Life cycle optimized system solutions for densified housing with massive wood technology

Michael Zwölfer, Peter Thomas(*), Claus-Jürgen Schink, Volker Koch
Ifib, Institut für industrielle Bauproduktion,
Universität Karlsruhe (TH), Germany; http://www.ifib.uni-karlsruhe.de.
(*) HATI, Gesellschaft für Handwerk Technik und Innovation GmbH, Berlin, Germany http://www.hati.de

The objective of the joint project 'Life cycle optimised system solutions for densified housing with massive wood technology', short form Basys, was the development and application of an open building system for sustainable construction in a virtual enterprise. Four partners coming from building economy and a university institute developed the building system in a comprehensive planning process. By applying massive wood technology, most requirements of densified housing can be met and individual buildings can be produced on demand.

1. Backgrounds and Goals

1.1. Situation

The central goal of Basys was the development and application of an open building system for sustainable construction of densified housing. The system was to be elaborated by specialized partners through a comprehensive planning. A common characteristic of all the partners is that they come from small and medium sized enterprises applying traditional craft techniques in small on demand projects. They were all eager to use new technologies and strategies for solving problems associated with structural changes.

The common line of action was determined by the form of cooperation and the applied information and production technology. The different partners were localised over a large geographic space from the triangle Munich - Karlsruhe - Berlin. This is why the virtual enterprise was chosen as form of organisation (Müller 1999). An Internet based platform enabled the partners to cooperate in a virtual "project space".

The technological background for Basys was given by an innovative massive timber construction method, that has been developed in the last 15 years. Wooden lamellae are joined by wooden dowels to form large panels. They can be used for walls, ceilings and even roofs. The advantages are a homogenous arrangement of a comparatively large quantity of wood with a very positive impact on the indoor climate, a very good processing due to the homogeneity of materials and the possibility to use cheaper second quality wood. The participating enterprise for timber construction disposed of a CNC-plant for assembling and processing large components.

In an economic environment like Basys the production equipment in use is generally not up-to-date. For example the mentioned CNC-plant used by the timber construction enterprise was controlled by an Intel 80286 processor under the operating system MS-DOS 4.0. which was the common industrial standard until the mid-90ies. Extensive dependencies between hard- and software did not allow upgrading the whole system at reasonable costs. The chosen product models had to integrate proprietary and obsolete standards.

Most partners already had experiences with the timber construction technology.

The range of solutions was determined by the existing production equipment, the available knowledge and the chosen forms of organisation. It reflects typical relationships in the European building industries and craft sector.

The role of the university institute (ifib) was to provide a wide range of digital services. These services concerned the modelling of the design and the building system for fabrication. Furthermore the transfer of knowledge between the partners was implemented, in a general communication framework (communication model). The academic interest of the ifib resided in the relationship between product and communication modelling in a pragmatic cooperation process of designers and small-scale building industries (SME).

1.2. Sustainability

Sustainability in the building sector is often reduced to the use of “healthy materials”. It is important to point out the more general definition of sustainability applied in Basys during the system development. In addition to the common view of sustainability focussing on ecological aspects, the economical, the cultural and the social dimensions were also taken into account as shown in the following figure:

