AN INTEGRATED SYSTEM FOR THE CO-OPERATIVE DEVELOPMENT AND MANAGEMENT OF PROJECT OBJECTIVES AND BUILDING REQUIREMENTS

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ABSTRACT: A detailed and structured capture of project objectives and requirements that considers the whole life cycle of a building, is a fundamental condition for an effective and sustainable building design. This paper describes a system for a cooperative development and management of strategic project objectives and requirements for interdisciplinary design projects in the area of AEC. This system provides a participative capture of various thematic aspects, the determination of their adequate weighting and their thematic classification. This specification of the thematic context helps to disclose the thematic interdependencies and serves as a basis for an requirement control and conflict management throughout the whole design process. An "objectives planning pilot" supports the integration and participation of stakeholders such as the building owner and future users and offers a methodical guideline for the accomplishment of the objectives development process. Furthermore a software prototype (Objectives and Requirements Manager) is presented, which has been developed as an assisting internet based tool. Demonstrations to practitioners has indicated positive feedback in support of its usefulness in practice.

Keywords – design brief, requirement management, conflict management, quality controlling

1. INTRODUCTION

The increasing demands for higher quality and comfort, lower energy costs as well as the environmental compatibility of buildings (Kohler 1998) result in a high complexity of the planning context and require a reorientation of the design process. One possible approach is the application of a holistic requirement-oriented design methodology, which takes into account an integrated cooperation of all involved disciplines and project participants.

Throughout the process of building design assessment, selection and decision processes shape each phase of the project. They filter out the best possible design solution of the multitude of possible alternatives, which should be developed further and completed. If this assessment is to be based on rational considerations, it has to be oriented according to special objectives or design requirements. A detailed and structured capture of project objectives and requirements, that considers the issues of all stakeholders and the impact on the environment throughout the whole life cycle of a building, is a fundamental condition for an effective and sustainable building design (Both and al. 2004). As described in contemporary literature (Both 2002), an insufficient capture and specification of objectives and demands of the stakeholders results in a low efficiency of the process and in an inadequate building quality. Thus it is astonishing that the objective and requirement engineering in Germany is incomplete or intuitive and only in single cases strategically and systematically practised (Kuchenmüller 1997). In contrast to the developments in Scandinavia, Great Britain (Tzortzopoulos et al. 2005) and Switzerland, in Germany less importance is attached to the phase of the design briefing. Though a German norm (DIN 18205 "Requirements Planning in Building and Construction") was finalised in accordance with the international ISO 9699 in 1996, there are no fundamental modifications in the design and planning process. A systematic process model for the development and management of requirements does not exist for the area of AEC yet (Both 2002).

2. RESEARCH METHOD

The potentials of a consistent capture and management of objectives and requirements are increasingly recognised. In the last years, several research pilot projects have been accomplished in Germany, which strived for a detailed analysis of the needs and demands of the stakeholders and the specification and compliance of project objectives (Both and Schramm 2000). It became evident, that an intensified planning effort in the early project phases results in higher quality and user acceptability as well as in a decrease in the needed resources throughout the accomplishment of the project and the whole life cycle of the product. Experiences, which have been gathered by the Institute of Industrial Building Production (ifib) in these pilot research projects, show however a major need of further methodical support of the capture, management and controlling of requirements, especially in a spatial separated project context (Both 2002).

The integration of the building owner (stakeholder), the future users or inhabitants of the building and also the architects and engineers into the process of requirement capture assumes appropriate professional competence. A great deficit concerning this matter became evident on the side of the building owner, because he is overcharged by these professional problems in most cases (Kuchenmüller 1997). Thus, a real mitigation can only be achieved if the project participants are furthermore methodically supported to capture and handle the requirements. To facilitate the application of an integrated and requirement oriented design, the development of a holistic objective system has to be supported, that enables a complete capture of all relevant aspects and allows their linking under consideration of their thematic interdependencies. These so specified partial objectives and the related requirements serve thereupon as criteria for the assessment of design solutions. Thereby, the different thematic aspects of building design can be considered adequately. An important point here is the arrangement of the responsibilities for the objective planning and controlling, which can be achieved by a linkage to the organisational structure of the project and the assignment of organisational roles.

