THE NECESSARY BACKGROUND FOR IMPLEMENTING AND MANAGING BUILDING DESIGN PROCESSES USING WEB ENVIRONMENTS

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SUMMARY: *Presented here are some case study results from an enterprise management project conducted during a building design and construction process, using a web based environment for project management. It is important to note that the professionals involved had not used any project extranet before and the building design and construction process evolved using such a tool with the simultaneous management of the information flow between the owner and several contracted professionals such as structures, foundations, and facilities design professionals, construction contractors and consultants. In order to establish the process the first steps described dealt with the motivation and training of coordination and design team members. The whole process was managed using the same web collaborative project management system developed by the research group. The use of this web environment intended to facilitate the communication of the technical teams, improving the flow of information among them with the optimization of the entire project development. The management planning tasks involved the development of action and communication plans. These action plans were very helpful in defining task workflows and schedules, timing for hiring teams, team members' training, certification and responsibilities. Moreover, they were crucial to the final process of matching the several design disciplines, like architecture, structures, foundations, and facilities' designs in order to minimize interferences and improve the harmonization of the whole building design. The communication plan proved to be very important in maintaining the project teams' dynamics as a whole, and the flow of information for the entire process. A critical review of the system performance is presented here, including the benefits and shortcomings observed during the information and communication flows, in the management project carried out.*

KEYWORDS: *building design harmonization, extranet, enterprise project management.*

1. INTRODUCTION

Virtual organizations have been reported to exist before the development and consistent use of the World Wide Web (herein designated as simply the Web). Chandrasekaran and Schary (1999) observe that in the beginning, the virtual organizations were based on informal cooperation deals and alliances, focusing synergy based on a hypothetical inter-dependence. With the advent of Information Technology (IT), the concept of virtual organizations became synonymous with a business strategy differentiation in the highly competitive market of high-tech companies (Henderson & Venkatraman, 1993) following the concept defined as the “new economy” paradigm by Tapscott (2001).

Although the pattern of virtual organizations was rapidly incorporated by various industrial sectors, it was observed that the civil construction industry was still reluctant to adopt similar trends during projects. The first signs of change in the business posture of the civil construction industry were the gradual use of production methods and techniques well known in other industrial sectors, such as the concepts of lean production (Womack et al., 1990; Koskela, 1992) and simultaneous engineering (Anumba and Kamara, 1999; Ballard, 1997).

Engineering project management involves managing processes and systems. Slack et al. (2001) define a project process as a set of resources and correlated activities, and the project system as a set of components in the production chain focused on the achievement of a defined objective. Alternatively, an engineering project can also be defined as considering static and dynamic aspects. The static aspect considers the project as a final project, composed of auxiliary elements to the production of the final product. The dynamic aspect involves management and compatibility of all different partial solutions necessary to assemble the final product (Verzuh, 1999). The managing success of the dynamic aspect of an engineering project is the consistent maintenance of the information flow among all team members involved (Sekine and Arai, 1994). Slack et al. (2001) saw the importance in defining an organizational structure in order to achieve and maintain an organized and logical flow of information along the project production chain. Usually, the top of an organizational structure of an engineering project is composed of a general manager, a project coordinator, and a project harmonizing manager. The general manager is responsible for the final and strategic decisions during the project’s production. The project coordinator implements and optimizes the decisions taken by the general manager. The harmonizing manager is responsible for avoiding and solving any interference or conflict among the several sub-products generated by the independent and multidisciplinary design teams involved in the project production chain.

Koskela (2000) classifies the project activities, taking into consideration aspects such as transformation and flow. The same author introduces the concept of transformation of an idea (hypothetical and abstract aspect of a project) into a final product with high intrinsic worth, satisfying with the needs of a particular client, using a high level flow of information among all project teams involved. The objective is to reduce the waste of time and material resources, due to insufficient information.

The implementation of the methodology proposed by Koskela (2000) is only possible if a consistent system to manage the flow of information along the project production chain is developed. In order to achieve this, a web based collaborative tool such as a project extranet might be used.

This paper describes some case study results obtained during a building design and construction process, using a web based environment for project management. The process evolved using such a tool with the simultaneous management of the information flow between the owner and several contracted professionals such as structures, foundations, and facilities design professionals, construction contractors and consultants. Taking into account that the professionals involved did not have any previous experience with extranets, the necessary initial preparation and management process steps presented here, include the motivation and training phases and the construction of action and communication plans.

