Architectural design management within the digital design team

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ARCHITECTURAL DESIGN MANAGEMENT WITHIN THE DIGITAL DESIGN TEAM

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Abstract:
In this paper the possibilities for implementing modern Internet based ICT tools for the management of architectural design teams are explored. The theory of Davenport on information ecology, Schön's approach to design thinking and design team behavior, and decision process management and information technology theories are combined in a proposal for the design of project based digital design teams. It is argued that the implementation of so-called Project Web Site Technology may lead to significant improvement of architectural design team performance. The structure of Project Web Sites (PWS) within this specific context is described as well as implications for the working procedures and the management of building design teams.

Keywords: Information handling, information ecology, information behavior, design information management, data web house.

INTRODUCTION

Recent developments in the information environment of the building industry lead to the need for ICT implementations (Spekkink, D. 2001). However implementations of ICT- tools can hardly be organized project based, but are mostly implemented market driven per organization. Practice has showed it is very hard to implement those tools centrally, in a network of design firms collaborating in a building project. From the view of the multi disciplinary distributed design team, the result of the organization-based implementation of ICT tools is a very fickle and unstable information environment.

Growing design teams and information overload

Architectural design teams in the –Dutch building industry- are mostly temporary, project based, multi disciplinary, distributed teams with a client and several stakeholders in a building project environment. Often, standardized information systems and procedures are lacking. The configuration of a design team is unique as each project is. In most design processes, several design organizations with specialized knowledge are contracted by the client for the development of the design: architectural designers, specialist designers and technical advisors.

With the increasing building production and technical complexity, the number of design specialists involved rises (Loon, P.P. v. 1998). This lead to the need for the management of the design process, which in this context mainly can be interpreted as the management of information handling between the participants in the design team.
A design process can be described in terms of processing, multi disciplinary, design information concurrently through different design organizations.

Aspects within this process that give rise to the need for improvement of the information exchange flows are:

Design object aspects:
-Complexity and volume of architectural projects;
-Grow of the volume of information;
-Changes and risks to mistakes in design.
Team aspects:
-Time pressure to the design process;
- Number as well as globalization of the design partners;
-Differences in information behavior of design partners.
Information exchange aspects:
-Number and variety of digital and non-digital information systems;
-Double, incomplete or not updated information in different information systems as well as changes to information systems;
-Speed of technological progress.

In the recent past most efforts to cope with these developments were directed to setting up a prescription of a building as a collected assembly of information entities (object modeling). In the Netherlands for instance we have had BIM (with Idef technology) and COMBINE (with ISO-step technology) as the two major efforts.
BIM (SBR, 1989) was a large research project within the context of the so called Innovative Research Program for the Building Industry (IOP) led by the Dutch government, which resulted in several 100 pages of IDEF-0 descriptions of building sub-processes. Due to its high abstract level, its low level of practicability and its complexity it didn't really come to practice.
COMBINE (1990-1995) was a multi-national 70 man-year effort funded by the European Union. It has led to the first prototype of integrated building design systems, with emphasis on the back-end integration of building assessment tools. The research concentrates on establishing a data infrastructure and tools for managing the information exchange in a building design team, with emphasis on the energy HVAC consultant.
Momentarily BNA, ONRI, IGBI (all Dutch branch organizations) and market partners are developing B.A.S. (mostly based on procedures, rules and appointments).
Also attempts are done to model the information exchange process, mostly based on object modeling theory: Electronic Data Interchange (EDI) and Product Data Interchange (PDI). Successes were booked for instance in civil engineering and installation industry.
These holistic attempts to model objects as well as processes up till now weren't successful in terms of implementation in architectural design.

Architectural design processes appear to be too complex to model on the one hand while on the other hand these types of models had their own substantial complexity to implement. Having deterministic formal descriptions of objects and processes doesn't necessarily improve the architectural design process, because designers don't think and communicate primarily about strict information entities but about–architectural- concepts, functions, and performance. Also these models don't give much insight and support to improvement of the aspects of information exchange as stated, as well as to their managerial aspects.
Easy to use and easy to access information systems, with a relative low formal modeling grade, and with good opportunities for information control, might better solve the need for the enhancement of these information exchange processes.

Data Web House

A new types of ICT tools, the so-called 'digital project hosting systems or project websites', based on the use of Internet, web technology recently entered the market. These tools are strongly focused to collaborative project based information exchange rather than on formal process or object modeling and will be called in this paper "Project Web Sites" (PWS).

While object and process modeling attempts for building processes were mostly undertaken from within the building industry, the PWS tools are strongly technology pushed, and mostly originated from GroupWare package producers.

In the next parts of this paper the nature of information exchange, handling and management is discussed, then applied to architectural design processes within multi disciplinary design teams followed by an attempt to investigate the consequences of the implementation of Project Web Sites for designing and design management.