A main part of the problems in the area of integrated product design emerges concerning the semantic, as there is no consistent notation. The different designations i.e denotation of requirements, objectives, tasks as well as qualities, attributes and their instances hinders an efficient cooperation. An essential assumption is therefore the specification of a consistent ontology and notation for the requirements and objectives management. The research approach was thus the elaboration of a consistent system for objectives, requirements and tasks, which enables the management of different objective types, aspects and granularity levels as well as their weighting.

The examination of the accomplished pilot projects served as a basis for the development of this objective system. Also the collaboration in the research project LUZIE (Both 2004) with a project partner, who operates as a building owner representative and consultant, offered the possibility to analyse existing design briefs of already completed design projects. The analysis of these design briefs and requirements specifications enabled the identification of the process of objective and requirement capture and the specification of the structure of an objective system, that is able to capture and manage all identified requirements and objectives.

Another result of the analysis of these completed projects was the awareness of a lack of methods and means for a thematic coordination and conflict management. So inappropriate handling of thematic interdependencies could be observed. Even if mutual dependencies have been detected in some cases, they have not been considered in the design process adequately. This absence of thematic coordination becomes apparent especially in the topic of life cycle consideration. Here the experiences of the pilot projects show, that the impacts of further life cycle phases are inadequately considered in the design phase. Thus, in addition assisting mechanisms for a thematic coordination and conflict management have to be developed, that allow the detection and handling of life cycle oriented interdependencies. For the warranty of a best possible performance of the specified requirements, also an assessment of the elaborated design solutions and a decision process concerning the further design procedure is essential. The aim here is the support of a requirement oriented iteration i.e. back coupling of design solutions by validation methods and tools. Recapitulating the following fields of action can be derived:

- Development and implementation of a consistent objective and requirement system
- Methods and auxiliary means for a thematic conflict management
- Concepts and tools for a requirement oriented assessment of design solutions

3. RESEARCH FINDINGS

To integrate the objective and requirement management in the holistic context of the project, the objectives system has been developed as a partial model of an integral project model (Both 2002).

3.1. The Integral Project Model

The coordination of spatially separated design processes requires an explicit cooperation method with rules and auxiliary means. At the Institute for Industrial Building Production (ifib) of the University of Karlsruhe a so called “Project Model” was developed (Both 2002), which is based on the concepts of system engineering. This model integrates the different aspects of object design and project management and enables a holistic, objective and process oriented accomplishment of a project in a team-oriented manner.