2. RESEARCH METHOD

To build a scenario for the paper’s proposition, a case study was evaluated, observing the development process of a construction engineering project. The research method involved direct observation of the different construction design teams and measurements of performance parameters. The data obtained from the research were analyzed, cross-checking the final results obtained with the expected performance collected during interviews with the help of questionnaire application.

3. CASE STUDY DEVELOPMENT

3.1 Characteristics of the Enterprise

3.1.1 The building

The appraisal building used was a bank. It was a three-story building catering for public services, office space for the bank's employees, and an underground parking lot. The owner of the enterprise, under the rules of location for a predefined time, was a financial institution, and the general contractor was a construction company. The chosen structural system was reinforced concrete (most commonly used in Brazil), stonewall panels made externally and internally of drywall. The finishing touches were to be more in the 'vogue' style. The facilities were designed with thermal comfort requirements, private security TV circuit, a security alarm system, fire detection sensors, integrated communication network, etc.

It is worthwhile mentioning that a modification in the preliminary design had already been made, owing to the increased number of parking lots required by the city code, due to the traffic flow in the streets surrounding the building.

3.1.2 Mandatory design specialities and documents

For case study purposes, the entire building design was divided into three phases: preliminary design studies (in which a programme of requirements was established and agreed upon); schematic design (in which a number of alternatives were examined and a final design agreed upon); and contract documentation or final design (in which the design was developed and a set of working drawings and specifications produced). As is usually the case in building construction, the specific design areas were: architectural design and its complementary systems: foundations, structures, roof, HVAC, electrical installation, communications and network, hydraulic and sewage systems, fire and security protection, internal TV circuit and video recording, and sound (see Table 1 for contracted design areas).

TABLE 1: Contracted Building Design Areas

Architectural Design (including Furniture, Visual Communication and Signs, Landscape)	Atmospheric Dischage Protection System
Foundations	Security (tv closed circuit/alarm system)
Reinforced Concrete Structure	Sound System
Steel Structure for the Roof	HVAC
Electrical Wiring and Power Supply	Hidrosanitary Systems
Telecommunication and Networking	Fire Protection System and Safety Signs

As usual for this type of building, the owner gave his guidelines during the briefing for the preliminary design (pre-design) phase and the building design, with the agreed established programme of requirements following the national standards, building codes and public regulations. All the work for each specific pre-design, schematic design and final design may have had descriptive and quantitative registers.

All the design documents produced by the specific design teams were appraised by the managing group (project manager, co-ordinators, and harmonisation supervisor), after the verification of all owner's requirements in the contract. Some of these design documents had to be approved by public works' departments and others. There was an intense collaborative effort during this activity, facilitated by the use of the extranet, which according to Nitithamyong and Skibniewski (2004) was the appropriate instrument required to achieve this goal.

3.2 Design Teams

The design teams were made up of professionals from different specialties and distinct geographic locations (5 different cities including one in Germany). There were two different companies involved and fifteen professionals as follows: one architect, nine civil engineers, one electrical engineer, one mechanical engineer, university two consultants, and one construction technician.

None of the professionals involved had any previous experience with extranets. The whole team signed a contract that stated their commitment to the research being developed, complying with the management team requests, and the mandatory use of the extranet for communications with the whole team. For example, all the initial design requirements for each specialty were to be available in a specific time for everyone, through the extranet use, and everyone had to make an effort to harmonize the whole design and its details.

3.2.1 Design team members' rights and duties

Every team member was entitled to access and operate the system (log in/ sign in). This activity was prepared by the co-ordinators, and they were responsible for putting the information at the disposal of every team member, so that they could carry out their duties.

The team members' responsibilities were defined and adapted from the owner's guidelines and requirements, to be found in the technical reference book "General Guidelines for Harmonization in CAD2D" (Sinduscon, 1995) in the preliminary design studies, and especially developed for CAD3D in the schematic design phase. The process adopted for the project was based on the practical experience of the co-ordinators, and was adapted for the collaborative environment.