INFORMATION HANDLING PROCESSES

This chapter aims to develop a more holistic perspective on information environments within the context of -multi disciplinary- architectural design teams.

Information and communication

When considering information there are six connected terms often entangled with each other: data, information, communication, knowledge, knowledge base and document. In this paper these terms are defined as:

- *Data:* abstract, formal, sometimes symbolic entities like elementary facts, letters and -binary- numbers.
- *Information:* according to Drucker (1988), when a string of data is endowed with relevance and purpose it becomes information. When data becomes information the problem of –personal and thus subjective, meaning and interpretation arises.

- *Communication:* a process of exchange of information between sender and receiver to equalize the information on both sides. Within the exchange as constituent steps can be distinguished: -information gathering and transmission (the sender's activity); -information receiving and interpreting (the receiver's activity); -information storage and retrieval as well as information publication (activities done by sender and receiver). The proposed generated meaning can be distorted or –partly- lost during all these steps.
- *Knowledge:* specific data and information in the human mind related to intelligence, experience skills and attitude, which can be subject of manipulation in terms of navigating, combining, reflection, synthesizing or even redefining the meaning of data strings.
- *Knowledge base:* the total collection of information, which exists within a person, organization or system, is called its knowledge base. Concerning a knowledge base a distinction can be made in tacit knowledge (implicit meaning and understanding) and explicit knowledge (formal structured knowledge).
- *Document:* a string (collection) of generated data, which are physically stored in one way or another, made ready for transmission as part of a communication process. A database is a special kind of digital document were data are placed in a formal structure on such a way that they can be meaningfully retrieved and updated on a variety of ways.

Considering human communication, it is useful to distinguish the next three aspects:
1/ 'Face to face / meetings' and 'on distance' communication: -By communication 'on distance', information is exchanged primarily verbal by short messages (Shannon, 1949) or non-verbal by using documents; -Within communication 'face-to-face / meetings' verbal communication combined with non-verbal behavior as part of the transmitted data enrich it's meaning substantially.

According to philosophers like Dretske (1981) and Ayer (1934), one can communicate not only information, but also errors, opinions, ideas, experiences, wishes, orders, emotions, feelings and moods as well as strength and weakness, disease and heat.
2/ Formal and informal communication: By formal communication is meant, communication that in one way or another is structured and based on specific agreements and rules for information exchange; Informal communication is "that which remains when rules and hierarchies are eliminated as ways of coordinating activities". It has a recognized role in an organization, as it is communication that is spontaneous, interactive and rich (Dickson, K. 1996).
3/ Types of information exchange: -Not document based: verbal and non-verbal behavior in terms of direct interpersonal communication; -Document based static: graphical information (drawings, sketches, symbols & icons, diagrams & schemes, images, articles). Non-graphical information (text, numbers, formula's, matrices); -Document based dynamic: video and audio.

Definition of Information Exchange, -handling and -management

According to the definition of communication the following activities concerning information exchange can be distinguished: Generating-, transmitting-, receiving-, interpreting-, storing- and retrieving as well as publishing information.

Below these activities are further explained:

- *Generating:* for instance by means of thinking, searching and selecting (databases, books, norms and rules etc.), replicating, expert consulting (experts and expert systems), experiencing and experimenting.
- *Transmitting:* this means filtering in terms of selecting the amount of useful information to be send, transforming the information in terms of making a data structure which can be sent, distributing by selecting the receivers, actually sending the information, and eventually accreditation by giving guarantees of validity.
- *Publishing*: a special form of transmission by exposing useful information using public media.
- *Receiving:* this means actually getting the information, eventually while being able to trace it in terms of having insight in the information origins (the sender, the generator, date and time, location), by having insight in status and routing (transparency), and to confirm receiving.
- *Interpreting:* processing the information –cognitively- trying to detect it's meaning, and adapt it, and eventually redefine it in terms of further specification (level of abstraction), aggregation (adding information), changing (it's constituent data) and finally approve it.
- *Storing:* the actual saving of the information, eventually back up it and adding sourcing data, as well as maintain it, hold it accessible, updating it and finally destroy it.
- *Retrieving:* re-use previously stored information.

Information handling is defined as the compilation of all activities of a design team necessary for information exchange processes.

There are several typical information exchange processes, which can be composed out of these activities:

- *Gathering information:* this is a three-step process, which starts with the generation of information, followed by transmission and storage.

- *Linear information exchange:* this is a one way process between a sender and a receiver or a group of receivers which consists of a linear sequence based on generating, publication, receiving and interpretation. Like newspapers, magazines, and WebPages. Response from the receiver is not expected.
- *Dual information exchange:* this is a forth and back going process, which is consisting of a sequence of linear communications characterized by the fact that a receiver of information becomes a sender while responding. Response from the receiver might be expected. For instance sending letters by post or emails to one or more receivers.
- *Parallel information exchange:* this is a multiple concurrent forth and back going process, by definition between a group of senders and receivers characterized by the fact that senders are also receivers.