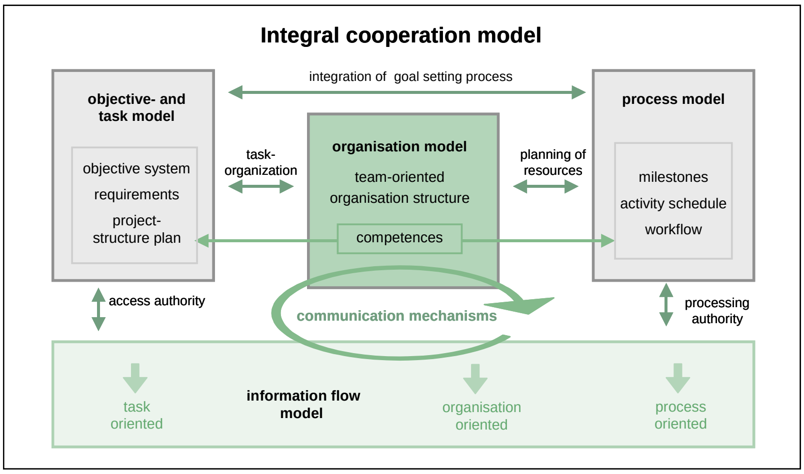

Fig. 1. The integral cooperation model

This project model, shown in figure 1, represents a kind of a building set i.e. kit, which contains the necessary elements, structures and rules for the development and coordination of the design project. In order to cope with this integrated approach, the various aspects of project coordination are worked out as partial models and are integrated in the superordinated entire model with regard to their interdependencies: The performance of the project is effected by the execution of processes (process model), which modify the information flowing among them (model of information flow). The processes are initiated to achieve special objectives and to solve specific problems (objective and task model). All of these objective-oriented processes are executed by appropriated resources and are coordinated by special organisational roles (organisation model).

3.2. The Objectives and Requirements System

At the beginning of the project, there are in most cases only abstract wishes and demands of the customer respectively building owner available. Therefore an important point of the objective planning is the deduction of these fuzzy formulated aims and needs of the stakeholder into specific and quantified requirements by the planner team (figure 2). On the contrary, there has to be a feedback of the deduced requirements with regard to the superior objectives throughout the design process.

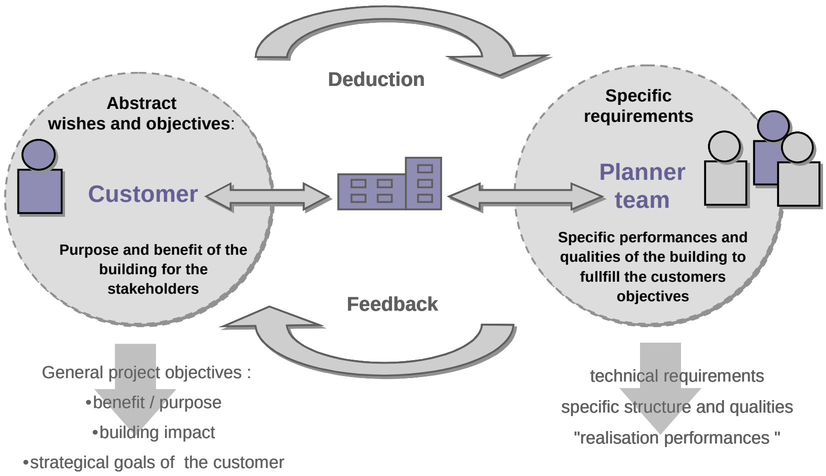

Fig. 2. Deduction of customers objectives into specific building requirements

The presented objectives system (figure 3) offers therefore several detailing levels to enable this deduction of abstract objectives in the early project phases (general strategic objectives of the customer) to tactical objectives and then to specific requirements and tasks.

