Virtual Reality in Architectural Design Management

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ABSTRACT

In this paper new forms of network-based organizations are discussed in general and within the building industry in particular. Special attention is given to cross functional network teams. New emerging building design and construction functions within these network teams are explained. Network-based organizations in the building industry are considered to be virtual organizations "avant la lettre". The shift to these types of organizations in the building industry can strongly be supported by developments in information technology. A new IT-concept, the extranet is introduced and explained in the paper.

1 INTRODUCTION

Technological, socio-economic and political developments are drastically and irreversibly changing roles and responsibilities in the process of architectural design and construction. The knowledge required to realize an architectural design that satisfactorily fulfills governmental instructions and technological, functional and financial requirements, has proportionally increased over the past decades. This knowledge is distributed amongst an augmenting number of disciplines. Large and complicated buildings require at least the contribution of architects, structural engineers in concrete, steel, wood or synthetic materials, consultants in the field of building physics, foundations, water, heating, ventilation and airconditioning installation equipment (HVAC), cost engineering, finance, maintenance and exploitation management, contractors and experts in governmental regulations, building law and insurances.

The engagement of a large number of participants with interlinked activities necessary demands for adequate and continuous mutual adjustment, planning and control. Additional complications are the market pressure to realize quantum leaps in speed and efficiency and - stimulated by EC regulations - a tendency of competition and cooperation on an international scale. To manage the increased complexity and speed, additional vehicles to support an effective and efficient design, communication, and decision making process between design and building partners, suppliers, principals and other stakeholders are necessary.

The paper will explore the possibilities to enhance effectiveness and efficiency in the architectural design process. The challenge is to overcome the natural barriers between the various partners in the architectural design process. These barriers are not only
caused by the usual independency of property between the partners and their financial interest, but also the usual geographic distance between the partners, the diversity of professional background between the design team members and the temporary character of their cooperation. The mutual interdependency to achieve a satisfying overall design performance, however, is a strong incentive to cooperate. The paper will discuss some organizational and management options to successfully integrate design contributions made by design team members in the various fields of architectural design and construction. The temporary project organization to realize a large and complex architectural design may be called a virtual organization "avant la lettre". Current developments such as the interlinked application of CAD, PDF, virtual reality systems to imagine the design, long distance video conference systems and groupware based decision support systems will reinforce its virtual reality character. The paper will also discuss the value of these new systems to improve the state-of-the-art in Architectural Design Management.

2 NETWORK-BASED ORGANIZATIONS

In the past decade, rapid technological change as well as shifting patterns of international trade and competition, have put intense pressure on organizations to keep pace with a set of new and often unpredictable competitors. To cope with these strains, two apparently opposite developments emerged:

- A growing internal independency between organization units, noticeable in the formation of independent Business Units within companies and the privatization of public owned organizations;
- A growing mutual external dependency between organizations, caused by a tendency to focus on core activities.

The result of both apparently contrary processes have led towards a great variety of network-based organization forms. Network-based organizing stands for a different way of positioning the individual organization and its strategy. If an organization is seen more as a subset of its environment than as an independent unit in its environment, it becomes easier to discover that "third parties" such as suppliers, customers, public institutions and competitors, besides opposite, also have parallel interests. This implies that they may well become partners, on a more or less temporary and on a more or less intensive basis of cooperation. By combining complementary competencies of individual organizations, successful multifirm networks can be created.

According to Miles and Snow (1986; 1994), an increased use of joint ventures, subcontracting and licensing activities occurring across international borders, and new business ventures spinning off from established companies are already evident in several industries. These network-based organizations will most likely have one or more of the following characteristics:
- Division of labour based on specialization of functions. Business functions (such as product design and development, manufacturing, marketing and distribution) are performed by independent organizations within the network;
- Linkages among partners are created and often managed through a "broker-like function". Besides a coordinating role, a broker may also perform one of the specialised functions within the network;
- Value added partnerships. Financial compensations are especially based on agreements on the added value of each of the contributing partners;
- Shared information systems. Based on mutual trust, participants in the network organization share their contributions and are open to exchange information in continuously updated information systems.

3 NETWORK-BASED ORGANIZATIONS AND THE BUILDING INDUSTRY

The building industry always has had some special characteristics, which distinguishes it from other fields in the industry (Roelofs, 1994; Twijnstra and Duijs, 1980):

- Building projects are normally realised as "unique events". The specific functional requirements and restrictions necessarily ask for unique design and execution solutions;
- Every building project has its own unique production site. To realize the building project, every building site has to be temporarily organized and equipped as a production plant. A significant part of building production still is in the open air. Climatic factors such as rain and frost, are therefore influencing the production planning;
- A lot of parties have to be involved to design and execute a building project of some magnitude. The mutual relationships and interdependencies between these parties are numerous. Also a lot of authorities have to be consulted and will have to give their approval on considerable parts of the building design and execution.
- An important characteristic of the process is also, that most building projects are uniquely organised cooperations on a temporally basis. The building partners are not necessarily familiar with each other. Because of the temporally character of the cooperation between the participants in the building design and execution process, a building project can be considered as a special form of a network-based organization.