The organization of information handling within the borders of a project, including the strategic design, implementation and control of all different information exchange processes is called information management.

INFORMATION ENVIRONMENTS

The framework for information handling as far as discussed now isn't adequate to address the complexity of day-to-day business processes when complex multi disciplinary projects, like for instance architectural designs are discussed. An architectural design team will use a variety of information exchange tools in their desire to communicate (Donker, 1999). Communication between two persons only can take place when data which exist on a personal cognitive level in form of knowledge, is used to generate information which can be transmitted. This is the normal way of looking to information exchange. What often is neglected is the fact that knowledge not only exists on a cognitive level but also is a valid phenomenon within groups of people and even in machines. So also an organization and even the external environment in which it behaves can be characterized by their knowledge and information environment. Temporary project organizations also are developing their own project bound knowledge base while working. Also knowledge can be assigned to the project environment. Communication within an architectural design team for a multi disciplinary building project takes place between all levels mentioned above.

Architectural design processes

The information handling between designers within a design team to a certain extend is of a special character. Designers can be characterized as creative, visionary and spatial as well as abstract thinking people with a high level of technical knowledge and experience. Their key information carriers are sketches, schemes, images and drawings. In this chapter the basic questions to be answered are: how the information handling of designers can be described, and what are the special features of a design team's information environments.

Information exchange between designers

Expert explicit knowledge, as well as a huge amount of expert tacit knowledge characterizes the knowledge base of an individual architectural designer. In fact this makes that a designer is able to solve routine problems (based on his technical training) as well as is able to handle relative unfamiliar problems requiring rule-governed data gathering, diagnosis, inference, and hypothesis testing leading to some kind of problem framing.

With the aid of creative consideration a designer can even more come to problem finding. Problem finding means using reflection and intuition to consider unique, uncertain or conflicting situations (Allison, 1997; Schön, 1987). Problem finding might relate even more to tacit knowledge as to explicit knowledge. Specifically for a design process is that as a result of the process the knowledge base of the designers involved is extended. As a consequence of the nature of design processes there is a traditional reluctance by designers for almost every kind of modeling and structuring; in terms of design methods and systems as well as in terms of applying managerial activities.

As is known, verbal communication on inter-personal as well as group level has the highest percentage for chief executives and managers. A designer often is a manager as well as a worker in the concerned project in his own design organization. Concerning the design team, the same often is true for an architect. As stated before, designers inform others basically by sketches, images and drawings, most of the time, together with a verbal, explanatory story. These pictorial documents exchange may have –to a certain extend- subjective multi-meaning layered properties, ranging from the poetic cultural interpretation of the design to technical production information.

Formal communication within the design process is important to explicit choices and motivations about the design, however informal communication is important for the designers to get discussion and interaction about design proposals. Because of the nature of the design process as a process which to a great extend is depending on tacit knowledge, reflection and intuition, and given the subjective multi-meaning layered properties of drawings as the key information carriers of design information, it becomes of essential importance to create a collective coherent and consistent understanding of the projects knowledge base.

The information environment of –architectural- design organizations and multidisciplinary design teams

Because of the complexity of the knowledge structure, which exists on all these levels the 'information environment' approach of Davenport (1997), partly based on Mckinsey's well-known 7-S model, is adapted within the information framework developed in this paper. Davenport is chosen because of his holistic approach that encompasses firm's entire information environment on both a theoretical as well as case study level. Within Davenport's theory, an information environment can be characterized by the following six components; information strategy, information politics, information behavior and culture, information staff, information processes, and information architecture. However, Davenport doesn't explicit information systems. Because of the attempts for information modeling in architectural design as stated and because Mckinsey's 7S model is related to Davenport's model, the definition of Mckinsey for 'Information systems' is recognized as a separate component.

Information strategy

Information strategy mostly is a continuous, incremental process of setting and resetting organizational directions and revolving around the questions 'What do we want to do with information within this organization and how can we do this efficiently?'. Due to these characteristics, information strategy rather has a dynamic instead of a static character and has to be formulated on the business level of an organization.

Worldwide, architectural design organizations to a large extend are characterized by the small number of people employed per organization. This implies for instance that up till now strategic ICT management isn't a very well addressed issue, due to a certain lack of general business professionalism as well as to a lack of financial means (Cavanagh, P. 2000). Besides that a variety of information systems are used within these organizations, combined with not formalized information handling procedures.

Multidisciplinary –architectural- design teams mostly are based on temporary project collaborations. Within the involved design organizations, mostly, several independent projects are running concurrently. Because of the temporary nature of building projects and the different projects running concurrently, it appears to be hard, to develop project based information strategies. Besides that within the Standard Regulations of Dutch architects (so called SR'97/2000) information handling isn't addressed at all as a separate, explicit design process function.
Also it has to be remarked that design fees are so much under pressure that regularly there aren't enough financial means to address this process function within projects. As stated before, most likely all participants have -or have not- their own different information systems.

