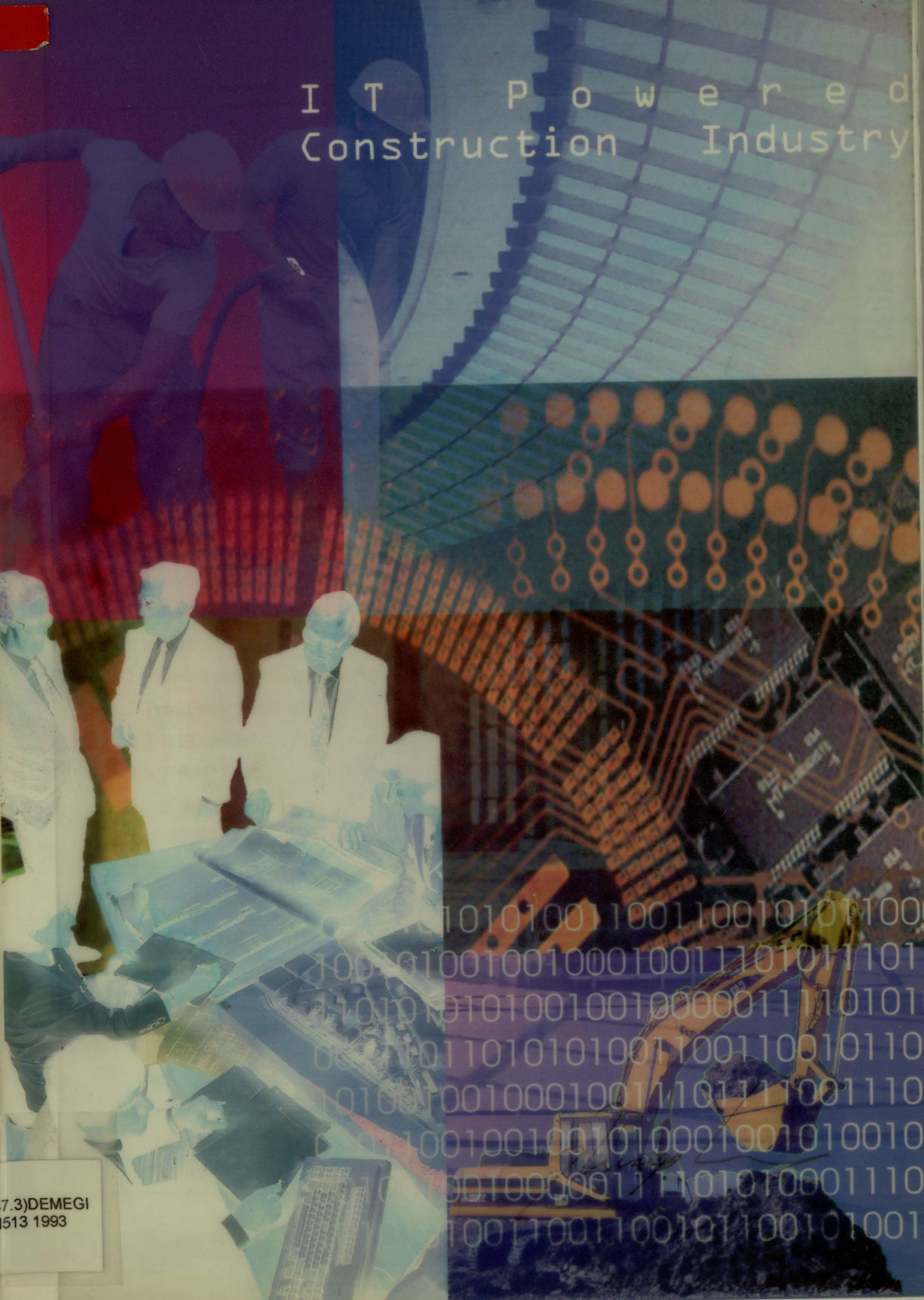
IT Powered Construction Industry



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Executive summary

The problem behind this study translates a real need of the Construction Industry: How should a Construction Company deal with the huge amount of information generated by its projects?

Although it seems to have a direct approach, the solution does not appear as isolated as one could think. The dimension, dispersion, differentiation and dynamic of the Construction Industry (CI) make it a special and complex case in managing information in industrial enterprises.

The company which co-ordinates the project must manage a diverse and extensive network of participants. The efficient management of these information flows is on the basis of its survival. Such efficiency can be recognised as the capacity to manage teamwork between participants, building corporate knowledge from individual knowledge.

The CI as tried to solve its problems separately, leaving no room for an integrated solution. This way, each of the activities has developed its own solution apart from every other, causing strong incompatibilities of the traded information. Using a common base to exchange this information would definitely boost the Company's global performance.

The traditional technologies of information flow management do not meet all the specifications of this Industry. However, GroupWare has revealed itself truly efficient as an information management concept, allowing immediate results.

1. Introduction

This report is the written output of a project carried out at the Technische Universiteit Eindhoven, in co-operation with INFOCUS - Management Consultants B.V., under the SOCRATES/ERASMUS framework for Student Exchange, lasting for a period of twenty weeks.

The aim of the project was to investigate the functional demands of a Project Information Management Tool in the Construction Industry and to what extent were these already covered by generic applications.

It derived from a real problem of the Industry, as it felt the need for an integrated solution which could deal with all the information generated by its projects. Integration is the key factor, as individual solutions are already developed for individual clusters.

The scope of this analysis will be the Information System which is able to blanket the whole network of participants that constitute a construction project.

1.1 Methodology

1.1.1 Phase 0 - Setting up a background

During this phase, the focus was set on the recollection and subsequent analysis of relevant literature, building a knowledge base to support further considerations.