3.3 Management of the Design Process/Project

Every project discipline had its guidelines defined by the team co-ordinators. These guidelines were divided into three main stages: Preliminary Study, Schematic Design, and the Basic (or Final) Design. Therefore, every specific area of design was to have a list of requirements and specifications divided into the three described phases that were characterised by the production of some products/documents (specifications and drafts).

The specific designs were made compatible by the supervisor at the end of every phase. He reported some interference and this was subsequently transmitted to the responsible professionals. When these professionals received these reports, they were able to utilise the plan of communication to solve the detected interference. These tasks were developed through the use of a checklist and solved with the help of a prototype system for 3D building design harmonization (interference analysis, consistency and compatibility verification).

The following sequence illustrates the general scheme utilised in the establishment of the design process using the extranet:

- Chosen case study: building design for banking purposes and requirements and first specifications;
- Owner: financial institution;
- Preliminary studies for the architectural design;
- Contracted building design:
  - General project manager: a civil engineer;
  - Design co-ordinators: three civil engineers;
  - Project and design harmonization: a civil engineer;
- Contract the design team: General project manager;
- Training: Design co-ordinators;
- Qualification and task attribution for the design team: Design co-ordinators.

A general diagram for the whole design process can be seen in Fig. 1 that shows the rationale for the project's process. It is important to note that the term phase was used instead of stage as the latter implies one would be completed before the other begin. In practice the activities in the phases overlapped with interactions. Every phase had distinct objectives and comprises a basic set of tasks. The input/output of each task in each phase was information and the mechanism was the extranet.

Despite of this, the process obeyed the three stages earlier established, with products well defined for each stage: preliminary design, schematic design and basic design. The model worked like a "cascade" which obtained a defined result, at the end of every stage. After approval it was possible to start a new stage in the process. These periods of waiting and supervisions/inspections besides helping to eliminate re-working, were also positive in the sense that many mistakes were avoided. After all, according to the thoughts of the 'Lean Thinking' they should have been eliminated (Womack et al., 1990).

Fig. 1 shows that more intense communication occurred between the owner and the designers at the first phase, mainly related to the architectural design. This occurred because it was necessary to make the owner's requirements available in a graphic form. The initial communication plan was written and the information and interference matrices (MII) (see section 3.6) began to be mounted. In the phases that followed, there was a more intense exchange of information among the designers. In the study case, despite of the intensive interaction and simultaneous work, the design professionals developed their design tasks in their own manner as in the traditional design processes, only making them compatible. This direction caused some re-working that could have been avoided. A continuously reviewed communication plan and MII matrices might have helped with this situation.