In the building industry, dozens of network-based projects can be distinguished. Differences between these network-based projects are based on the following three connected factors (SBR, 1992; Geluk, 1996):

- The contractual relationships between the various participants in the process;
- The division of tasks, responsibilities and liabilities;
- The manner and points of time participants are engaged in the process.
If considered closer, these numerous network-based projects can be reduced into three main forms: the Split-up network team, the Turnkey network team and the Cross Functional network team. These three network-based organization forms will be discussed in the following sections.

3.1 The Split-up network team

The Split-up network team (also called Traditional structure) is characterised by a clear division in time and responsibilities between design and construction. The architect (assisted by engineering consultants) is responsible for the design phase while the building contractor (assisted by subcontractors) is responsible for the construction phase of the building project. The principal’s involvement is at its highest during the initiative, briefing and concept stage in the beginning of the project, and again towards the end of the construction stage, as the principal begins to consider the occupation of the building. The architect starts to become involved at the briefing stage, helping the principal to define what is needed. Normally after approval of the scheme design and determination of the budget, the architect will also involve structural engineering consultants and HVAC consultants in the design phase.

It is only after completion and approval by the principal of the detailed building design, that the contractor will get involved in the building process. The principal will commission the construction of the building design to a main contractor (or a selected number of contractors), normally after a formal process of bidding, coordinated by the architect. During the construction phase the architect, assisted by the engineering

Figure 1: Two alternative structures of the split-up network
consultants, will control the work carried out by the contractor and his sub-contractors, and will normally represent and look after the principal’s interests. The possibilities for the principal to manage the building process in this split-up network structure, are above all dependent on the competence of the architect. A variant to overcome the potential risk of a bad managed building process therefore, is to incorporate an independent project management consultant in the team as a representative of the principal. Because of the need between architect and project management consultant to work in close cooperation, a careful selection of both is desired. They should not only be selected on the basis of their competencies and experience, but also on their ability to work together. In figure 1 two alternative structures of the split-up network team are depicted.

3.2 The Turnkey Network Team

In the Turnkey network team one coordinating party takes full responsibility for the whole design and building of the project (see figure 2). In this case the building is offered to the principal as a completely finished product. The advantage of this network structure is a closer cooperation from the beginning between designers (architect and engineering consultants) and the persons responsible to carry out the building construction. The principal’s ability to influence the building process however, can be considered to be minimal. This turnkey network concept is comparable with the “ready to wear” concept in clothing. The building will be delivered according to requirements, budget and time specifications, agreed on and fixed in advance. To overcome the disadvantage of this minimal influence, a variant on the Turnkey concept, the General contracting (also called Design & Build) concept emerged. The principal is offered during subsequent phases of execution to give his approval or to adjust the project as far as needed.

Figure 2: Example of a Turnkey Network Team
3.3 The Cross Functional Network Team

The Cross Functional network team (also called Building Team) can be considered the most advanced form of cross functional integration. All participants involved in the building process assist during the definition, design and execution phase of the project. This means that a contractor who is hold out the prospect of the construction of the whole project is involved as a building design consultant. This contractor is expected to comment in the design phase on the project’s design feasibility, the time needed to build and the building costs, all seen from the perspective of a contractor. Besides this, the contractor will also try to influence the project in such a way that the design will fit with the capabilities of his own firm. The Cross Functional team offers the project principal the best opportunity to stay involved during the whole process and to manage this process where needed. This will be particularly important in cases with very special or strict requirements, demanded by the project principal. In figure 3 a structure of the cross functional network team is represented.

![Diagram of Cross Functional Network Team]

Figure 3: Example of a Cross functional network team

4 NEW DEVELOPMENTS IN ARCHITECTURAL DESIGN MANAGEMENT

A striking development in the Dutch market for housing and utility buildings is the transition from a supply market (any new built building will certainly be sold) towards a demand market (only a building that certainly will meet a customer need is built). This development requires from designers (architects and engineering consultants) as
well as contractors a change towards an active market driven approach.