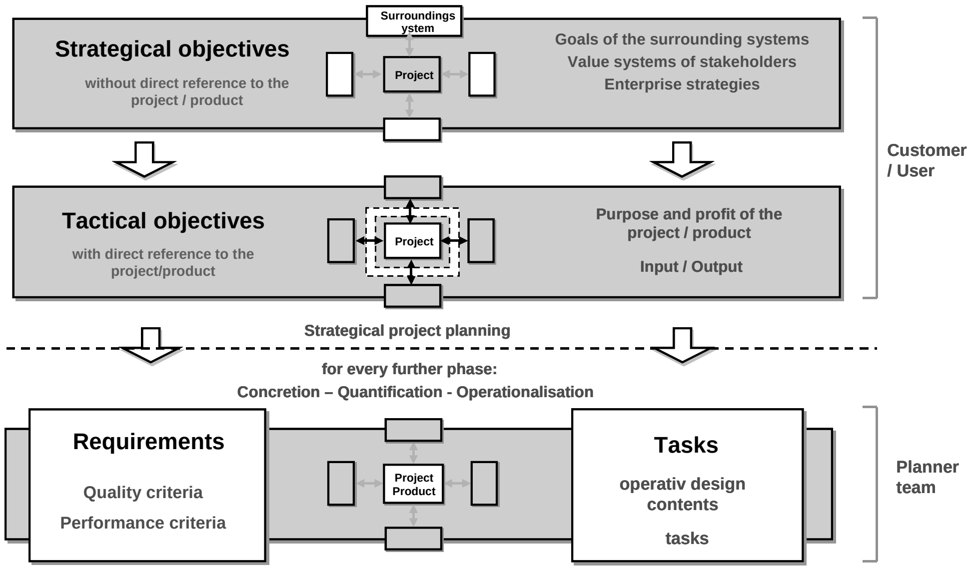

Fig. 3. Levels and elements of the objective system

The strategic objectives of the customer enable a representation of the subjective value systems of the stakeholders and surrounding systems (like environment and society). Tactical objectives describe what shall be effected or prevented by the future product. They define thus the purpose and benefit of the object respectively building without describing its specific structure or quality. So the reference object is not the product itself but objects of the superior system surrounding it. Both objective levels should be verbalised results-oriented and concretised, operationalised and quantified by the transferring into tasks and requirements along the phase oriented project planning. The deduced quantified requirements describe the specific future characteristics of the product by performance and quality criteria. They represent the actual design variables and serve in the context of quality control as criteria for the assessment of the design solutions. The tasks describe the exercises and operations to fulfill the project objectives.

3.3. Thematic Classification as a Basis for Conflict Management

It depends on the method of structuring the objective system, at which time conflicts can be detected and how many options are still open to counter the conflicts by constructive design solutions. Consistent structuring encourages holistic thinking by the disclosing of existing dependencies, guides to systematise and helps to find alternative solutions and also facilitate the identification of partial problems and thematic conflicts at an early stage.

A conflict of objectives and requirements is defined as a mutual, founded dependency between at least two objectives or requirements, in which the gradual fulfilment of one objective prevents the fulfilment of the other objective [Both04]. Therefore an objective conflict possesses three components:

- At least two objectives or requirements are concerned
- The interdependency emerges due to a joint reference object
- The conflict is caused by a specific characteristic i.e. criterion of the joint reference object

A basic assumption for the handling of objective conflicts is, as already described, the detection of existing thematic interdependencies and overlappings. To answer the question concerning, amongst which thematic aspects these interdependencies can emerge, there is - with regard to the definition of the objective conflict – at first the joint reference object to mention. Transferred to the context of building design, it means an object oriented assignment to building components and other relevant object systems. Referring to a method based design procedure, which initially starts from a functional description of the design object, not only concrete physical components have to be considered as a reference unit. Thus a transfer of abstract object functions to design principles and then to concrete building elements is facilitated. By this representation of object functions, which can be handled as a kind of "black box", conflicts concerning functional building performances can be detected in a very early stage of the project.

The second approach to detect conflicts is the classification of specific parameter i.e. attribute classes of the reference object. Thus for example a conflict concerning the parameter "construction costs" can emerge. Based on system engineering thinking, all system characteristics can be deduced from the base items energy, material and information (Daenzer and Huber 1992). By this system parameter the system states can be described as well as the system interfaces, which refer to the input and output. In this way quality criteria and also performance criteria can be specified. The static system parameters represent state classes and can be described by quality criteria. By performance criteria, functions for the transformation of these system parameters can be defined. As these input and output parameters are related to the system interfaces, like product – environment, a 2-dimensional classification system is obtained, by which beside the actual objective type the origin can also be read out. The acquisition of the system describing parameters is also an important assumption for the accomplishment of life cycle analyses and the capture of energy material and cost flows (Kohler and Lützkendorf 2002).

The named system parameters specify the characteristics of the system especially as state attributes with regard to the dimensions space and time. The item space can be described by functional topologies (networked functional areas) and by specific room structures, so for the representation of the temporal dimension an allocation to the life cycle phases of the system are necessary. This phase oriented classification of objectives and requirements facilitates a vertical integration over the whole building lifecycle.