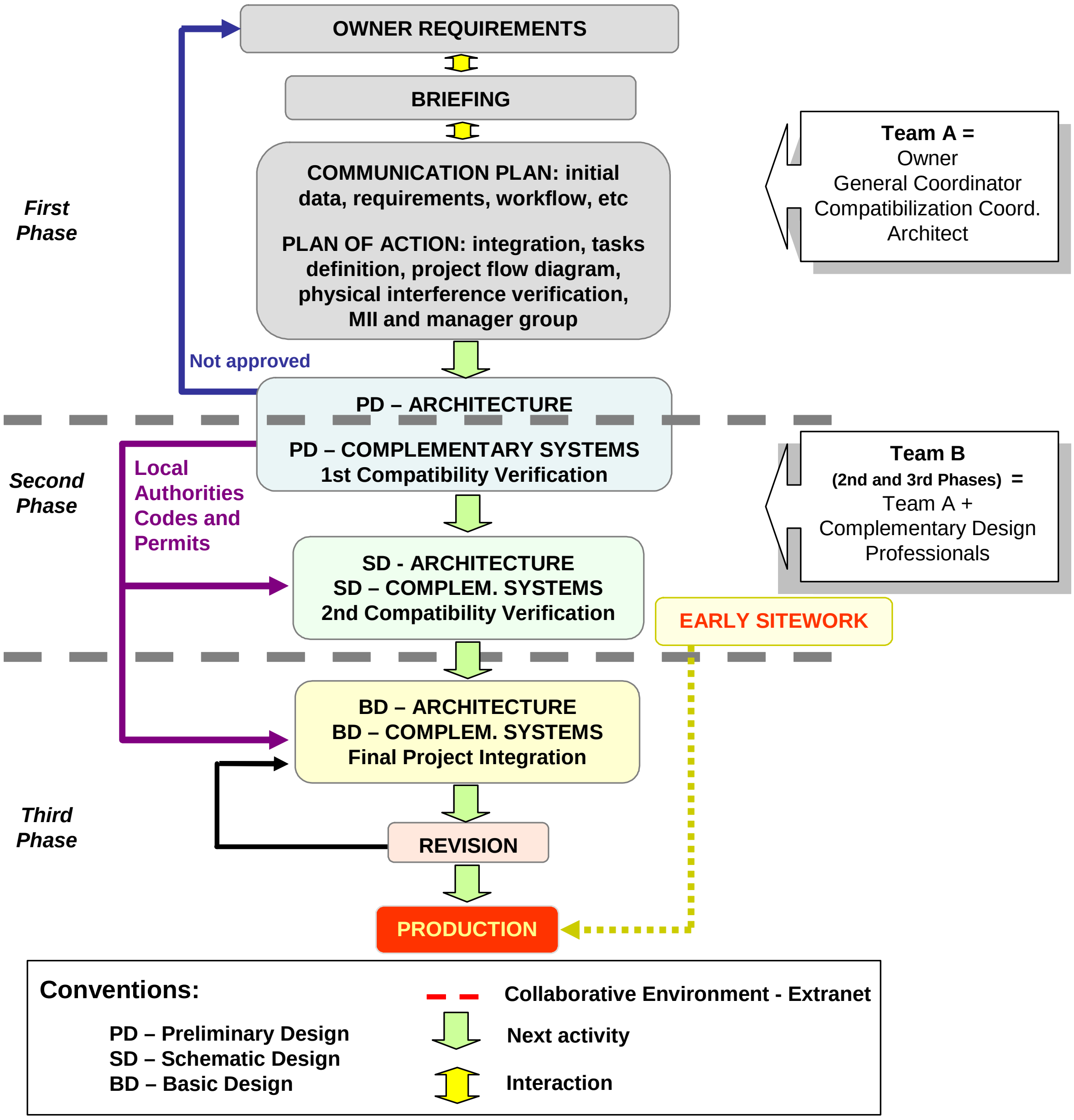

FIG. 1: General Diagram for the three-phase Design Process with Extranet

3.4 The Project Extranet

As mentioned before, an extranet was used to serve as a repository of files and the main communication system.

The extranet (*SIGEP - System for Project Management*) was developed by the Information and Communication Technology Group (*GrupoTIC* —http://www.cesec.ufpr.br/groupotic) at the Federal University of Paraná. It implements a central database environment with a three-layer paradigm for projects (my projects, my activities, and my tasks). The interface permits the users to visualize how, when, and which information will be at their disposal and is exchangeable among members; to promote communication through information transfers (any changes can be automatically communicated by electronic mail, mural and repository of files with easy versioning control).

A user's manual is available at the main menu of SIGEP with the objective to present a general vision of the functionalities of SIGEP (http://www.cesec.ufpr.br/sigep).

3.5 Action Plan

Based on the documents listed in section 3.1.2 a plan of action containing the necessary information for the development of these works was prepared. This action plan was submitted to those who were involved in the project during extranet training. Thus, it helped in the comprehension of the collaborative work process, the task scheduling, the workers' contracts, the training activities, the role of each member of the project and the definition of their duties and responsibilities, and finally, in the strategy to produce design compatibility and harmonization.

3.5.1 Training method

The training was developed in three parts, as follows:

- Part 1: The plan of action was presented with the flow of works for the project process, schedule, staff, structure of the chosen SIGEP extranet, and definition of the responsibilities.
- Part 2: At this stage, the trainees were navigated through the SIGEP system to present the interface, the structure of the activities and the responsibilities of each team member, as well as the different forms of communication and document uploading and downloading.
- Part 3: The objective of this stage was to get experience with a first activity of communication in the SIGEP extranet:
    - A file containing the definitions of responsibilities in three design phases (preliminary studies, schematic design, and final (design) project) was included in the project activity for each different specialty;
    - This file was presented to the designers and they were asked for the requirements to carry out the three phases;
    - After the team members were informed about the requirements, they revised the files using the SIGEP extranet.

3.5.2 Questionnaire

After the workers' training, two questionnaires were handed out to establish the profiles of the fifteen professionals involved, as well as their expectations about the system's usage.

