which were to be preserved. Also doors and windows were modelled.

Non-bearing structures, such as internal walls or lowered ceilings were not modelled at all to rationalize the work. The definition of conservation and demolition was made by the project architect..

3D-modelling work was done with standard Autodesk Architectural Desktop –package with Cyclone Cloudworx plugin to managing measuring material. Modelling was based on measured 3D point clouds, which were viewed in 3D and also sectioned during actual CAD-modelling.

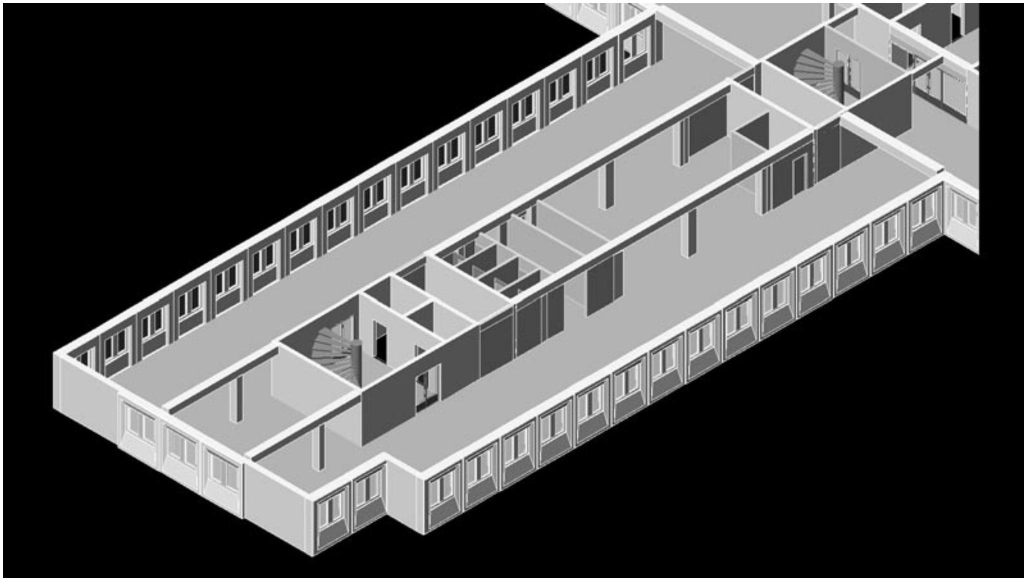


*Figure 4*
*Final CAD-model of a single floor plan.*

Building facades were modelled using ADT-reference files. Since the actual building was exceptionally simple, the facades were constructed from 7 different CAD-elements describing the real concrete elements. Modelled facade elements were referenced to the floor models.

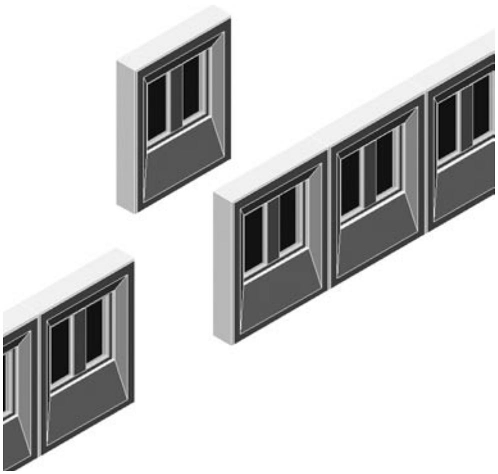


*Figure 5*
*CAD-model of facade elements.*

The most tedious part of the modelling work was done in the basement floor, since most of the bearing structures were unique with no geometric repetition.

In further projects the actual appearance of the modellable building affects significantly to the volume of the desired 3D modelling task. The more repetition, structural clarity and simplicity the target has, the easier modelling task will be.

The overall building modelling task in 3D took in two phases about 280 man hours.

## 5th phase - Distribution of model data

Last phase was to distribute the modelling results to the design team (Table 1). Data exchange was done as ADT-models in dwg-format. Up to 55 files (30 MB data) were transferred via project web. Since the structural engineer used Tekla Structures program, which is a true product modelling platform, also IFC-data exchange format was used.