An important reason for this transition has been the gradual withdrawal of the government as a regulating authority for private housing. Urged by the subsequent need to become more market oriented, demanding principals and swelling competition have driven building parties to search for opportunities to better serve customer needs by offering improved solutions for accommodation needs. Furthermore, the tendency, noticeable nowadays to focus on core competencies, has directed towards a deliberate choice within firms to outsource or purchase non core products. Professional purchasers within enterprises are used to ask for several biddings and to compare these biddings on different criteria. Important criteria for selection of a building solution are: fitness for purpose, total costs of ownership (TCO) and time to completion. Purchasing staff members within companies but also public institutions, prefer to deal with only one single party who can be kept responsible for the whole building process and result. In other words, a party that can offer a "total building solution". To realize this, a dynamic network with characteristics as distinguished before, appears to be successful: an effective contribution of all required specialized functions, a broker-like entrepreneuring role, initiating and integrating the contributions all these specialized functions, an agreed rewarding system based on the added value of each participant in the process, and advanced information systems shared on the basis of mutual trust.

Specialized functions
As explained in the introduction, the knowledge required to realize an architectural design that satisfactorily fulfils all functional, technological, financial requirements as well as governmental instructions, has proportionally increased over the past decades. This knowledge is distributed now amongst an augmenting number of specialized functions. To coordinate and integrate the building design process effectively and efficiently, the design manager as a new and separated function, is more and more finding acceptance in the process of building design.

A broker-based role as a building process entrepreneur
As stated before, public and private principals increasingly demand for integrated product solutions instead of separated design and construction expertise. This means that the concept of "design for purpose" (traditionally the domain of the architect) and "design for constructability" (the domain of construction experts and contractors) have to be incorporated into one legal responsible body. An interesting discussion in this respect is the question which party should take the initiative and the lead in the process to develop and offer total product solutions to clients. In principle three options appear to be feasible: the architect’s firm, the contractor or a management consultancy firm. According to Roelofs (1996), the party who can bring in the most essential and integral process functions, will also play the leading role. This means that a medium sized architect’s firm will not likely fulfil such a role in case of a complex industrial building project in which substantial financial securities are required. Nor will a contractor in case of tough aesthetic and designing requirements. The building of a multistorey car park consisting of prefabricated concrete elements may well be initiated and coordinated by a concrete supplier. In case the equipment costs of a building
project form about 60% of total building costs it will make sense to have the process coordinated by a party who is knowledgeable in the field of equipment.

Value added partnerships
Financial compensations between the contributing partners are especially based on agreements on the added value of each partner. This means that traditional fees and biddings are replaced by compensations based on real work performed and its added value in the building design and execution. The coordinator is expected to settle clear financial agreements with all participants involved. A key success factor in a network-based organization is mutual trust between participants. Participants should be and stay convinced that everyone is getting paid according to their added value in the building process.

Advanced Information systems
The temporary project organization to realize a large and complex architectural design may be called a virtual organization "avant la lettre". Current developments such as interlinked application of CAD, PDI, virtual reality systems to imagine the design, long distance video conference systems and groupware based decision support systems will reinforce its virtual reality character. The success of this new way of organizing will depend to a large extent on clearly made agreements between participants about their respective functions in the building design and execution process. In the mean time however, considerable developments in the field of building information technology are required. These are discussed in the following section.

5 VIRTUAL REALITY IN NETWORK-BASED ARCHITECTURAL DESIGN

The shift to network based organizational forms in the building industry can be strongly supported by recent perspectives in building information technology. In this section three principal solutions are described for the development of advanced building information systems that facilitate cross functional building network organizations.

The three building information systems described, can be seen as stages in the development of a Virtual Reality Distributed Interactive System (VR-DIS) for the management of advanced, innovative building design processes. (For a more elaborate reasoning about VR-DIS see van Zutphen (1995). In the context of this paper the 'S' of the VR-DIS acronym is interpreted as "Systems" instead of "Simulations" like van Zutphen does).

All three systems have in common that there is a so called extranet implemented. An extranet is a project-bound intranet, accessible for all the participants of a certain project. The three stages will be introduced shortly below:
- Even in its simplest form an extranet can have a tremendous contribution to the process speed and process quality of building design projects executed by cross functional network organizations. A simple extranet is described as stage 1 in the development towards a more sophisticated design management VR-DIS platform.

- In stage 2, the information flow between the participants is optimised by means of the implementation of a building product model which unifies data exchange and the format of project data information.

- A next step is to control, by means of a moderating system, all data exchange and storage. The building information model described in stage 3 can be seen as a first idea for a design management VR-DIS platform.

5.1 Stage 1: Extranet

In its simplest form the information system consists of a project-bound intranet to which all the involved parties are connected. Common shared building information exchange, primarily consists of a geometric building data structure (electronic drawings) and other -mostly- graphical information (VR-simulations). Every party however interprets these drawings on its own way and add its own type of - geometric and non geometric data, mostly in separate, not exchangeable formats. Therefore adaptations of received data and separate data generation is necessary as input for the used, participant specific, building models. There is not a central accessible, structured data-base with building information (therefore a consistent advanced -generalised- building product model is required). In fact every participant uses and maintains his own branch-specific building model, only some geometric information is really shared. All specific building information is stored in separate files.