Information politics

The formal way in which an organization is hierarchically organized, and the way internal information processes are designed and managed, has to fit. This critical component involves the power information provides, and the governance responsibilities for its management and use.
While design information strategy within architectural design organizations often is poorly developed, the same can be stated for explicit information politics. For instance the role patterns of general business management, project leadership, and project execution is often diffused among the employees. So within a project for instance a drafter's work is controlled by the main engineer, the project architect, as well as the managing director, without clear defined managerial patterns. Within the context of architectural design there are very less procedures developed to store design knowledge. So except formal information, (like technical product data from suppliers), very less organizational knowledge is made explicit.

Within multidisciplinary –architectural- design teams, information politics mostly isn't explicitly present to a certain extend. On the other hand it has to be remarked that a design firm's success is strongly depending on the understanding of the implicit information politics in its surrounding.
It appears there is often role diffusion between participants. For instance identification of the role of the design leader and the position of the design management function in regard to the project management. Also the positions of the design firms involved and the architecture for the project bound information processes and systems have to be identified clearly. Because of the co-ordination task of the architect in fact no information can formally be added to a project's knowledge base without his formal approval. On the other hand the architect hasn't the formal authority and also has too less domain specific knowledge to judge the content.
As far as explicit professional information is concerned, parties involved in the team have different kinds of knowledge bases which defines to a certain extend their political position.

Information behavior and culture

This is about how people within an organization actually use and exchange information –and ultimately build a supportive information culture. It deals with information sharing, information overload and how to handle multiple meanings.

Within architectural design organizations, designers can be regarded as knowledge and information workers. Often personal and organizational knowledge to a certain extend is shielded to others in the project environment, while this is what's actually sold.

This inhibits true collaboration. So the level of information sharing is a bit corrupted by psychological factors bound to the characteristics of professional behavior in the field. Within multidisciplinary –architectural- design teams, a collective, coherent and consistent project knowledge base amongst design participants is of essential importance for an efficient design process. Specifically on the level of technical design specifications, sharing of design information as well as design changes is a very important issue for project management to avoid mistakes. The more or less psychological barrier of professional designers to share information is even more evident in case of collaborating organizations as when designers are concerned working within one organization. It might happen that the partner of today is the competitor of tomorrow.

Information staff

This component is mostly only defined within a large complex organization information management, as well as analyzing and editing functions within this context. In most organizations, information staff is only identified as technology experts who are familiar with hard- and software issues.
Within architectural design organizations, given the volume in staff, information managers hardly can be found. This is also because of the general lack of information strategies and politics. When CAD systems get popular within the field, in the larger organizations ICT managers were employed, who actually were implementing and maintaining hard and software more instead of developing information strategies. Within the multidisciplinary – architectural- design teams in building projects normally the information management function is not a separate discipline. This function usually is executed by the coordinating architect, the design manager or the project manager. Due to functional and technical complexity of the design and the project constraints the information handling within design teams is becoming more and more complex. For these reasons the need for specialized information staff is rising.

Information processes

This component determines information processes and all the work done by designers being knowledge- and information workers.
Within the field of architectural design less formal professional procedures are accepted. As far as they exist, they are linked to public law procedures or are mostly object related. Concerning the design process itself, there is the upcoming field of architectural design management. Trying to model to a certain extend the process for handling its complexity and managing architectural quality.
It is the earlier mentioned lack of information strategy as well as the nature of the design process, which implies that also on this aspect less formal procedures exist within design organizations.

This is also due to the fact of the already earlier mentioned reluctance of most designers to almost every kind of modeling in terms of design methods and systems as well as in terms of managerial activities applied to the design process.
Within the design teams there is a growing need for formalized design procedures since design projects are becoming more and more complex. This is especially of need concerning the management of changes in design information and because of the growing amount of distributed design team participants and organizations.

Information architecture

The central function of information architecture is to match information needs with information resources. Up till now there are no standard rules or methods for the design of the information architecture within architectural design organizations in the Dutch building industry, it is more or less an implicit grown structure.
It should be evident that every architectural design firm has its own information architecture based on the type of projects, their experiences and influences of the environment.
Information needs of employees in design organizations are often diffuse, in terms of the tacit knowledge needed, strongly project based, and partly something a designer has to generate himself as part of the design task. As far as this kind of information need is concerned, it seems actually impossible to make explicit, connections to organizational information resources within general information architecture. As far as the more formal information like technical product data from suppliers, standard contracts, rules, laws and so on are concerned, more and more design organizations are developing intranet based information structures.
For multidisciplinary design teams the problems mentioned concerning designing information architecture are even more valid as for design organizations. However because of the growing information overload generic as well as project specific information architecture is becoming necessary. Information architecture as far as it is made explicit and existing within design organizations seldom will have the possibility to be integrated within project knowledge bases of design teams.

