

### 3 4D CAD- An Efficient Tool to Improve the Production Method for Integration of Apartments in Existing Buildings

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#### *Abstract*

The aim of this paper is to give the reader information about an ongoing research project at the Swedish Institute of Steel Construction. In this project the value of using the 4D CAD concept is going to be studied by comparing the traditional planning process of a vertical extension on existing building project using Light Steel-Gauge framing system with the planning process of the 4D concept. This paper discusses how a 4D CAD tool together with an industrialised production method can be used for improving the production process for a vertical extension on existing buildings projects in order to reduce the construction time with secured quality. The reader will understand and appreciate the added value in using an industrial production with Light Steel framing and utilising 4D CAD as a management tool for a better production and a more efficient way of managing construction projects.

**Keywords:** 4D CAD, 3D modelling, Light-Gauge Steel Framing system, vertical extension



## INTRODUCTION

In many cities the city centre is the most coveted place to live in. Consequently this entails an increased interest for creation of more densely populated cities. One example is the capital of Sweden, Stockholm, where the city centre have the most popular residential and commercial properties.

One way to make more densely cities and meet the demand for more residential and commercial properties in the city centre, is to add apartments to existing buildings, such as shopping centres, offices or multi-storey carparks by vertical (on-top buildings) and horizontal extension or conversions. Conversions and extensions of existing buildings have successfully been used in several countries, for example: United Kingdom, Finland, Norway and Sweden.

An on-top building project has more constraints compared with building project in areas, which is not as much as city centres exploited, therefore the need of a good construction and production management is important. The complexness of an on-top building project, depends not only on the usual factors in all building projects but also factors as: lack of space for material handling on site, inner city traffic and its effect on the deliveries to the construction site, disturbance to the surroundings and to the existing activities in the all ready existing building due to construction activities, need of more understandable communication to the project involvers and to the tenders in the existing building. These factors compel that an on-top building project is more critical.

This paper will discuss how a 4D CAD-tool can be used in on-top building projects in order to render more effective projects. The paper begins with describing the current practice and the background and some related examples. Followed by the needs and visions of using 4D modelling in an on-top building project. This paper is based on literature study done for the research project “Integration of apartments in existing building by use of Light Steel Framing system”, [10].

### Light-Gauge Steel Framing System

The Swedish Institute of Steel Construction have during the last five years preformed research on Light-Gauge Steel Framing, (LSF). Light-Gauge Steel Framing has been developed by the Swedish construction industry for use in dwelling buildings. There are several systems for LSF that includes products and detail solutions for interior walls, exterior walls and floors. LSF results in a very light weight building compared with those of traditional materials, e.g. compared with a concrete building the weight is only one fifth. Therefore the need of reinforcing the existing building will be minimised. Consequently, this will reduce the cost of the extension of the building. Therefore is the LSF suitable for vertical and horizontal extensions of existing buildings. Furthermore, the steel is inorganic and hence the risks for moisture and mould problems are very small and with a suitable production method and production management the materials will remain dry during the construction time. In addition LSF has a relatively low use of resources and the materials have an established recycling loop, [1] [2].

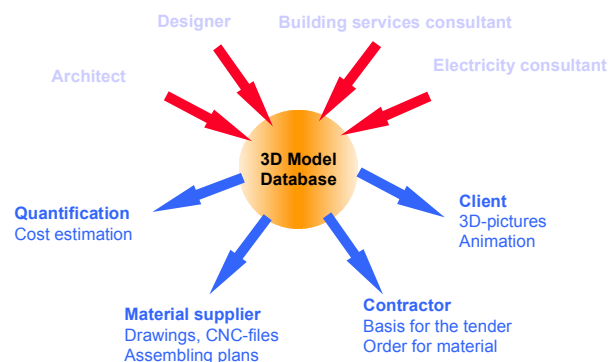
Research on Light-Gauge Steel Framing has shown that the construction time can be significantly reduced by an industrial production of building elements and a fast erection on the building site, [3] [4]. The general outlines for industrial production, which agrees with the production methods of the LSF system are:

- High level of prefabrication
- Light weight of building components
- Simple erection
- Narrow tolerances
- Accurate planning

## BACKGROUND

### 3D modelling

Common for all parts in the building process is the extensive use of information. The 3D model based on sharing a common database will provide the last versions of drawings and information available from the database to all different players in the construction process. From this database all types of documents can be produced, for example different 2D and 3D perspectives, material specifications and drawings for manufacturing and assembling. The database can also produce data for cost calculations, time scheduling and very important data needed for the client and the future lodger, [7].



*Figure 1: The 3D database model for construction*

In the Swedish construction industry Microsoft Project and AutoCAD is the most common tools used for planning and design of a construction project. In the early stage of a project, the architects use 3D modelling for producing 2D and 3D perspectives and not as a shared database being described above. Structural engineers use 3D modelling for e.g. steel structures analyses during the design phase. But in general, 3D modelling is not used in a great extent in Sweden. Lack of standards for the information stored in the 3D database for the lifetime of the building, conservatism in the construction industry and the lack of knowledge within the industry makes the use of 3D models difficult for the whole construction process. To use the 3D concept in its full extend, implies that the construction industry have to change its process. The design of the project has to be more integrated with the production planning. The 3D concept and its working methods, is about changing how organisation of a project ought to work and how the different partners in the project should utilise the advantage of the 3D model and the information stored in the database.

The 3D design model focuses on the design of the building, its spatial construction, material and its manufactures. The 3D model is a static model, built in the computer for representing the physical building. This could be seen as a drawback for the construction process since the construction process is a dynamic process and needs a dynamic presentation.

### Example

The block Näktergalen was the first project, in Sweden, where 3D modelling was used for a Light-Gauge Steel structure. The purpose was to investigate how 3D technology could contribute to a greater efficiency and quality assurance in the construction process. The building consists of a semi-basement storey of in situ concrete. Above the basement storey, four stories were built with Light-Gauge Steel Framing.

The potential of the 3D technology was confirmed in many different aspects:

- The total quality of the project was improved by better project planning.
- Moving parts of the work from the site to the field factory on the building site, where the work were done in a better environment improved the work environment for the site workers. The workers did most of the work indoor and used better ergonomic working methods. The only part done on the site was the assembly of the different elements and structural components.
- By using the 3D model the order of the assembly had been visualised. By a better planning process the construction of the building was smoother because of lesser changes and ad hoc solutions for problems. This radically reduced the total project time, [4].

The Näktergalen project proved that the industrialised building process demands a good collaboration between the design process and the construction process. A good result in the production phase lies in the work done during the design phase.

### 4D Modelling

4D CAD is a concept, which combines an object oriented 3D CAD model with time. 4D CAD is a kind of information visualisation that is easier to understand than traditional methods, such as 2D drawings and time schedules, which are used to manage construction projects. 4D CAD is a logical way of imagining a construction. With help of a 4D visualisation, it is easier to bring a product (the building) into line with consumer needs.

The 4D modelling tool is conceptually much closer to an intuitive picture of a construction process than 2D drawings and time schedules. The 4D concept visualises the dynamic process of the construction process and as a result the information will be more comprehensive.

The 4D concept is developed at Stanford University and to support the concept researchers at Stanford have developed a prototype that is being used in some complex construction projects in California. Research results shows that using 4D concept can improve the construction information flow between the partners of the construction project. The use of visualisation and 4D concept enable the partner to focus on the relevant information and interact productivity. By the use of a 4D tool more time could be spent on performing predictive tasks and more efficiently evaluating design, constructibility or construction scheduling, [8]. In this way the design and construction phase can be more integrated which will results in a more efficient construction process, [5].

In fact the 4D concept, by visualisation of the construction process, is an efficient planning tool to organise the logistic of the site during the planning phase instead of as today during the production. The site layout can be simulated and visualised with a 4D CAD tool for the actors in the project which in particular will help the site engineer to organise the activities, material flow and site logistic.