The user profile revealed that in the project team, that while more than 73% of architectural or engineering design professionals had less than five years experience in the market, they had high IT skills, whilst only two of them (13%) had little knowledge about extranet usage.

3.6 Project Process Sustainability

3.6.1 Information and interference matrices

The adoption of an extranet with a central shared database for the project permitted data and information integration. Moreover the matrices of information and interference (MII) concept (Andery et al., 1998) could also be applied to help the construction's success in the design phase. Some MII matrices were developed using basic tools like spreadsheets or text editor. Using hypertext functionalities it was possible to create links from matrix cells to page documents, thus helping the operation and visualization.

These MII matrices were uploaded to the SIGEP extranet folders and updated by the project manager or harmonization supervisor. The matrices' information could be obtained from the client requirement briefing, stakeholders' virtual communication area (available on the extranet), and physical interference report among the different design disciplines. Some samples of the MII matrices are illustrated in Tables 2 and 3.

TABLE 2: Information Matrix Sample

Destiny	*Origin*			
Design discipline	Architecture	Structures	Facilities/ Complementary syst.	Others
Architecture	X	Structural system solution to guide the architectural preliminary studies	Fire department regulations and available room space	...
Structures	Building usage plan for load evaluation	X	Water reservoir and structural loading	...
Facilities/ Compl.Syst.	Hydraulic pipe dimensions and bathroom	Which beams must/can have piping perforations?	X	...

Ref: adapted from Andery et al. (1998)

As can be seen in Table 2, the Information Matrix sample is in a structured and concentrated form to show all the necessary information for each specific design development.

TABLE 3: Interference Matrix Sample

Destiny	*Origin*			
Design discipline	Architecture	Structures	Facilities/ Complementary syst.	Others
Architecture	X	Column and window interference	Pipe and window interference	...
Structures	X	X	Holes in structural elements	...
Facilities/ Compl.Syst.	X	X	X	...

Ref: adapted from Andery et al. (1998)

The main objective of the interference matrix presented in Table 3 was to detect and organize physical interference that could produce re-working and higher costs for the building enterprise.

3.6.2 Plan of Communication

Gasnier (2001) recommends the preparation of a communication plan that defines the interested members (receivers), content (requirements), communication tools, format, frequency, and transmitters. Soibelman and Caldas (2000) considered the extranets to have growth potential in the communication and the exchange of inter-organisational information. This communication and collaborative resource helped to maintain the goals and objectives of the project.

The MII matrices were used to obtain a communication plan as seen in Table 3 (section 3.6.1). The design product (document/drafting), producer (*Transmitter*), and where the information is applied (*Receiver*) is shown in this type of plan.

For the communication development plan, the first activity of communication was carried out during the design team's training. Having obtained the requirements for every design phase, a plan was prepared, as shown in Table 4 below.

TABLE 4: Sample of the Communication Plan

Transmiter	*Receiver*	*Requirement*	*Mechanism*	*Frequency*
Structural Engineer	Project Manager	survey	extranet	according to schedule
Structural Engineer	Coordinator	preliminary design	extranet	according to schedule

In addition, in the actual plan, the archive formats were also mentioned, e.g. *.doc, *.xls, *.dxf, *.pdf, etc.

3.6.3 The Process Managers

For this case study, some activities were developed to monitor and motivate the exchange of information and communication through the extranet. Therefore, the following roles were established to manage the different design teams and staff: general project manager, project co-ordinators, and a supervisor for the project. As explained earlier, Ferreira (2001) and Picoral (2002) defines the first role as a professional that takes the strategic decisions at the highest level of the hierarchical pyramid; the second role makes the operational decisions; and the last one ensures that the interference and harmonization (compatibility) analysis has been carried out among the different project designs.

3.6.4 Risk Management

Verzuh (1999) defines risk management as the project management's main activity, and describes the following stages for it: risk identification, selection of possible alternative solutions, and the development of a monitoring mechanism. As a solution to an incident, a strategy of continuously monitoring the flow of information was adopted.

The managers of the process identified as the main risks, the use of innovative technology and the perceived increase of information flow and of the activities' rhythm over time. This activity rhythm, at certain stages, acts as an indicator for possible emergencies. Due to this kind of foreknowledge, a contract clause could be included, taking into account the design integration aspects inherent in the project process, the execution mode and the work's presentation.

