A Virtual Work Environment for AEC Project Collaboration

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ABSTRACT

Complex problem solving involving multidisciplinary participants requires a high degree of collaboration in order to reach a successful solution. Not only a high degree of transparency on the level of problem content, but also the awareness of the dynamically changing interdependencies among the participants are key factors for any strategy to integrate a project team. Over the past decades, many efforts have been made to support the design and planning process in the Architecture Engineering and Construction (*AEC*) industry with various *IT* components. However, these efforts were focusing mainly on the development of stand-alone tools, supporting single tasks. Attempts to integrate tools and project participants, through general building product models [6] [11], mainly on the level of planning content have not proven to be sufficient. Moreover, integrating project participants on a project management level in close combination with a content related design and planning environment has been addressed with very little effort. The emergence of disciplines such as facility management and its integration into long term investment strategies has currently enhanced the awareness of the potential of a design, planning and management environment oriented around a life cycle approach to buildings.

The work presented in this paper has been undertaken by the Institut für Industrielle Bauproduktion (*ifib*), University of Karlsruhe (TH) and addresses the implementation of a project specific *virtual workspace* for distributed collaborative work. A conceptual approach allows the dynamic definition of individual project structures and enables the specific application of tools, databases and other resources needed for project work [10] [13]. A prototypical web based implementation of the *virtual workspace* will be introduced. The applied approach also reflects the validation of scientific assumptions through industry partnerships and the application in realworld projects. The results from several R & D Projects undertaken will be introduced to evaluate the effectiveness of the workspace.

Keywords virtual project space, collaborative work, integrated planning, team integration, CSCW, groupware, information management

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1. INTRODUCTION

Several research projects have shown that the integral development and optimisation of buildings requires an active and appropriate support of the integrated design, planning and management process [13]. The definition of appropriate methodologies and collaboration models for such an approach has been the subject of various research efforts for many years. Based on key elements of systems theories [5] [17] and design theories [2] [20] [18], the planning philosophy of *integrated planning (IP)*[2] has been developed mainly in Germany and Switzerland since the early sixties [12] [21].

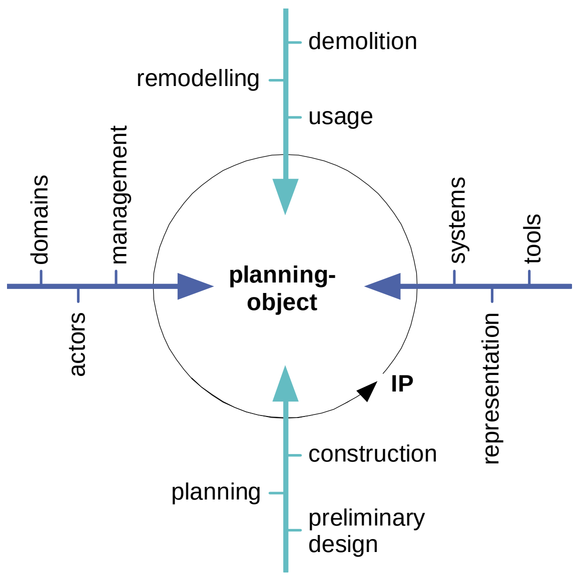

Fig. 1: Vertical vs. horizontal integration

Integrated planning pursues a life cycle oriented planning approach. The term *integrated* stands not only for the vertical integration of building phases over the building life cycle, but also the horizontal integration of the team participants through collaboration and information exchange. With a strong focus on team work and its integrating methodological elements, *IP* is also often refered to as a holisitic approach. Among other key elements, the strong focus on the dynamic development of life cycle oriented project *goals* and *objectives*, starting in the preleminary design stages, is most important.