The use of 3D-4D modelling has many benefits for owners, architects, engineers, contractors and subcontractors. The overall benefits of 3D-4D modelling are summarised in the main points below, [9]:

- Better coordination of subcontractors
- Clear communication of the project schedule within the team
- Visualisation of the work flow
- Efficient identification of constructibility factors
- The 4D model shows the status of the project at any time

### Example

The pedagogic benefits of the 3D model with a linking to time dimension, has been proven in projects like kv. Krympmättet, Sweden, where a simple visualisation of the construction process has been used to describe the process for the contractor and the site workers. By visualising the different time in the production process of the building, the production process was brought out for the site workers and site managers early in the production phase. The main purpose with the visualisation was to visualise and clarify the structure of the building and the erection of the structure. The visualisation was also used for describing the project process to the owner and the contractor. The aim was also to use tools, which is used in the Swedish construction industry such as AutoCAD R14 and Microsoft Project for linking the time with a 3D model.

The method for the visualisation in this project was to build a 3D model in AutoCAD. Different time in the production process was laid in specific layers, and thereby by lighting and shutting down layers, different time sequences of the model was visualised. The model was primarily defined by solid elements. This solid elements carries more information e.g. volume, center of gravity, than the elements combined of areas and lines. The use of the 4D thinking in this project was very simple although it proved the advantages of using 4D modelling. The method has of course many shortcomings, both technically and theoretical but the aim was to use the visualisation for pedagogic usage of 4D modelling in the project team meetings and to present information for the contractors and subcontractors during the production planning process.