Information systems

Information systems as defined in the 7S-model concern all hardware and software tools as well as procedures and protocols, used to process information. This also includes daily mail, agenda, and reception functions.
Within architectural design organizations a variety of computerized information systems is used for modeling in 3D as well as in 2D. More and more software for building specification is used also. Besides that, systems for general administrative and management activities are broadly implemented. However the connectivity and integration between all these systems and the information they generate, is normally lacking. Because of the above described more or less chaotic information environment, the component Information systems is regarded within the context of this publication.
In the multidisciplinary –architectural- design teams, collaborating design organizations use different systems as well as different working methods and code systems for –digital- design information, partly based on the possibilities of the used system and partly based on uniform codes and norms.

This causes severe problems in the exchange of design information between collaborating design organizations in a building design team, in forms of information sorting and identification problems as well as format- and IT problems caused by the use of different information systems.

Information Ecology

Information exchange takes place in a complex configuration of information environments, which according to Davenport (1997) act all together as a kind of ecological system. It can be called ecological while humans are the centre of the information world, and not machines and technology.
The term also fits while it addresses the dynamic nature of information exchange processes with all the diversity in information types and with the fact that observation and description are the main vehicles to analyze it.

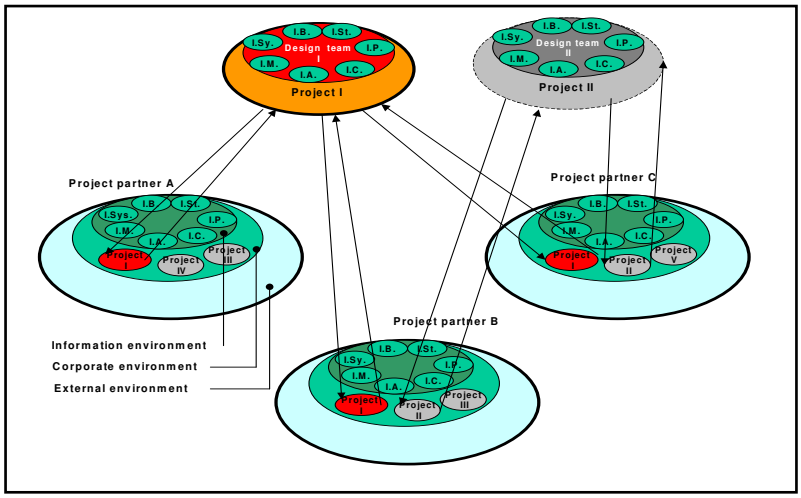

Figure 1: *Information ecology of the –Architectural- design team*

THE PROJECT WEB SITE (PWS)

In terms of information handling, a PWS applied within the information environment of a collaborating team, in principle offers digital opportunities for all types of information exchange processes as are defined in paragraph 2.2. Within the framework developed in this paper a PWS can be –a part of- the 'systems' component of the information environment of a project team.
When, instead of e-mail, which is a specific transmitting information tool, Internet is used, which is a publishing information tool, the information is stored only once, somewhere on a physical place, and can be viewed by everybody who has access to the site.
Using this communication tool, besides the speed of exchange, compared to traditional –postal- information exchange, especially considering the management of design changes, another difference appears. Updates or adaptations mostly imply storing the complete set of information again to assume that receivers are well informed and don't lose overview over the retrieved information or may get confused. In complex information environments, like in architectural design teams, information overload as well as information politics of the partners may easily cause a mess in the information exchange and is of great danger for the effectiveness and the efficiency of information handling.

Characteristics of a PWS

In fact a PWS is a protected and shielded part of the Internet with access for identified users and used by organizations as well as for a specific project. Within the borders of this definition there is no principal physical distinction between the so-called Intranets and Extranets, although there are essential differences in the usage of them. Intranets are mostly accessible only for employees belonging to one organization and Extranets are controlled accessible mostly for employees of several organizations. Furthermore, Extranets mostly are project based with a temporary character focused to information exchange and management, while Intranets mostly have a more permanent character and are more focused on information storage and retrieval.

By using the Internet the question of ownership of published information arises. To a certain extend information becomes collective the moment it is put on the Internet.

Digital keys can be acknowledged to users by a certificating organization to assure that data put in, used or transformed can be labeled to a specific user. Identification of all users of a PWS is necessary to keep overview and for tracing information sources. Most PWS's offer opportunities for identifying users by producing so called meta-data. Meta-data are facts about the processing of data within a PWS. The most important meta-data that can be produced are: information sources, time and date of putting information in and out as well as viewing of data, and user-identification. These data give important information management indications of the process that actually takes place.

Features of PWS

The basic features of the PWS are a protected Internet environment with tools for controlled user access and identification, for viewing of published information and /or with tools to download published information. More advanced PWS's also have different digital information tools integrated in the Project Web Site for further information handling ranging from e-mail, chatting and video-conferencing, to web-cams (for instance with views on the construction site).