The intranet has a "mailbox" with actual messages and building information which is accessible for all participants of the process. The content of the building information in the mailbox is the information of previous phases of the process of which the decisions are irreversible made. This building information consists of a relative traditional collection of separate files and documents. Besides that, all participants can communicate on the network on an individual basis with each other. In general, information exchange between participants and information sent to the mailbox is controlled on a local, participant’s level.

Plenary sessions can also be held on the network with real time discussions (e.g. chat-boxes) and file distributions, possibly with the aid of computerised video conferencing facilities. This type of automation of the building process requires at least an agreed system of geometric representations and in particular, an agreed layering system of building information on drawings.

With the actual state of the art in building informatics, such a type of process automation can be relatively, easily realised. Especially the speed of information exchange (no postal delays) and the possibility for plenary sessions without spoiling
time on travelling, will increase the speed of the building process. However to the authors no precedents are yet known of a full-implementation of such an information system in the actual building practice.

5.2 Stage 2: Extranet plus

The building information described above can be improved substantially, if there is a generally accepted, consistent building product model. This product model replaces the building information, stored in a collection of separate files in the mailbox-like system described above. In this case all building information added by the participants is stored in a central, structured database and is more or less interrelated, at least with the geometric level.

Changes in the central database in this type of system, only can be made after plenary agreement. So the central database in every phase of the process, represents the state of the latest decision document. Actual changes are made in the local versions of this data-structure. In the time between the formal process phases (plenary agreement on decision documents) participants exchange building information on an individual basis.
Figure 5: The extranet plus concept

The realisation of such a system heavily relies on the developments in the field of building product modelling (especially the decomposition of a building object in entities which are valid for all parties involved, see also Prins (1992) and the field of product data interchange (PDI/EDI, Express, ISO-Step and so on, see Schenk & Wilson (1994); de Vries (1996)), and the connected agreement systems within the building industry.

The big advancement, relative to the system described before, is the far more consistent data exchange, which enhances process speed by reducing the creation and change of building information, needed as input for all separate branch specific building models. Because of the consistent data exchange, also the total volume of data can drastically be reduced by having such a building product model available.

5.3 Stage 3: Design Management by using the VR-DIS platform

In the two models described above, due to the current lack of an accepted, consistent building process model, there is no "moderator" (broker/building process coordinator/design manager) who explicitly controls the information flow between participants. The implementation of such a moderating system is the third essential step in the development of a real VR-DIS platform for the building industry.
The moderating system prevents the need for having local versions of the central building database. The moderating system determines the information which can be added to the central database as well as the amount of information that is accessible on a local level.

The control of the moderating system can be given to the design manager or the participant who has, in a certain phase of the process, the most added value. In the latest case, the control of the moderating system can be a changing role between the participants.

In order to gain the process model required for implementation of a moderating system, much more knowledge is required about design process strategies, the interdependency of design decisions and individual mandates of the process participants. This type of knowledge is studied in the field of architectural design management (Prins and Halman, 1996).

Having a moderating system implemented, the amount of formal decision phases, and connected to that the amount of plenary sessions, as well as the total volume of data exchange, can substantially be reduced.
6 CONCLUSION

Technological, socio-economic and political developments are drastically and irreversibly changing roles and responsibilities in the process of architectural design and construction. Concurrent engineering and IT-based design and communication vehicles will substantially change the building design and execution process in the near future. More and more, the building process organization will take on the characteristics of what is recently called a virtual organization. Depending on the expected added value of each participant in the building design and execution process, the contribution of each participant will vary. A number of the distinguished functions discussed in this paper, are not yet well-defined and may get a different emphasis in practice. For a new emerging field this is not at all surprising. If the emphasis is on building information technology, the coordinating role will predominantly be filled in by an IT-moderator. If the accent is on the design process, the design manager role will prevail. Similarly, a construction project manager will predominate in case of a pressure to complete the construction on time and within budget, and likewise a broker-based entrepreneuring function will be required to initiate and find a demand based integral product solution for a specific client.

It is the aim of the new school on Architectural Design Management Systems (ADMS) at the Eindhoven University of Technology to educate professionals who are capable to play a leading role in this new process of architectural design. The ADMS school strives to attract young engineers with a building-, structural or business engineering degree on an academic level. In a full time two years course, course-members are trained to design and manage architectural design processes. For a more elaborate review of this course we refer to Prins and Halman (1996).

The key word for the near future in an active demand driven building industry will be partnering. Traditional divisions of roles and tasks may disappear or lose its dominance, giving opportunities for new network-based cooperations. These network-based cooperations may even go beyond the temporally project-bound character and continue as well-balanced network-based organizations with a long-term focus. This process will facilitate and enhance innovation in the building industry.

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