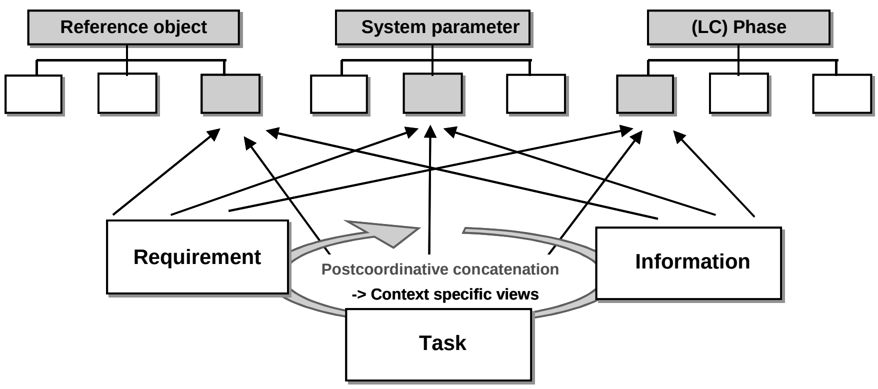

Fig. 4. Thematic classification criteria

As shown in figure 4, the explained classification criteria enable by dint of post coordinative concatenation mechanisms the generation of thematic and problem oriented views to building information, requirements and tasks out of the current project context.

3.4. Objective oriented Assessment Process

The process of decision making is shaped by the collaboration of the interacting planning partner and is accomplished in a team oriented manner. The process of assessment and decision making is partitioned into three partial steps:

1. Gathering and preparing of all decision relevant information and design solutions. A validation of the elaborated design results by validation methods and tools, which are specified in the dedicated requirements, enable a normed assessment.
2. Preparation of the assessment process: Generation of thematic views concerning the special thematic assessment context, which allow a comparison of the current solution values with the target values.
3. Decision making: Assessment of the design solution or comparison of several design variants and decisions about the further design procedure like the release of the results as a base for the next design phase.

The coordination of the assessment is enabled by the support of different decision levels, a team oriented assessment as well as a superordinated project assessment level. As shown in illustration 5, the decision and assessment processes are therefore integrated in a phase oriented process model (Both 2002). The decision processes are related – depending on the level – to the editing status respectively enable status of the team processes or phases. By the conception of this processing status, the execution of an iteration problem solving cycle can be facilitated.

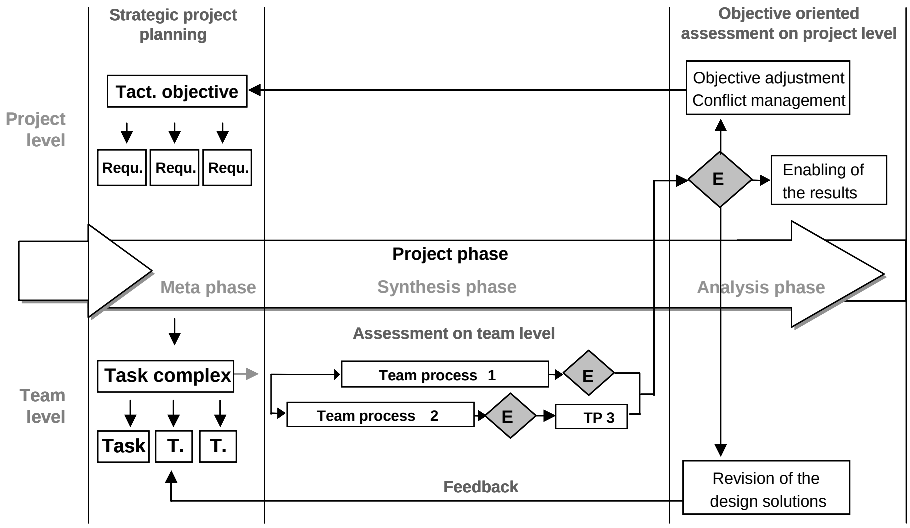

Fig. 5. Integration of the decision levels into the process model

3.5. Data Scheme of the Objective System

The ER scheme in figure 6 illustrates the partial model with the contained elements and relations. By the pictured structure the hierarchical relations of the objective levels are described: From the strategic objectives the tactical objectives and finally the requirements are derived. The task hierarchy is represented by so called operation packets, which are deduced to team oriented task complexes and finally person oriented specific tasks. A concatenation with the process model enables a temporal coordination of the operations. The relationship to the organisation model allows the definition of responsibilities by organisational roles. The single element classes have also a class internal structure, by which the thematic overlappings and conflicts can be represented.