*Figure 6*
*Structuring the modelelled CAD-components .*

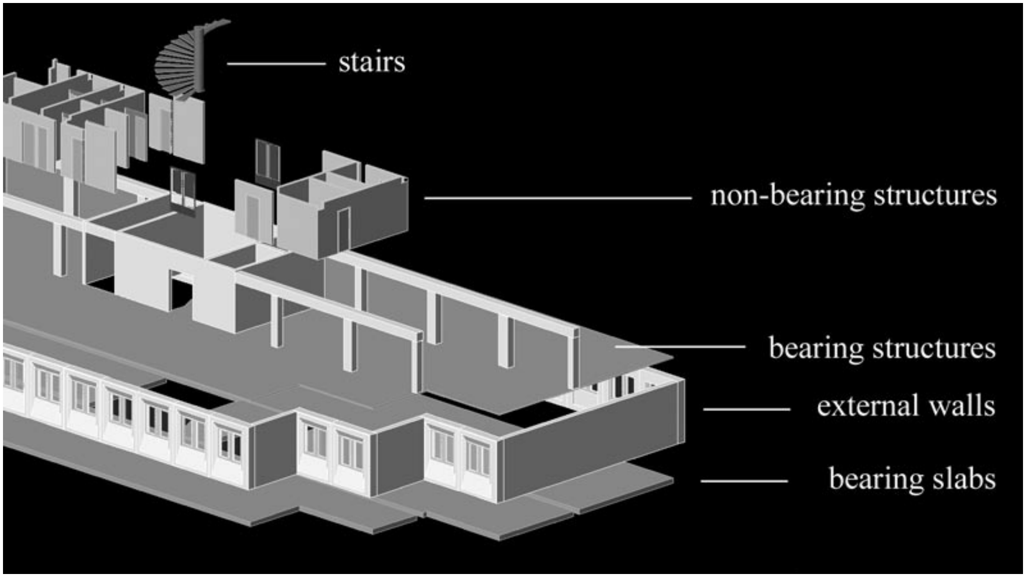



*Table 1*
*3D model data exchange to other project participants.*

| participant | software | data exchange format |
|---|---|---|
| architect | ADT | ADT-model in dwg-format |
| HVAC | MagiCAD | ADT-model in dwg-format and IFC-model |
| constructor | Tekla Structuc-tures | IFC-model |

Both ADT-model and IFC-model transferred the building model data between the applications well with similar results. The most remarkable irregularities between ADT-model and IFC-model, though, were in the staircases, which were transferred as proxy graphics. Other modelled objects were transferred as AEC-objects.

## Results

When performing measuring survey which aim in transferring and documenting the existing buildings into CAD-drawings, the measurement definition and actual measuring work has to be done differently than in 3D CAD-model based documentation. More traditional method of modelling the measured objects as surfaces was not acceptable within the case projects CAD-environments, and it was also against principal project objectives.

The surveying and measuring companies are much more accustomed in documenting and distributing their results in traditional drawing formats, rather than in 3D-model formats. Hence, when selecting surveying participants it is important to prepare and advice them to work with 3D-modelling rather than more common 2D-documentation.

The survey & modelling task has to be defined in detail before the job to avoid unnecessary measurements. Useless measured points are wasting surveying resources. Formal and accurate pre-definition of measuring points without a clear understanding of the proper need for it, should be strongly avoided. It is no need to perform extra measuring for safety's sake, or just in case. Using laser scanning technology could reach more accurate and comprehensive result with reasonable resources than more traditional methods of point-by-point measuring.

Another important area in surveying definition are the tolerances and orthogonality of the objects. The key question is how much tolerance is accepted both in surveying but also in geometric 3D-modelling work. Using just orthogonally rectangular coordinates is almost never reality on renovation sites (Thurow & Donath, 2005), nevertheless it may still be acceptable to simplify the modelling task.

Building modelling objectives should be described by the real needs of the project participants, but also the CAD-software tools to be used in the project. Those elements which are needed in design, should also be modelled with proper accuracy, hence the elements should respectively be measured.

## Conclusions

Despite the fact, that this was just one case project, one measuring survey and one performed modelling task, nevertheless, product modelling methodology will be applied in renovation design - a rather novel area for model based design.

While almost just new buildings have so far been piloted in model based design, the project owner and facilitator collects experiences and develops new methods for renovation design. Key questions to be answered are, how product model based design methods should be adjusted to renovation projects and how existing contemporary design methods and practices should be changed.

This pilot project also strengthened the experiences in ordering surveys and model-based building documentation properly. Some essential features of survey & modelling definition are collected to Table 2. To achieve a useful and working basis for further renovation design tasks, needs a clear strategy and vision from the project owner in defining the renovation project needs.

*Table 2*
*Assessment of measuring surveys and documenting practices.*

Traditional measuring documented in 2D-drawings
- + surveyors are familiar with the process
- + measuring & documenting expenses are known & accurate
- – does not fit well to modern design processes
- – sometimes scarce or even useless concerning height information

Draft measuring documented in light 3D-models
- + survey & modelling cheaper to perform
- + 3D-models support spatial design properly
- – surveyors are not always familiar with modelling needs
- – correcting measurements often needed due to scarce data
- – scarce (coarse) data may lead to false design assumptions later

More accurate measuring documented in detailled 3D-models
- + 3D-models support spatial design properly
- + more detailled model decreases later design mistakes
- + detailling supports renovation design better
- – expensive to perform
- – the amount of survey data may become vast

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