At higher level in the PWS development are PWS's, which provide features like tools for all procedures that can be automated without user intervention (inter-active documents: Electronic Document Management). For example certified change documents (which means an automated standard procedure for all changes made in stored information), standard procedures and forms for requests for information, redlining facilities, automated generated alert messages for new information put in the PWS and so.
This development level can also provide features with automated tasks of users, like for instance standard contract forms, bidding opportunities for inviting external parties, lists with tasks to do, their dependencies and priorities, and other workflow like facilities.

The next development level of PWS's is the level with automatic generation of user inter action and information handling of the users in form of recording, assembling, sorting and classifying of the meta data of the PWS. This feature for instance provides management information concerning time spent between retrieval of a document, changing it and storing it again. A high level of collaboration and qualitative management, because of the Orwell's 'Big Brother' effects, is needed in case a PWS is implemented with opportunities on this level.

Two implementation modes of the PWS

There are two essentially different types of PWS's; the non-distributed (central)- and the distributed PWS. These differences have substantial implications on an organizational level as well as in terms of the physical design of the PWS itself.

When the PWS is used as a non - distributed tool one of the users or organizations within the collaborating team has to manage and supervise the PWS. In a group of users with a low grade of hierarchy and a high level of collaboration this is a difficult item to solve and time is needed to negotiate. The question of ownership of stored information arises and isn't easy to solve. The recording of the meta-data of the non-distributed, central PWS must have the approval of all collaborating partners. If this is disagreed by one of the collaborators this important function of the PWS is eliminated.

In a distributed PWS all users have their own PWS in which they store design information by projects. To get an overview of all published as well as downloadable digital information in one of the PWS's an overview page with links to the specific URL's has to be developed, implemented and maintained. Each collaborating partner guards, protects, controls and manages its own information with its own user rights and protection tools.
The meta-data produced by the PWS can be used for the internal organization as well as for the collaborating team but might be at all times controlled by the owner of the distributed part of the PWS.

Advantages of PWS's listed as beneficial are: -saving up to 30% of total project costs; -improvement of project delivery time by approximate 30%; -substantial reduction in avoidable errors which take account for 3-5% of total construction costs; -substantial reduction in the volume of 30% of the mistakes made in the building industry, which are due to people using outdated drawings; -reduction in time to complete an request for information (rfi) by up to 80%; -reduction in travel costs by 20-40%; -substantial reduction on FedEx charges; -administrative costs can be reduced by 10 – 15%.

Those who are experienced in daily practice however know that mostly information isn't easily stored on computers – while it's more than 'data' and that the more complex an information model is the less useful it will be (Davenport, 1997). Fixed procedures can easily become deadly instruments to kill a creative design process. With the framework developed in this paper the possible advantages of the implementation of PWS's in architectural design teams will be discussed more systematically.

Compared to the earlier attempts for process and object modeling within the building industry, the PWS developments are promising in terms of their relative low formal modeling grade. The PWS also might give opportunities to generalize process knowledge out of projects, so providing strategic generalized insight in working procedures. The amount of projects executed simultaneously at most offices traditionally inhibits the implementation of complex project based systems. The relative easy –technical- implementation of a PWS might overcome this problem.

A PWS as part of the information environment of a multidisciplinary distributed architectural design team

In this paragraph the information environment of a multidisciplinary distributed architectural design team with a PWS implemented is discussed on the level of each of the seven constituent components of an information environment.

Information strategy

Depending on the team collaboration, the willingness and trust (Handy C. 1995) as well as the ICT level of the participants, choices have to be made for a central, or a distributed PWS. The ownership of information put in the PWS as well as the viewing-, the changing- and the download- rights for all participants have to be organized formal and explicit. Participants have to agree to the use of the meta-data, produced by the PWS, for the management and improvement of the information handling processes in the project.

It is advisable to put the appointments and responsibilities of all partners in the design team in the contracts. Due to the fact that designers like to communicate by all means of communications, strategies have to be developed to stimulate designers to exchange design information digital as much as possible.

Information politics

As stated, the reluctance of most design professionals to formalize design processes as well as design information handling is mostly high. In respond to that, there must be a facilitating low profile character for a PWS offers an easy to accept way of process management, also providing some solutions to the traditional role diffusion in leadership within the design practices. As argued before, in terms of information processes, the aspect arises of tracing of information sources and information ownership.
User rights can shield specific parts of the PWS when information is confidential or secret. When the profits, which can be gained as a team evidently, are overruling personal interests, team members without conditions will be willing to share information. In all other cases to certain extend the willingness and trust (Handy C. 1995) of team members to share and integrate information in a project knowledge base is depending on credits and ownership (copyright). For this reason participants might insist on the use of ownership meta-data within the DWH.
The use of meta-data also might make specific information politics of the participants explicit. Therefore participants might refuse to deliver parts of the meta-data (for instance actual time spends on a drawing or a specific procedure) of their PWS (distributed), or even to use the meta-data recording facilities (central PWS).