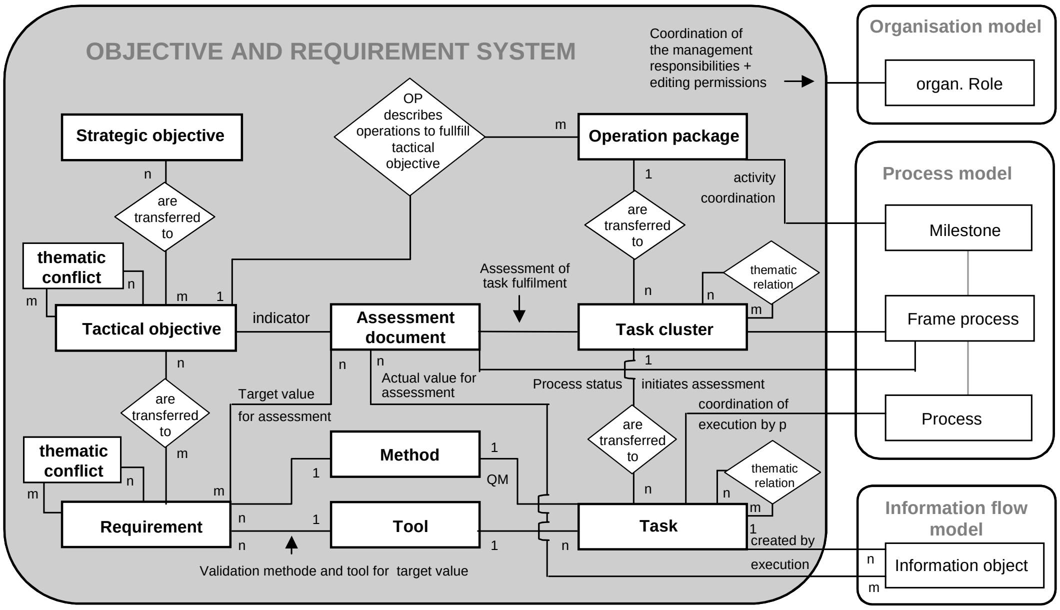

Fig. 6. ER scheme of the objective system

The scheme shows in addition the objective oriented assessment of the task solutions by assessment documents, which enable a comparison of current and target values. The information objects contain the design solutions and provide the current values, the objectives and requirements provide the target values. The allocation to validation methods and tools, for example methods for life cycle analyses, facilitate a standardised i.e. normed assessment. The task oriented provision of assisting methods and tools offers methodical and technical support for the task processing and supplies a contribution for quality management.

4. THE SOFTWARE PROTOTYPE

The software prototype has been developed as a software component of the internet based project platform *SyProM* (Both 2002) and enables a flexible global access to the tool in a cooperative project context. The implementation of the prototype is based on the groupware system Lotus Domino with client/server-system architecture. The domino technology allows flexible access to the database functionality by platform independent WWW-Browser by accordingly transferring requests over the Domino-http-server to the database application and returning the results interpreted in HTML-format. Client requests by HTML-pages, generated by Domino or by embedded graphical navigators are forwarded directly to the database application or transfer-units (notes agents).