Implementing *IP* in practise requires both, a strong conceptional commitment of the client and planning participants, and the capability to bring the approach on its way. To reach the required team awareness, a capable project moderation is needed that runs not only under financial or simple time constraints. Since the benefits of such an integrated life cycle oriented approach are not clear to many practitioners and clients, (*IP* approach typically pays

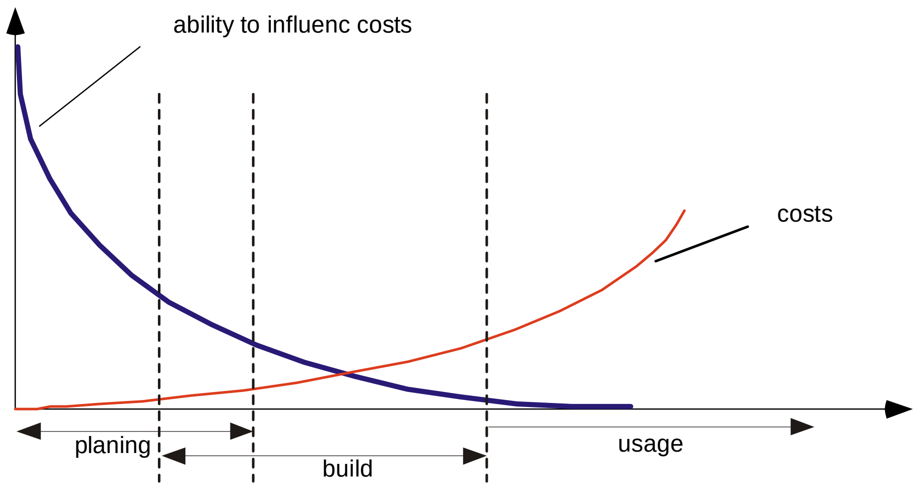

Fig. 2: Cost control vs. occurring costs

[2] Whereas in the English language the term "planning" relates to a very focused activity being part of the overall efforts undertaken by the building design team, in the German language the term comprises any activity related to the design and build phase of a building project.

off in later project phases through meeting user needs better and achieving lower operational costs etc.) it is a matter of fact, that mainly large investors and institutions having a visible gain from such an approach are starting to utilise *IP* [22]. Additionally, the utilisation of supporting team management and collaboration techniques (e.g. value management [23] [24]) needed to achieve the required team awareness and collaboration normally fails because *AEC* practitioners are not trained to do so during their education. Successfully applied collaboration structures which overlap the planning and building phases of a project can be found in the field of *concurrent engineering*, although they are focused on one part of the life cycle approach. With a focus typically on serial production, *concurrent engineering* explores a three fold integration approach on tools, methods and principles. However, this approach is aimed only to optimize the production process and therefore, issues of an initial integral definition of the project scope in terms of global goals and objectives remain unsolved.

When looking at large planning projects with their numerous domain specific demands, the need for a more holistic approach becomes evident. In accordance with this, the motivation for the work described in this paper comes from the growing demand for energetic optimisation of buildings. Since energy conscious design explicitly requires a great deal of collaborative work among project participants, representing many different domains, the need for an integrated approach is obvious. It was in response to this need that in 1996 the German ministry for education and research (*BMBF*) assigned joint research contracts to academic and industry project participants, aimed to develop new concepts for the integrated planning of solar optimised buildings (*INTESOL*)[3] [10] [13]. For the duration of three years, these participants jointly worked on interrelated project components. Beside the development of simulation tools developed through the *Institut für Kernenergetik und Energiesysteme* (*IKE*), University of Stuttgart [3], and the development of an interface model for HVAC planning through *Rudolf Otto Mayer* (*ROM*), Hamburg, conceptual work has been accomplished by *Ebert Ingenieure* (*EB*), Munich to formalise the Definition of energy related project goals and objectives. In addition, a conceptual model for computer-based collaborative planning under the constraints of an integrated planning approach has been developed by the *Institut für Industrielle Bauproduktion* (*ifib*) University Karlsruhe. Taking into account the current developments in *IT*, various prototypical implementations of groupware tools and insight gained in related R&D projects [15], the development of this conceptual model lead to the definition of a virtual work environment, supporting the integrated planning process.

Out of the underlying constraints for a work environment based in the virtual realm, the term *virtual project space* emerged, where the methodological approach of *IP* merges with the supporting technological systems. In the *virtual project space*, traditional as well as new types of documents, tools, communication facilities (e.g. email, video conferencing systems and workflow components) are integrated into a teamwork enabling environment.