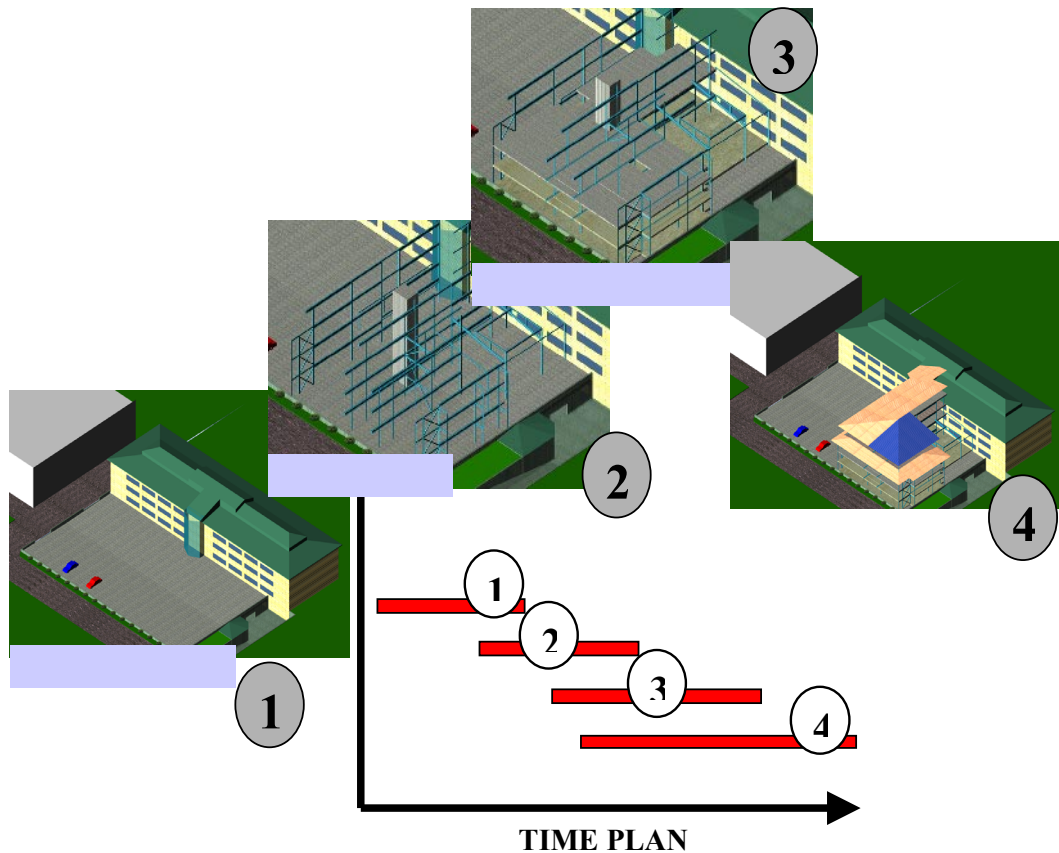


Figure 2: Visualisation with time linking in the project kv. Krympmättet, PIAB PI i Göteborg

## THE USE OF 4D CAD IN THE ON-TOP BUILDING CONSTRUCTION PROCESS TOPPING

### The obstacles of an on-top building project

Disturbance to the surroundings of a construction site during the production time is one of the major obstacles in on-top building projects in the city centres.

When converting an existing environment many aspects must be considered. These aspects could be:

- Influences that the new building will have on the existing building.
- Influences of the new building's activities on the already existing activities.
- Influences of the production activities of the on-top building on the everyday activities of the existing building and its surrounding throughout the construction time.
- These factors have to be considered in the planning process.

The duration of the disturbance time on the existing activities and buildings will be minimised by shortening the construction time. For a more efficacious construction time for an on-top building project many aspects have to be carefully considered in the planning process. In the first place, a better construction planning results in an improvement of the work at the site with lesser errors. The limitation and constraints of the project has to be considered in the early stages and before the actual site work begins. By considering constructibility,

production methods, interdependency of tasks and matching manpower to available work in the design phase, the design work will be more integrated with the production work and thereby delays and changes in the total project will be minimised. Consequently, this will result in shorter construction time, [5]. In the second place, the logistics from and to the construction site is important for minimising the disturbance to the surroundings. The management of people, equipment, material storage and waste, on the site is an important work in order to minimise the disturbance factors. These factors should be considered at an early stage in the project and before the actual work on the site begins. Furthermore, it is important to give relevant information to the concerned partners in the project such as tenders and other people working or living in the existing building, in order to expound the understanding for the disturbances related to the construction site. The neighbours and other people affected by the construction should be informed of the construction process in an easily understood way. This will not directly minimise the disturbance but will increase the acceptance level for the produced disturbance due to the construction, [6].

The influence of the extension on the existing building must be considered early in the design phase. Examples of factors to be considered are:

- Shafts and piping for ventilation, water, sewage and drainage
- Location of lifts, staircases, facilities for washing, storage and garbage collection etc
- Building physics such as: sound insulation, moisture, heat supply, fire safety etc
- Solutions for security and separation of residential housing and other use
- Compatibility between the existing building (structural components and material) and the new structure
- Work methods and production methods, which not disturb the surrounding activities much and suites to the existing building

Most important is the industrial production of components where a fast erection can shorten the construction time and as a result minimise the disturbance. Industrial production implies for detail planning process before actual work on the site begins and better integration between partners in the projects.

In order to meet the challenges mentioned, an efficient IT- tool can play a significant roll in meeting these demands. Research results has shown that visualisation techniques can efficient the production planning and the production of the buildings, [11]. The 4D modelling tool can meet the necessities for a better construction process, especially for projects having many complexly interrelated parts.

#### The use of 4D modelling tool

By using a 4D-tool in the design phase of on-top building project, the design team will be able to simulate the integration of the new building with the old building. The different alternatives for the integration of the building could be simulated in order to find the most process efficient solution. The construction process will be visualised in the computer in order to coordinate the work on the site. This will give the opportunity to eliminate potential problems with constructibility, design conflicts assembly order of building components and the deliveries to the site. The visualisation also assists the project team by showing the status of the project at any time. For examples, the project can be simulated for the neighbours of the site in order to inform them about the progress of the project and how the project affects them during a different period of the construction time.