The *Objective and Requirement Manager* supports the process of objective and requirement capture and control on the management side (management level). It also facilitates the consideration and handling of requirements during the cooperative design process (user level). The main graphical user interface (GUI) of the tool represents the named user level. As shown in figure 7, an efficient access to the project relevant objectives and requirements is provided by several thematic views, which refer to the explained thematic classification criteria. Thus these object oriented views list the requirements as target attributes of object components in the sense of a simplified product data model. A room

oriented view enables a "requirements room book". The dynamical generation of these views allows an updating of the requirements over the progression of the project.
The elements of the objective model are represented by discrete information objects (by an instantiation of the element classes) with specific attributes and meta information. Figure 8 shows the element form of a requirement.

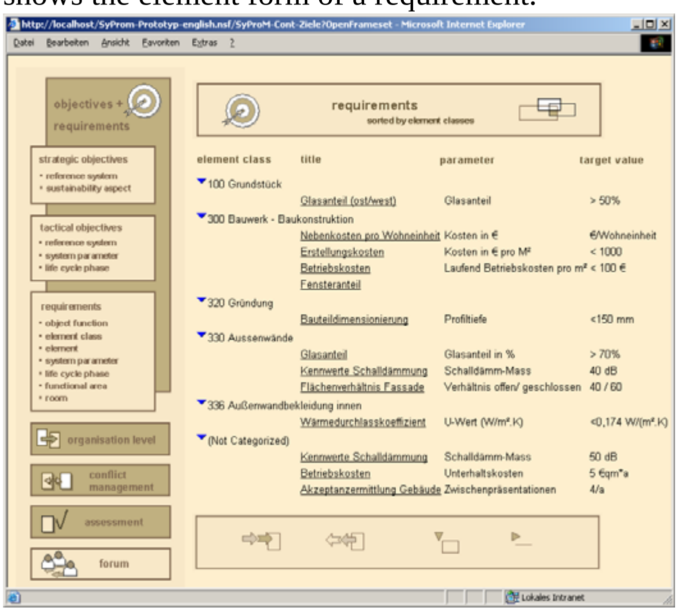

Fig. 7. GUI of the user level

Fig. 8. Form of a Requirement

The specification of the target values is effected by defining the requirement parameter and the parameter value. Thereby fixed point values, ranges with declaration of the value margin as well as optimisation values with a description of the optimisation direction can be specified. In addition validation and assessment methods and tools can be added.

By the implementation of an "objective planning pilot" a methodical process model can be represented, that guides the project members through the process of requirement and objective capture. The pilot, shown in figure 9, supports the process of requirement capture by the description of specific steps, for which adequate methodical means, checklists and guidelines are provided.