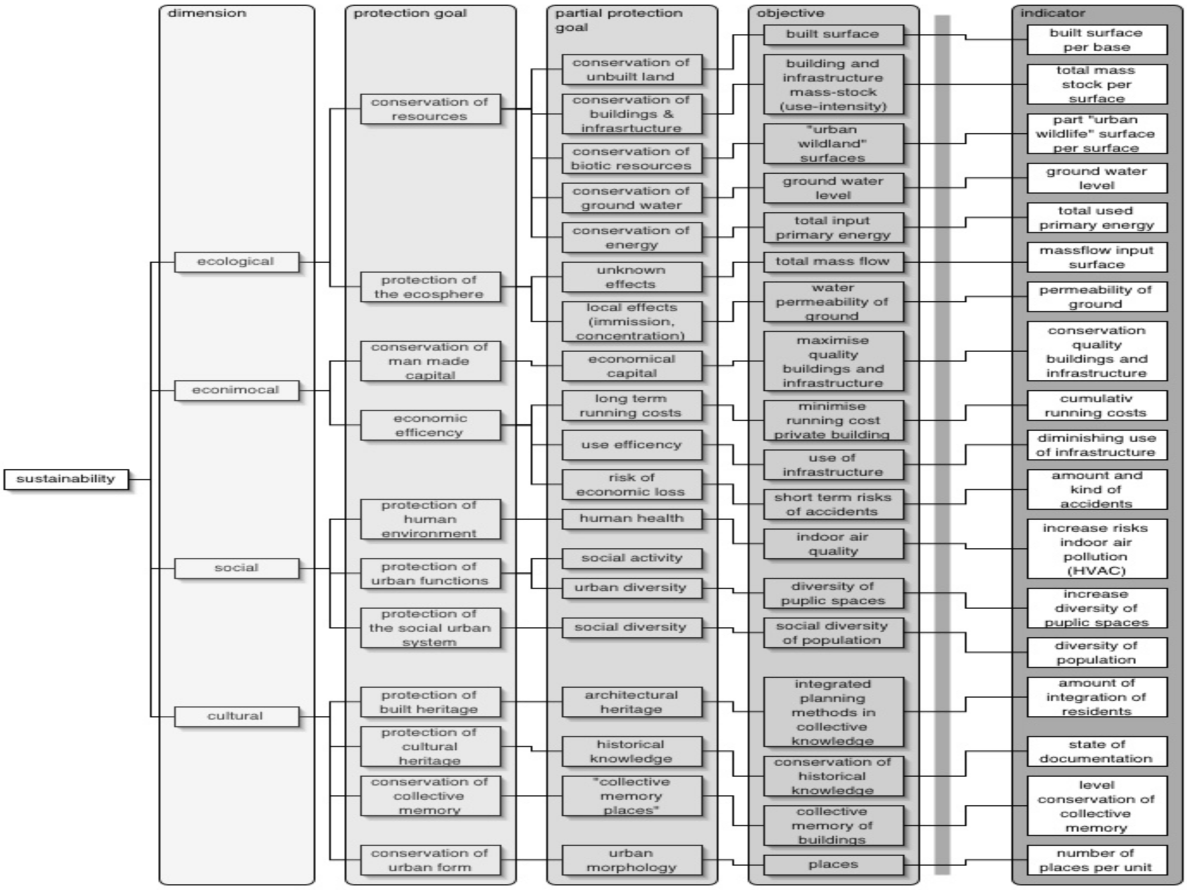

Fig. 1: Overview of the sustainable development objectives applied in Basys

The conservation of natural resources and the protection of the eco-system is an essential aspect of sustainable building. In Basys this was achieved by mainly using renewable materials that tie CO_2. Considerations of urban planning led to land-saving densified housing. A high degree of standardisation of details and the absence of composite materials allow an easy dismantling during different life cycle phases.

The economical aim was to insure the competitiveness of the small and medium-sized enterprises and to lower costs in a long term (lifecycle costs). This was achieved by the reorganisation of the actors in an open structure within the virtual enterprise. During system development complexity was reduced to by concentrating activities in two teams of execution. The interests, competence and experience of all partners were integrated permanently and at an early stage. This model of cooperation has the potential to replace the current exclusively price based tender competition by an explicit quality-price competition of systems. The long-term effect is the improvement of comprehensive building systems instead of the development of cost saving rationalisation measures, which lead to a lower long-term quality level. The objective of sustainable construction is to relate the demands of the users, the quality of construction and the reduction of environmental impacts.

The social dimension of sustainability aims at the protection of human health (workers and users) and the raise of the indoor comfort level. Both were achieved not only by the chosen materials, the structural system, the cladding but also by new forms of integration of the technical equipment.