2. COLLABORATION IN THE VIRTUAL

As was described in the introduction, the principles of *integrated planning* require a great deal of effort in the joint goal definition, project moderation and collaborative work on content. In addition, project participants (e.g. building users, architects, domain specific engineers etc.) have to become involved in much earlier project phases as is currently common in practice. The application of these principles in practice has been relatively slow, not only but practically due to the limited means to support it. The emergence and integration of

[3] INTEgrated planning of SOLar optimised buildings

information technologies such as digitized information processing, interconnected computer systems, local and wide area networks and the platform independent internet media (e.g. world wide web) has opened a whole new field which supports these concepts. Accordingly, it is the aim of the *virtual project space* to provide geographically dispersed project participants with a virtual work environment that supports all activities of an *IP* approach, beginning with the design brief (where the client first consults experts) and continuing over the phases of planning, construction, and building operation and refurbishment.

The *virtual project space* makes use of internet protocols as a platform independent environment that technically integrates any number of users and also aims to ease the dynamic utilization of external knowledge and expertise available on or through the world wide web. The planning structures created in the *virtual project space* are not limited to only the direct project participants (architect, engineers client etc.) but through the potential to dynamically model the project structures (based on project needs), new project participants, and information can be incorporated. In this respect, the emergence and development of the frequently cited global market can benefit the *AEC* industry if it utilizes virtual structures for project development. The following paragraph will draw a distinction between virtual structures that rely on forms of traditional project development (e.g. aimed to support and control the common project team) and virtual structures that focus on the integration of additional resources that are now economically justifiable through technological integration.

2.1 Classes of virtual structures

The current development of virtual structures in the *AEC* industry is mostly limited to enterprise internal structures. Those *intra-organizational virtual structures* typically emerge when an enterprise has reached a certain number of employees or is split into two or more geographically separate units. The focus of these structures is mainly:

- Efficient information interchange (e.g. documents, shared databases)
- Time and place independent co-ordination of actors
- Synchronous and asynchronous collaboration on content

Intra-organisational structures in this scenario reflect mostly periodically occurring processes, that are partly standardised. Therefore, the resulting work environment is tendentious static in nature. In this scenario, interface structures to communicate with other enterprises are also formalised according to internal restrictions. A well documented example of an intra-organisational structure for an architectural firm, dispersed over two locations in Germany can be found in [15].

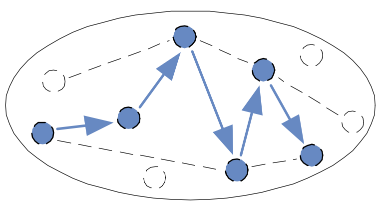

Fig. 3: Intra-organizational structures

However, building design projects are focused on a one of a kind product and that typically comprises several participants (architect, engineer, quantity surveyor consultants etc) gathered to work together for a limited time on a single product. Moreover, the number and type of participants are also changing over time, which means that many of them have to be dynamically integrated into the project team during the design and planning process, or are leaving the team in later stages, according to their specific tasks. By entering the team at any phase, they have to be introduced to all relevant information, project goals and not least, the collaborating team members. Their contribution must also be available after they have left again. This results in the need for virtual structures, enabling flexible interconnections among the participants. With respect to the previously described philosophy of *IP*, it becomes therefore obvious, that both, a successful horizontal and vertical integration strongly rely on the definition and implementation of *inter-organisational structures* (described below).

While developing the model for computer-based collaboration during the *INTESOL* project, it became obvious that the strong focus on *inter-organisational structures* with respect to the implementation of an *IP* work environment also opens up a whole new field to reduce time to marked and costs. As stated previously, the main focus of *IP* is to improve the quality of the product. However, reducing time to market and process costs ads the required selling argument to the approach. Despite any other advantage of the developed collaboration model, the selling factors have to be considered to bring the model to practice.

Therefore, developing *inter-organisational structures* requires a different approach, compared to common reengineering processes typically focused on the rigid modelling of processes and therefore not relevant to building project structures. Whereas *intra-organisational structures* can be defined and maintained according to often static enterprise structures, *inter-organisational structures*, to be tailored for an individual planning project also have to reflect