Information behavior and culture

In a PWS environment it is assumed that users will have a positive attitude to the use of digital communication tools.
Weather speech, typing, drawing, sketching, imaging is used; the key factor is that all design object information will be produced digital by team members, and in fact be recorded in the PWS. This is essential for the effectiveness of the PWS and the efficiency of the information handling. A disadvantage might be that this positive attitude easily might cause an information overload within the PWS. On the contrary the possibility to view all generated information and the openness of the information might increase confidence between participants and encourage collaboration.
Although there are sometimes –psychological- barriers to share information, having a collective, coherent and consistent knowledge base within a team is one of the most essential success factors. The PWS, being the digital part of the dynamic design information environment, might constantly challenge the team-members to make their knowledge and competence explicit. With this aid, the design process might become a more continuous process instead of dividing the work into pieces. All team members are able to react, to give their vision to the solution of the problem, with their knowledge and competence, at the same time or in time. Because all information is recorded, the sequence of reactions and results is recorded also. A PWS might stimulate team members to stay active, until the problem is solved to a satisfying level. It is like being put as a team into a closed room that only is opened when the team has come to a satisfying solution that all team members have agreed to.

Information Staff

The PWS also asks for its own management. With the use of the DWH, information handling becomes a more prominent part of the management process within a project.
The need for the management of the design process and the management of information handling as an important part of it by using the PWS even becomes more evident.
Managing the PWS asks to a certain extend specialized ICT skills which might not be available in all design organizations within the building industry. It might be assumed that the need for project based information staff will be lower when distributed PWS's are used by the project team compared to the situation when a central PWS is implemented.

Information processes

By using PWS's, the information handling within design has to be distinguished and organized. An important issue is to make as much information exchange processes digital as possible. For every process, specific rights as well as duties to information handling have to be set and managed. Double and not updated information in different media often causes problems, which can be prevented by using a PWS. It is quite obvious that well organized, sorted and classified information might increase the efficiency of the design process.
Especially within design processes it is important to have a clear view on the differences of information exchange processes. For instance like that with the client and the users, within the design team with the building (sub-) contractor(s) and the suppliers of materials, with the local authorities, and with all other stakeholders.
In terms of information processes within multidisciplinary design teams the aspect arises of the tracing of information sources and information ownership.

Information architecture

The organization and design of the PWS can be central or distributed. For each configuration, specific regulations have to be set up and followed by all team members.
With information architecture in a PWS the question of information life cycle arises. Not only the use of digital information during collaboration might be important; also the final revised information after the project closure. The final information might be important for client's use afterwards but might be organized and structured different. Another aspect of using PWS's within projects is to make the knowledge stored within the DWH generic for re-use in other projects. PWS's in this sense are structures for capturing precedent-based knowledge. This type of use of the PWS requires high-level information architecture based on general object as well as process standards.
Gathering design information within intranets for re-use develops possibilities for the design team to create a knowledge base of design information by the linking of a collection of URL's and distributed DWH's.

Information systems

The PWS implemented within architectural design teams forces participants to use digital information tools for generation, storage, exchange as well as publication of design information. In that way the PWS might become one of the primary communication tools within the design process. One of the big advantages of the PWS's while using Internet technology is that information exchange can take place relative independent from all the different hard- and software used by team members.
The extensive use of document viewers within PWS's implies that real integration of design information between the team members will not take place. In this respect digital documents exchanged within a PWS just are replacing paper documents without adding data integration. The total collection of design information as stored within a PWS however adds something substantially new to the traditional design process in terms of a collective project knowledge base.

CONCLUSIONS AND RECOMMENDATIONS

Regarding the aspects for information exchange improvement as stated in par. 1.1, on one hand the technical functionality of internet based ICT tools like PWS's can be effective to solve problems concerning design object information aspects as well as speeding up the process of information exchange and storing. On the other hand team aspects and especially differences in information behavior of design partners in complex projects can easily enhance the information chaos in which the PWs can't be active anymore.
Within the digital design team, digital design information exchange, storage and publication will have a most dominant position. Due to the nature of digital information handling the collaborating design partners have to become more pro-active and inter-active in the design process. Much more design information becomes explicit then has ever been before.
This might be the introduction to a paradigm shift in design organizations while more and more design and design management will be interpreted in terms of integral, inter organizational, information handling. If this paradigm shift doesn't occur, a lot of the promises PWS's offer for the improvement of the architectural design process will not be gained: the key purpose of information is to inform people, as stated before.
Verbal as well as informal communication is important in the very early design phase to create a specific mindset within the team about the design. However in the process of decision making and documenting these, the easy to use aspects of a PWs as well as the accessibility and transparency of the stored information can be very effective to increase this process. Especially in a concurrent design & engineering project the design team has to deal with: - a) high level of information sharing; -b) a certain formal level of communication; -c) standards for information storage and exchange; -d) the ICT functionality level and –e) the variety in information systems (CAD – sketches) used by the design partners.