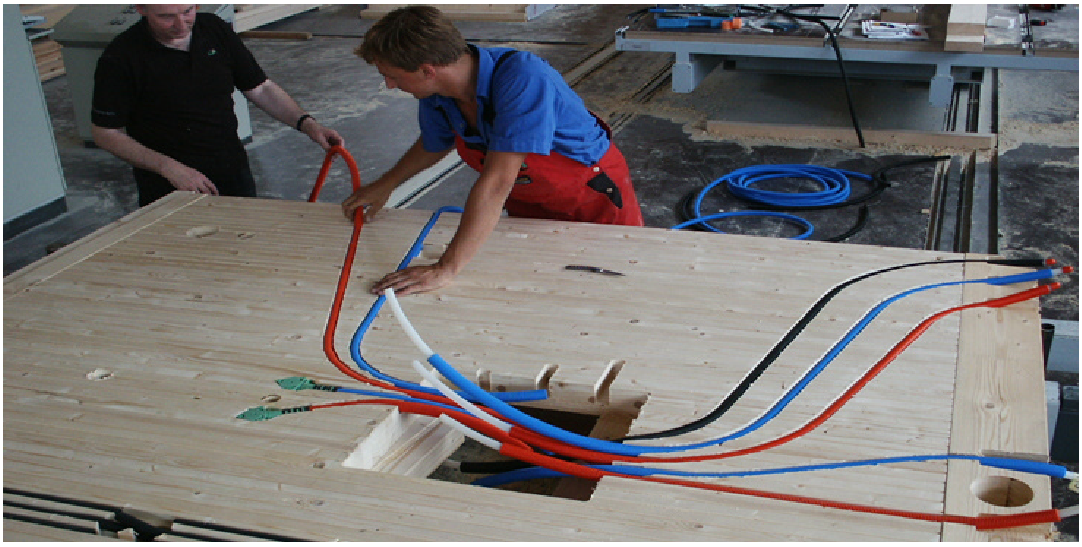

fig.2 typical plot of an integrated technical equipment on the CNC-plant

As a contribution to the cultural aspects of sustainability, the goal was an open building system supporting a large diversity in all aspects of design and use. The development and optimisation of the system lead also to a higher expertise and gain of additional knowledge, compatible with the traditional craft knowledge. This relation between traditional craft knowledge of crafts and new technologies can be used in teaching and will constitute a supplementary contribution to the long-term protection of technical and cultural knowledge.

2. Results

In a traditional construction process each actor derives his knowledge from his particular perspective or view. The views and the knowledge of the other partners involved are hidden to him. With the comprehensive planning and construction approach used in Basys, however, the knowledge of the partners is explicitly integrated and made available as system knowledge. In the course of the project the accumulation of knowledge took place while the actors dealt with construction tasks ranging from the production of a partial prototype to be presented at a trade fair to the erection of a complete building ending up with the production of an entire settlement in the city of Potsdam. On the one hand a central platform was created to enable the upload and exchange of documents describing the system. On the other hand tools were created for the automation of the system-related work. Both components served as a catalyst for the system development and limited the broad range of possible solutions for the system itself. When the project Basys was finished after two years, it had led to new and better solutions for about 80% of construction problems in the particular field of the project. They were considered as real improvements to the system responding to the high standards of sustainability set up in the project. A simple dwelling house can be constructed entirely using these solutions.

2.1. Product Model

A digital building product model is a virtual image of a building where the building components and their properties are modelled in a computer. It is generally used to simulate and define particular properties and their complex interactions. Moreover centralized standard product models are used for integration of software applications (e.g. Industry Foundation Classes (IFC 2002), Datentransfer im Holzbau = DtH (DGfH 1999)). They are called integrated product models if they model the flow of information during the whole life cycle of a product.

The necessary rules which have to be set up by standardized and integrated product models to describe even a simple building with all its components tend to reach a complexity, which cannot be handled today in a general professional environment. Only partial solutions can be used in specific professional environments. These solutions have to take into account the general state of development of the used technologies, with the risk slowing down the development of the general models.

From the point of view of a small or medium enterprise this approach to a general standardisation demands resources, which are urgently needed elsewhere, i.e. in daily business. It is the small and specialized software developers - in contrast to the big software enterprises - who are familiar with the particular needs of their customers. However, due to these high hurdles, it is difficult for them to participate in the modelling process. This is why practical knowledge and experience on the one hand and their quick feedback into modelling efforts on the other hand are underrepresented.

Recent research keeps this in mind and tries to overcome the concept of an entire object model in a static sense in favour of evolutionary models with dynamic structures which can link specific requirements just in time and when there is sufficient information available in the planning, construction or assembly process (Rank 2004).