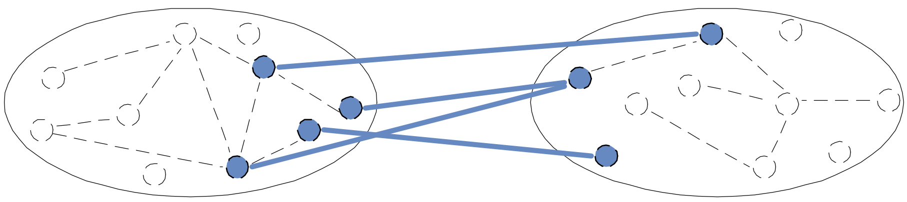

Fig. 4: Inter-organizational structures

the dynamic nature of the project under development. This implies that they can be partly formalised only within certain limits. The *virtual project space* therefore utilises an phase oriented approach, aiming a phase oriented redefinition of goals and its connection to the overall planning process. Within a particular phase, the definition of goals and objectives according to general project requirements builds the basis of tasks to be taken over by individual project participants or task specific teams. Based upon this, the required collaboration structures to accomplish those goals can be set. The collaboration structures established do reflect the individual needs of a specific task last only as long as the involved team exists. As stated previously, this approach requires permanent team management activities, underlying any structure of collaboration defined or technology-based process support provided. The *INTESOL collaboration model* therefore provides not only ways to define project specific *inter-organisational structures*, but also takes into account the vital need of group awareness and process oriented team management. The application of the results in practice [4] has shown that the allocation of a *virtual project space* and its resources does not automatically change the users habits in an expected scale. Instead, it became clear that there is a strong need for an instance adopting the role of team management and methodological support. For example, through its close collaboration with the *GIT Siegen* planning team [4], *ifib* could evaluate ways to combine the *IP* related aspects of team management with the classical project management instance. To clarify the typical differences between the currently dominating intra-organisational oriented approach to reengineer *AEC* enterprise structures and an inter-organisational approach reflecting elements of the *INTESOL collaboration model*, main elements of both rudiments have to be compared. The following table summarises advantages and disadvantages of either approach:

Table 1: Intra-organisational vs. inter-organisational structures

Aspect	**Intra-organisational**	**Inter-organisational**
Structure	*Structures within the legal and organisational boundaries of an enterprise.* *Project organisation typically static.*	*Structures overlapping the legal and organisational boundaries of several enterprises.* *Requires a dynamic project organisation.*
Goals	*Implementation of a continuous intra-organisational information flow.*	*Implementation of a continuous inter-organisational information flow.*
Benefit	*Support of optimised, hierarchical structures.* *Grouping of competence.*	*Support of problem specific collaboration structures.* *Networking of competence.*
Problems	*Has tendency to become an "island solution".* *Inflexible, little interface to external enterprises.*	*Case-based co-ordination and collaboration.* *Inefficient due to a lack of integration of intra-organisational information flows.*

In addition to the utilisation of *inter-organisational structures*, the *INTESOL collaboration model* and the resulting *virtual project space* is based on an extended view of the term, *inter-organisational structure*. Currently, *AEC* project participants are mainly part of an enterprise which is involved in a building project on the basis of a formal contract. However, virtual structures which are dynamically defined allow, in principle, the extension of the notion of project participants to so called *external resources* such as publicly available databases, software applications miming human expertise (e.g. software agents) or human experts. Although the integration of these external resources is possible in common project scenarios, it is usually way too expensive and time consuming to seamlessly integrate them due to a lack of adequate means. While the integration of structured information into the planning process (in the form of e.g. printed product catalogues and technical literature) is common practice and the same information stored in databases accessible over the internet is becoming popular, means to provide domain specific expertise on demand are not widelydeveloped.