4. RESULTS AND ANALYSIS

The results obtained are summarised in Table 5. They are obtained through direct observation, interviews a questionnaire application. Every aspect or functionality of the SIGEP system (extranet) is analysed critically according to its performance and the expectations of the agents involved.

4.1 Project member expectations

All the extranet users indicated the importance of the system's usage, for themselves and for their companies.

In regard to the anticipated success of the system, most of the answers did not expect a guaranteed success of the system's usage. Besides the ease of use provided by the use of technological and the allocation of financial resources provided for the initial experiment and the user's enthusiasm, there was some doubt about the availability and understanding of each project team member.

The questionnaire (section 3.5.2) answers about system's usage showed moderate optimism about the expected goals. The questionnaire contained questions about technical and business goals, user requirements, and the time needed for implementation.

The changes brought about by the system's usage were considered favorably in most of the answers given. Finally, in accepting the changes by each design department the answers given indicated a relaxed and friendly organizational atmosphere.

TABLE 5: Web Project Management Functionality Evaluation

Item	*Aspect*	*Performance Evaluation*
1	Competence of the team	To break the barriers and resistance as well as the use of the extranet and integrate the team members.
2	Project Process	The general flow diagram helped the design team in the comprehension of the process and the manner of interaction.
3	Plan of Communication	Made communication and flow of information feasible among the design team; made the provisions available and verified the information transfer and the dynamics of the process; an on-line system via chat or video-conference may be useful. Notification by e-mail appeared to be the most usual and useful.
4	Collaborative environment and mechanisms for general control of revision changes	It was used the extranet repository for storage all the communication files. It was verified a good evolution of the extranet (SIGEP), in the following: better server performance (new hardware provided); access and profile control; flow of information and signals; time for loading and downloading; and, in the management of the versions/revisions (rules for documents)
5	Process Management	The managers helped to elaborate an integrated project, following the requirements and demands of all design disciplines and team. The project integration allowed fast decision making and communication available to all members. Transparency and comprehensive responsibilities distribution.
6	Risk Management	In the identification of risks, development of solutions and monitoring of the process (risks and responses).

5. FINAL CONSIDERATIONS

The establishment of an action plan created a consistent framework for the project's process. In this framework all the process activities of the each specific design through the web were identified, analysed and planned in relation to the technological platform and collaborative environment.

The competence of the stakeholders was very beneficial and motivating. Therefore, it helped in the suppression of fears and imagined prejudices that arose from innovation and change. At the same time, it permitted the gathering of profitable suggestions. A significant instruction methodology was adopted, contributing concrete experience to the collaborative work and extranet concepts.

The previous increase in all activities related to the project and the planning, making it feasible in a virtual environment, was extremely useful in the visualisation of problems, which constituted part of the barriers that had not allowed an efficacious plan in earlier experiments. This helped to realize the solution and detach, in a clear and distinct manner, the processing failures originating in the technological infrastructure or by its operation in a collaborative environment.

The general sequence for the establishment of the design process allied to Fig. 1 made the comprehension and contribution of the specific agents' responsibilities, concrete. The early determination of the responsibilities, duties ('workflow') and the guidelines with information and approvals at every stage, established a friendly climate of openness and confidence among all the professionals involved. The communication plan demonstrated the process' transparency e and protected the managers from surprises and "sudden losses".

During the research described, the need for a proper project process applicable to an Information and Communication Technology (ICT) tool – collaborative project environment/extranet – was noted. Thus, the search continues for the adaptation of the collaborative environmental dynamics for the agents and their professional routines and vice-versa.

In the case study, the collaborative work supported by an extranet resulted in a more effective communication. All necessary information for the interdependent project processes was available through the extranet (message log and file repository). It was mandatory that all participants were involved in the collaboration through the web environment.

The introduction of Internet-based technologies (such as extranets) and other CAD tools has begun to make inroads into the construction industry's practice (Abduh and Skibniewski, 2004). The knowledge managers have to revise their design practices, primarily to gain new knowledge and skills (Husin and Rafi, 2003). There have also been calls for architects and engineers to revise their strategic mission, skills, technology and knowledge continuously, in order to remain competitive in the industry.

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