The dynamisation of product modelling is crucial during the development of a building system like Basys. The model serves as a framework and it is used to check decisions against the requirements. Therefore it is indispensable. In the case of Basys the model had a template nature for a larger future solution and at the same time it had to allow direct integration of the gained knowledge during realisation by the actors themselves. The accessibility of the model was a key requirement.

In order to avoid errors transparency became an important strategic aspect: the complete network of partners discussed all important changes in the system design. Here the link between product modelling and communication modelling was established.

The number of partners involved, the width and the depth of the requirements led to a large number of specialized software products in Basys. This number could not be reduced without a limitation of the performance and the quality both of the partners and of the system. A heterogeneous data basis was therefore inherent. Most of the applications had no programming interfaces and stored their data in undocumented proprietary formats. In this situation the only solution was to develop an own partial product model. Another characteristic of Basys led to the same decision: for the mentioned integration of the technical equipment like electric installation, heating and water supply, no product models were available. The distribution systems were designed in a star shape to ensure a maximum of variability. All the pipes were laid inside tubular protections allowing future replacement and repair. In order to support the replacement of all pipes, the tubes were designed with large radii in a spline-like manner. In traditional construction this would have caused serious risks of damages through subsequent, non-coordinated interventions of other trades. But in Basys the same data were used for multiple purposes: at first the milling-code for sinking the tubular protections in the wooden core was generated, then the protecting code for blocking installed sensitive areas was generated while nailing the shell onto the core, then the sensitive areas were marked on the shell and finally the data was used to calculate the true length of needed tubes for ordering.

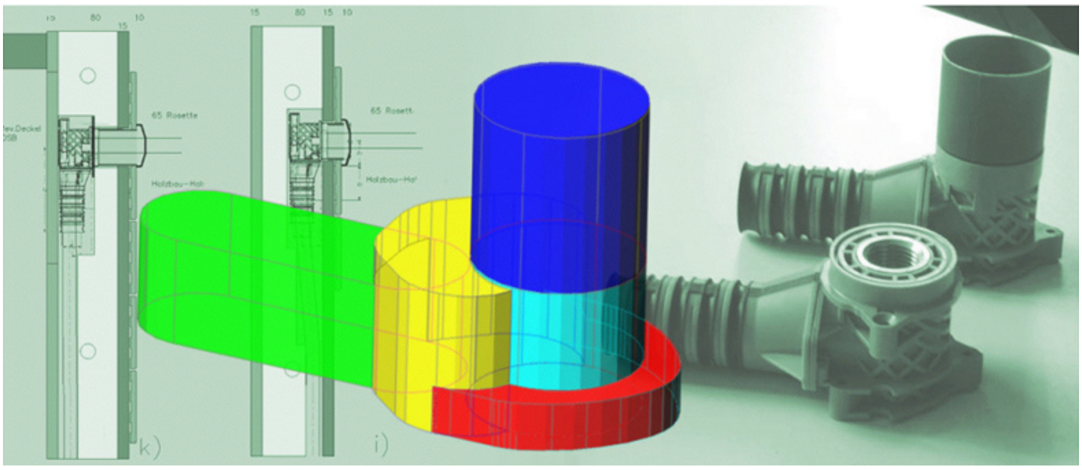

fig.3 adoption and modelling of technical components for the building system Basys

The partial model for this was developed for AutoCAD. It integrated the planning data from the architectural design and the technical designs into a single model specialized for plotting walls and other large building parts on the CNC-plant of the manufacturer. The architect delivered all his geometrical design data as a 3D-output of his CAAD model. The drawings were based on user-defined templates reflecting the system components with their specific layer composition. All layers were available as triangulated 3D-meshes. The outlines of the layers were regained by geometry analysis of the meshes and so the true geometry of walls and ceilings was created. These were used in the technical design for the arrangement of distribution and the localisation of technical components, which were in turn defined as individual drawing modules with appropriate CNC data. The CNC manufacturing finally occurred with the support of different processing layers, and tools.

The main difficulties were caused by the architect’s drawings, where most intersections of layers were generated automatically, i.e. in a geometrically correct way, but without consideration of product engineering aspects.