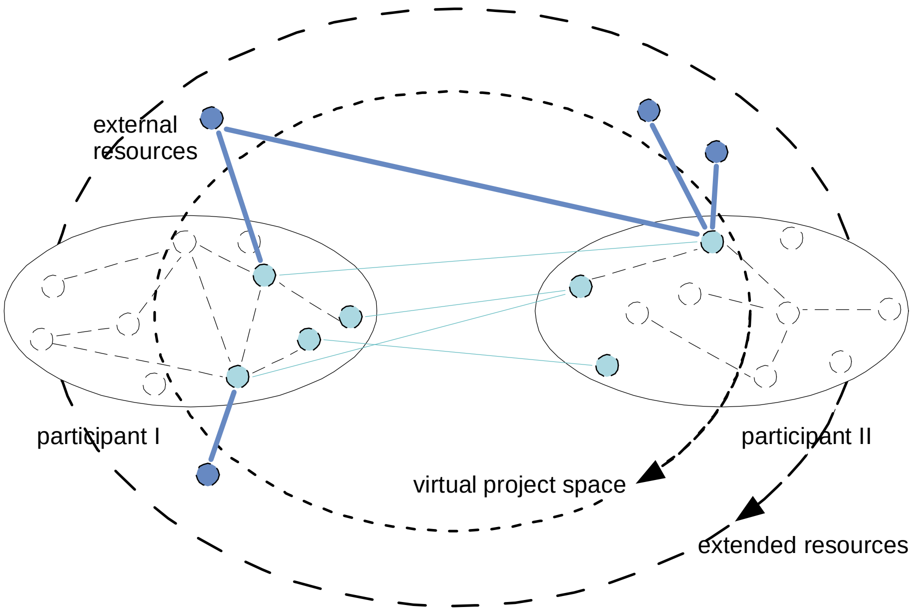

Fig. 5: Inter-organizational structures utilizing external resources

However, the technological components used to implement the *virtual project space* do allow the reconsideration of the need to integrate domain specific expertise as an decreasingly expensive available resource. For instance, in order to solve a domain specific problem, such as the development of an energetic concept of a building, architects currently have to consult technical literature (time consuming) or domain engineers contracted to the project (expensive, time consuming). Through virtual structures, the same resources can be made available in real time and at a fraction of the cost.

To utilise the advantages of this development, results from research dedicated to the seamless integration of modelled domain specific expertise into the process of project development [8] [14] and concepts to utilise human expertise on an ad hoc basis (e.g. community ware) [19] have been integrated into the development of the virtual project space concept. The next paragraph introduces the resulting methodological and technological concept of the corresponding inter-organisational collaboration structures.

2.2 The integrated planning collaboration model

While developing the model for computer based collaboration in building construction, *ifib* had a strong desire to realise the concept of an integrated planning approach to an extent not previously possible. However, since *IP* requires a teamwork oriented project management approach to be achived by the human participants, ways to structure the planning process, independent of the team composition and results, the degree of collaboration reached in each individual project had to be found. Reference projects indicate that typically a few but significant restrictions, to be defined in the preliminary design stages, do direct the project flow [22] [4]. Among those restrictions discovered, the following elements have been selected to bring a computer-based *IP* approach to fruition:

- Extensive, life cycle oriented specification of the project scope in the first project phase.
- The conscious development of a project specific organisation structure.
- Definition of goals and objectives in early project stages and through the project team.
- High level of transparency of goals specified and project content.
- Team definition according to project tasks and interdependencies vs. hierarchical structures.

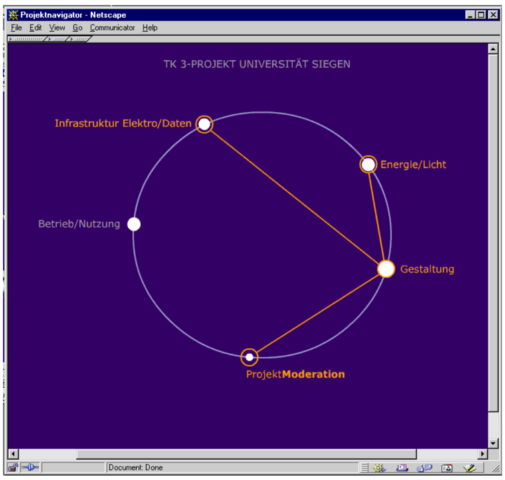

Fig. 6: Project navigator

To model and implement these requirements in the *virtual project space*, two levels of abstraction and several functional elements have been defined [7] [9] [16]. First of all, the *level of project organisation* is introduced to develop an individual project structure. Among others, the definition of several *context areas* (e.g. all project participants involved in the development of the structural system of the building) and their interdependencies (e.g. overlapping goals and objectives of different context specific teams) altogether describe the entire project on this level. Described in detail in [16], this level of abstraction is presented to the user through a graphical interface aimed at creating a higher level of project awareness. Figure 6 displays the implemented project structure where the so called project specific *context areas* and their *interdependencies* altogether convey a graphically displayed image of the project.