The transports to the site can be visualised in the 4D model together with traffic flow around the site in the city centre. Thereby the affects on the traffic can be investigated and the transports to the site planned in order to minimise the disturbance to the ordinary traffic. Site organisation and material handling on the site can be visualised in a 4D model and be of a great help for the site manager.

#### A list of expects of a 4D model

- Standardised information stored in the database and for presentation
- Easy to use and comprehensive
- For the everyday use by e.g site manager the tool have to be smooth and not time consuming
- Engage the subcontractors more in the planning process of the product and the planning process of the construction

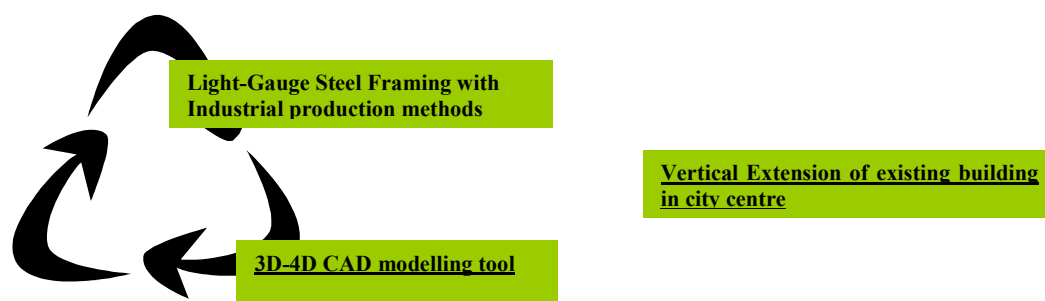
### **THE AIM OF THE RESEARCH**

New 3D and 4D modelling tools are under development in Swedish market. Enterprixe Software Ltd is currently developing a new 3D/4D CAD application/server called NetModeler. This product enables for the first time full multidisciplinary project collaboration to one single product model database over the Internet. Research is going on which will lead to a prototype tool in NetModeler where time schedules can be reviewed in the design model. Same model will also generate bills of quantity to cost estimating systems. The benefits of using the NetModeler's 3D-model as the 4D-model is data consistency.

There is a need to study how to implement the 4D modelling concept in the Swedish construction industry and how to overcome the obstacles.

New and more industrialised construction methods are needed for increasing the efficiency of the production process and minimising the production time.

The Swedish Institute of Steel Constriction has the vision to provide solutions for a more industrialised production methods using Light-Gauge Steel Framing. An industrialised production method needs a good management and planning tools. The aim of the research at the Swedish Institute of Steel Construction is to verify the benefits of 4D modelling in construction projects together with industrialised production methods, as for example on-top building projects using Light Steel framing. The study should identify unproductive parts that do not add value to the project in order to improve time planning, logistics and work methods. The results of the study should improve the 4D-tool and its use as indicated by the evaluation.



*Figure 3: Corn stones of the research project*



By using a 3D/4D model as basis for describing the final product result and how to produce the product, new forms for collaboration must be developed within the construction process. The use of these models will demand new roles in the construction process. The 4D model can describe the production process and it could be used as a production management tool. The construction process with the 4D concept demands for new roles for the architecture, consultants, contractors and subcontractors. These new roles have to be discussed. There is also a need to evaluate the 4D tool in comparison with the actual procedures for design, planning and production processes in the Swedish construction industry.

## **METHOD**

The method will be to studying an ongoing project, with 4D modeling tool, e.g. NetModeller 4D tool, and compare the process with traditional tools. By studying an ongoing project in Sweden the obstacles of using 4D concept will be clarified. Through using a 4D CAD tool parallel to traditional projecting methods in a project, the efficiency of the 4D CAD tools will be compared to the traditional tools will also be studied. As the problems of using 4D concept is exposed, the changes, which have to be made in the Swedish construction process will be pointed out.

The results of the project will give guideline to Swedish building industry to how implement 4D CAD thinking for a more productive building industry.

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