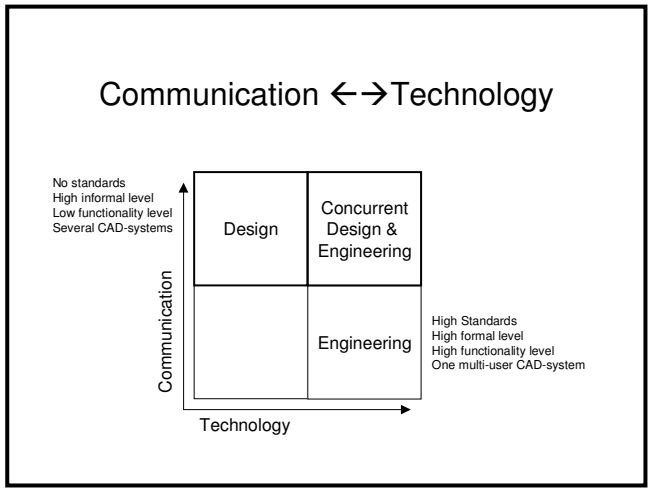

Figure 2e: *communication versus ICT technology*

Concurrent design possibilities will be made much more explicit when the design team acts pro-active and technical design information is available for the actual builders.

In fact architects will need more multi-media skills to prosecute their profession. Instead of verbal and written information, more digital information in sketches, images, schemes and documents has to be available as well as accessible for all design team members. The digital design team will be more vulnerable than before, working with digital tools in the collaborating design process, more or less depending on the tools used and being depended on the bandwidth of the network provider.

The meta-data of the design process might be used for improvement of the process and for acquiring generalized design process knowledge. So the process might start more or less in a chaotic way and improves to a structured process by using the recorded meta-data of the process.

Conclusions on the use of PWS's

In its most simple form a PWS can be seen as a registration bookkeeping tool, just recording what happened during the process. In this sense it offers a project team some of the options normal office management packages also have to offer. In a more pro-active approach the PWS can be used as a structuring and management tool with workflow management like facilities.
On the higher level of digital communication a PWS is used as a collective mind, representing the actual state of the art knowledge of the design team and stimulating continuous reflection in action (Schön, 1987). For this type of use a certain mental shift from the team's participants is needed. Design information has to be published and shared digital.
The accounting functions of PWS's offer opportunities for better management of the design process. In terms of the process blueprint the intuitive black box character of the process can be 100%, But also in terms of transparency a 100% clarity can be received by using meta-data of the tool to get an inside view to the recorded process. On the other hand one of the dangers of these systems is to organize too much on a technical and procedural level. As stated before procedures are deadly instruments to kill a creative design process. To find the most natural way to navigate through the process is essential (Kelly, 1994).

Maybe the biggest advantage of the use of PWS's might be the opportunities for acting as a collective mind for process knowledge as well as object knowledge. The accounting function of the PWS gives opportunities to gain generalized precedent-based process knowledge. As earlier process modeling attempts failed to address the everyday complexity of practice precedent based process knowledge as well as object knowledge, stored in a PWS might be more appropriate to fill this essential knowledge gab in the building industry. There might be challenging opportunities for the development of PWS's used within architectural design projects, in the incorporation of object models and process models within the systems offering better opportunities for the integration and re-use of design information.

REFERENCES

Ayer, A.J. (1946) *Language, Truth, and Logic* Dover Pubns; ISBN: 0486200108
Cavanagh, P. (2000) *Managerial development as a common platform* Architectural Design Management volume 15, Saam / CIB-W96
Davenport, T. (1997) *Information ecology* Oxford University press. Dover Pubns; ISBN: 0486240614
Donker, P.A. (1999) *Structuring communication in the architectural forum for on-line design* Delft, University Press
Dretske, F.I. (1981-99) *Knowledge and the flow of information* 2nd ed CSLI publications Stanford USA.
Dickson, K. (1996) *How informal can you be?* International journal of Technology and Management, special issue on informal information flow 11 (1-2), 129 –139.
Drucker, P.F. (1988) *The coming of the new organization* Harvard Business Review (66), 45-53.
Handy, C. (1995) *Trust and the virtual organization* Harvard Business Review (73), 40 - 49
Kelly, K.(1994) *Out of Control, the new biology of machines, social systems and the economic world* Addison-Wesley
Loon, P.P. van (1998) *Inter organizational design* Delft university press.
Schön, D. (1987) *the reflective practitioner in action*, pp. 227-231
Shannon, C.E. (1949) *The mathematical theory of communication* University of Illinois press
Spekkink, D. (2001) *Quick scan ICT in the Dutch building industry* final report to ARTB (Advising council for Technology Policy in the Dutch Building Industry)