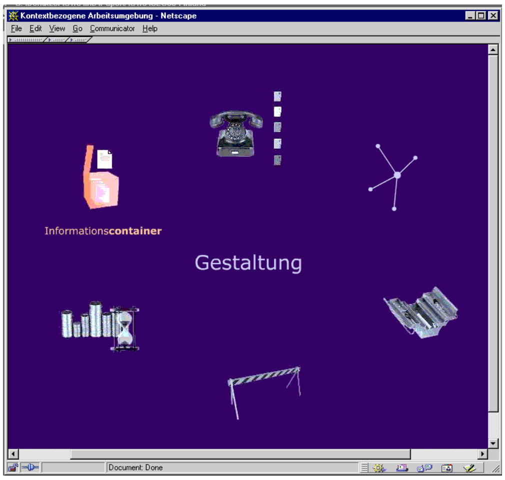

Fig. 7: Individual virtual work space

The second level of abstraction is called the *level of content* and reflects everything necessary to accomplish tasks, to define goals and objectives and to collaborate on the project content. An individual Workspace is provided for each *context area* where team members present in a specific *context area* share a *virtual desk*. This *virtual desk* comprises five elements for collaboration and work on content. Figure 7 displays a screen shot of such a context specific virtual work space featuring the *InfoContainer* (documents such as CAD, letters notes etc.*), Goals and Tasks* (context specific, and dynamically defined through the team), *TeamCommunication* (avatars of team members, personal information and e-mail functionality), *Interdependencies* (an interface to trace interdependencies towards interconnected *context areas*) and *Tools* (individually configured links to databases on the net and integrated external resources as mentioned previously).

The *INTESOL collaboration model* is designed with a strong emphasis on supporting the definition of project specific organisation structures in the virtual realm. Embedding team members on the basis of their project specific role(s) (task oriented) compared to the common practice where team members firstly represent their individual enterprise with its overall mission (structural engineering, thermal etc.) and a shared virtual work environment supporting collaboration on content has the potential to overcome the participant's differences in time, place and organisational affiliation.

3. CONCLUSIONS

In this paper, three dimensions of virtual organisation structures have been introduced and where discussed. Based on the definition of the need for an fundamental shift from common *intra-organisational structures*, underlying an inter-organisational collaboration *to inter-organisational structures* reflecting project specific requirements, the *IP* based *INTESOL collaboration model* has been drafted. With the term *virtual work space*, an instrument supporting these needs has been introduced. Besides its functional support of the communication and collaboration process, the system is document based to ensure compatibility with existing applications in practice. However, the future integration of partial product models such as *IKEs OPTIMA* input format [3] [13] is considered.

The internet based implementation of several *virtual project spaces* has been mentioned and is documented on the World Wide Web [10]. For further reading, detailed work related to the *INTESOL collaboration model* can be found in [13] and [16]. Questions addressing the dynamic integration of *external resources* in *virtual project spaces* can be found in [9].

The results discussed have been introduced to practice in several R&D projects. For brief information, the following paragraph introduces to general experiences gathered by *ifib* which are currently used as valuable input for current and future research work.

3.1 Application in Practice

Due to a successful *INTESOL* project presentation to industry and government representatives in October 1997, the *BMBF* decided to support the application of the *INTESOL* research results in practice. Within the promotion program *Solar Thermie 2000, Teilkonzept 3* it was possible to arrange the application of the *INTESOL virtual work space* in a real world project starting April 1998. Customised to the planning needs of an research and office centre situated on the campus of the University in Siegen (*GIT Siegen*), *ifib* developed a working version of the prototype that became a general work environment for all project participants involved [4].

While the technological setup of project participants and their introduction to the general functions and features of the *GIT Siegen virtual work space* was well adopted, the aim to pursue an exemplary *IP* approach during the process of project development required the continuous attendance of *ifib* representatives throughout the physical meetings of the project participants. However, due to the geographical distribution of the project team (general planner from Amsterdam, domain experts from the Netherlands and various locations in Germany), a significant efficiency gain in collaboration on project content and information interchange has been observed. Since the project will not be completed before October 2000, more publications on the outcome of the project can be expected.

Further R&D projects such as the application of the *virtual project space* for the planning and operation of several homes for older persons in Munich are currently underway and can be traced as practice projects on the *INTESOL* web pages [10].

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