The model for production consisted of:

- Templates defining the components of the building system according to the layer composition. These templates were used by the CAAD-system of the architect.

- Work orders for a system compliant use of these component templates. In some cases feedbacks were necessary in order to get satisfying results.

- Tools for the import of geometries from the architect's CAAD into the model for production.

- Templates representing the technical equipment in the production model.

- Tools for the CNC-compliant arrangement and linking of technical equipments.

- Tools for organising the processing. The output was a proprietary code (Homag, Weinmann und Partner [WUP]) that directly could be read by the pre-processor of the CNC-plant.

In conclusion, the product model in Basys was based on templates and drawings, which were editable by the user, and on a set of tools for operations specific to the system.

2.2. Communication Model

Building systems not only affect product modelling. They have a high impact on the sustainable quality of buildings and change the terms of cooperation significantly: ad hoc planning at the construction site is replaced by systemic planning in the preliminary stage. This is only possible through the integration of the contractor’s knowledge. Knowledge management and communication become central parts of the problem. The actor’s soft skills, motivation, confidence and even fun at work became often more important than pure efficiency.

fig.4 the virtual project-spaces; discussion of important changes to the system design

The comprehensive planning process in Basys was structured on three levels:

In addition to the real level of private workspaces of each partner at his home location there was a virtual level of several shared project-spaces organized by a single Internet platform. The platform handled the main project-space common to all partners as well as individual sub-project-spaces for any subset of partners with or without supplementary external partners. All project-spaces were dedicated to the specific involved partners. But each partner could decide to make information available to partners of any other project-space through the platform.

The third level of cooperation was a grid of jour fixes and workshops where the partners met face to face in order to discuss and integrate their experiences into the system. Of course the notification about dates and events happened through the Internet platform.

The general concept of the platform followed a pull-philosophy: each partner could download the information he estimated important at any time from anywhere. Through clearly arranged meta-information and statistics, the platform assisted the user in keeping track of the flow of information.

Technically the main task of the Internet platform was the comfortable and correct management of documents and work scheduling. But even more important was the benefit from a whole series of small confidence-building features like a buddy-list with the images of all the partners online. The multi-project-space structure was the technical, and confidence building the social condition for the intensive synergy between realized projects and the successful system development of Basys.

3. Conclusion

The method of comprehensive planning applied in Basys differs from other approaches by its broad comprehensive understanding and the intensive cooperation of all partners from architects, consultants to contractors. Product modelling and communication in building industries are understood as deeply interwoven. They are not optimised separately; instead they were developed continuously in a more pragmatic way and in touch with the users of the models. In this context the requirement of simplicity and broad availability of the applied technologies is beyond the requirements of automatisation and efficiency.

From a sustainable point of view there is a need for a more systematic way of proceeding in building industries. To achieve this aim in the environment of small and medium enterprises, a simple and robust communication based approach in conjunction with a pragmatic product model, which is influenceable by the users, seems to be the most efficient way.

References

DGfH, German association for timber research. (1999). Product Model Interface for Timber Structures. Brandenburg Technical University of Cottbus - Institute of Structural Analysis.

Eastman, Charles M. (1999). Building product models: computer environments supporting design and construction. CRC Press LLC.

IFC, Industry Foundation Classes (2002), http://www.iai-na.org/technical/documents.php (5 October 2002)

Müller, Christian. (1999). Der Virtuelle Projektraum. PHD thesis; faculty of architecture at the university of Karlsruhe (TH).

Rank, Ernst. (2004). Produktmodelle und ihre Bedeutung für vernetzt-kooperative Planungsprozesse. http://www.iib.bauing.tu-darmstadt.de/dfg-spp1103/de (10 February 2004)

Schwarz et al., Bernhard. (1999). Entwicklung neuer Konzepte der technischen Gebäudeausrüstung für den Holzbau. Fraunhofer IRB-Verlag, Stuttgart.

Zwölfer, Michael and Schink, Claus-Jürgen. (2002). Abschlußbericht über ein Forschungsprojekt. Final report of the project Basys.
http://www.baufo.net/seiten/index.php4?content=projekt&projekt_id=1&display=projektdetails (10 February 2004)