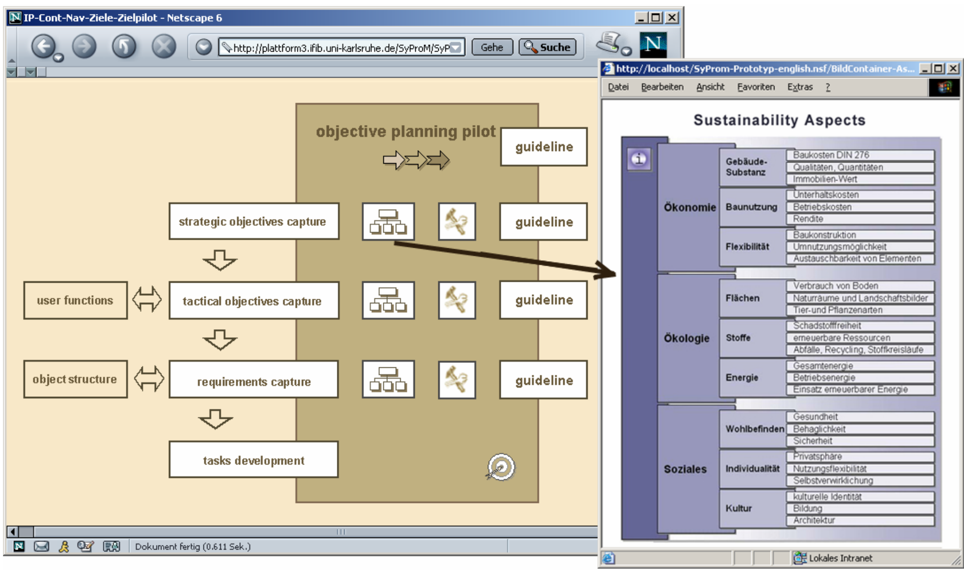

Fig. 9. Objective planning pilot with assisting checklists

For the support of the requirement oriented assessment a separate module is also offered, which provides beneath the assessment context relevant design solutions and requirements, also specific assessment documents and mechanisms for decision support (figure 10). In addition, the identification and the handling of requirement and objective conflicts is facilitated in the module for conflict management (figure 11).

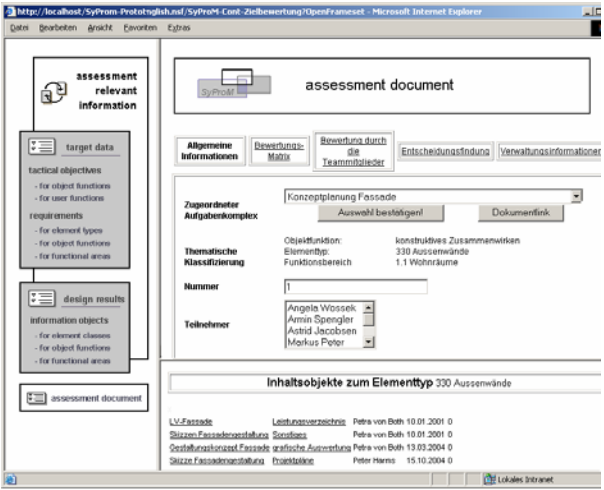

Fig. 10. GUI of the module for assessment support

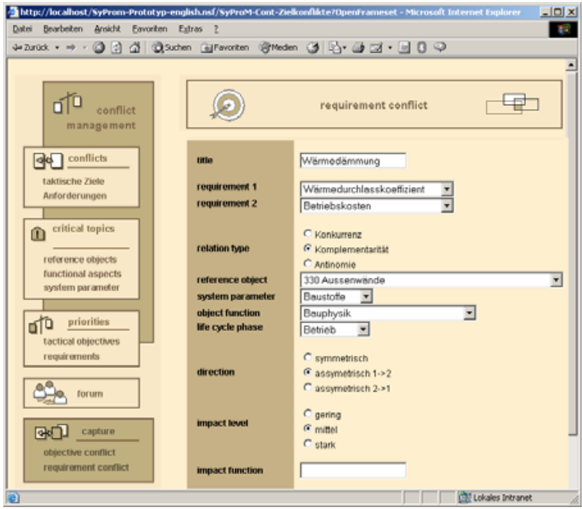

Fig. 11. GUI conflict management

5. CONCLUSION

The presented methods and assisting tools facilitate, starting from the representation of the specific value system of the stakeholders, a participative capture and cooperative management of objectives and requirements. A phase oriented detailing and concretisation enables the integration of already existing knowledge for design solutions. The specified requirement criteria constitute the basis for the phase oriented assessment of design solutions and decision making. Thus using methods and tools for quality control, the design process can be regulated in a requirement oriented manner. The systematic management of requirements and objectives enables transparency regarding the thematic interdependencies and facilitates a complete capture. In addition efficient access and distribution mechanisms for context relevant requirements and objectives can be provided.

The implementation of the methodical concept in an internet based software prototype supports a spatially distributed building design and allows the integration of all concerned groups in the process of objectives capture. Furthermore the provision of all relevant information (objectives, requirements and design results) are offered throughout the whole process always as a current and consistent version. The integration in the project platform allows the specification of responsibilities for requirement capture, management and controlling.

Positive feedback about the ability of the explained approach has already been received by the application of these concepts and auxiliary means in design practice by the germen project partner intep GmbH (Both 2004).

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