Production control in construction [Melles and Wamelink - 1993] was the stepping stone for this phase.

Much of the work presented in this report are original ideas, the result of combining the author's knowledge of the Industry, his education in Industrial Engineering and Management and personal interest in Information Technologies.

In fact, several dozens of articles and publications were analysed. However, they were only used to substantiate a 'freelance' interpretation of the system. The relative importance of an individual piece of literature is dimmed when compared to the melting pot of ideas, opinions, subjects, theories, more literature, practice, experience, and so on, that contributed to the end result.

This fact is further aggravated when the source of information has a dynamic nature. Most of the articles were collected on the Internet, where information is so volatile that it becomes unreal to expect to trace back any text older than a few months.

All these facts considered, it was the author's choice not to exhaustively include references to the literature used in the investigation.

1.1.2 Phase 1 – Investigation of needs

The objective of this phase was to determine the specific requirements concerning Information Flow Management within Construction Companies.

This is to say, it had to be understood how the CI backstage worked.

After having built the basis for interpreting and modelling the CI's framework in Phase 0, a more pragmatic approach was required.

To accomplish this, visits to some companies in the Construction business were made. Contacts with several people involved in this activity, followed.

It was intended to evaluate the current state of development of the IS in these companies, and the degree of automation allowed by the information flow process.

These interviews were made to Project Managers, Quality Managers and IS Managers, aiming to investigate their problems, needs and expectations.

By using simple question sheets – handed out in advance – interviews were carried out at the Companies' locations. Among other objectives, this aimed to evaluate and compare the resources allocated to the Information Systems division.

The dimension of the visited companies ranged from among the top ten in the sector's sales ranking – VERMEER BOUW – top twenty-five – STRUKTON – and top one hundred – ERA BOUW.

The information gathered was complemented with the experience of INFOCUS as a consulting company in that business. Personal background in Construction also contributed to the rapid assimilation regarding the *modus operandi* of the Industry.

The result of this phase was a specification list the elected software would have to address.

1.1.3 Phase 2 - Investigation of software packages

This was a research-intensive phase. Contacts were established with software developers and other researchers in this field of investigation, gathering information about the features, specifications and compatibility among applications. Experience in the area of the CI was also sought after.

Taking advantage of the geographic location of the University of Eindhoven, a visit was paid to the CEBit exhibit in Hanover – one of the most prestigious trade fairs in the IT business. Here, the author had the opportunity to establish important contacts and browse through the infinity of solutions presented. Because the fair took place in April, the project was still in an early phase, so it was possible to welcome new approaches to the CI challenge, other than the suggested by the supervisor.

In the scope of the research were the Project Management applications, Workflow Management Tools, *SAP R/3*, Electronic Data Exchange (EDI) and Management (EDM) and Group Work assisting tools.

1.1.4 Phase 3 - Comparison

Using the specification of the System ,defined in the Phase 1, it was observed to what extent each of the existing software packages could meet the needs of the CI, determining the applicability, in this context, of such tools.

In this phase, it was concluded which approach is more suitable to cope with the identified problems in the CI.

1.1.5 Phase 4 - Comparison between alternative solutions

After having identified the group of tools that are of interest to this subject, the attention was paid to the particular technologies or applications that could be used to implement the solution. The conclusions were then drawn.

2. The Construction Industry

2.1 Overview

The Construction Industry is by no means a standard one. It can be classified as probably the most complex and diverse of the Industries.

This statement is rather generalised in the Construction business and it is insouciantly accepted by whomever is related to it.

As it is crucial to the project's conclusions, some time has been spent to think about the statement and then to corroborate it. If a substantial reason could not be found, then the C.I. would not be sufficiently different in order to be analysed separately and so, the conclusions could be extrapolated from and to any other Industry.

By using a personal understanding of the industrial environment and sustained by the experience of the people that one way or the other, collaborated in the project, a brainstorm took place.

In the first approach, some distinctive reasons came to mind:

Both a capital-intensive and labour-intensive industry

Low-skilled labour force

Huge investment in equipment

Long time to complete a project

Multidisciplinary activities

Highly sensitive to weather conditions

Poor quality of some raw materials

Traditional activity

Construction sites far from each other and from the headquarters

Each project is vastly different from the others, Etc.

In this form, these characteristics are not so discriminating that can univocally distinguish the CI from the rest. In one way or the other, they can be found in every Industry.

Nevertheless, it is possible to combine all these items into a set of four independent variables which can be used as a framework to characterise, measure and compare the complexity of Information Systems (IS) in the Construction Industry.

This framework has been denominated -- the **Four D's Framework**.

To increase the fluency of the description, the analysis will focus the IS straight away, as it helps to introduce the system specifications, which are the purpose of this section.

Do note that in this report, an IS must be regarded as a blanket system that covers every single part of the organisation. It is meant by Information System not only computer-automated systems, but specially all the information flows and underlying processes, paper-based or electronic. Moreover, if the company has a Quality System implemented – which is becoming increasingly common, the IS will necessarily embrace it. Consequently, it is guaranteed that it will address the organisation structure as a whole, as desired.

2.1.1 The four D's Framework

The four variables of the framework are Dimension, Dispersion Differentiation and Dynamism.

Dimension -. This is a multifaceted variable. It quantitatively measures capacity in several ways: number of different products, set-up investment, cash-flow, administration costs, assets, equipment, materials, activities, methods, human resources, effort in conception and so on.

In Construction, every item of the list is big. In fact, it is quite common a contractor having several dozens of projects in progress. Set-up costs in the shape of land, equipment and resources --that are present well before the first inflow-- can represent up to thirty percent of the total. Poorly skilled manpower has to be managed. The number of different materials can easily surpass one thousand...

Although these facts could be found elsewhere, in the CI they appear simultaneously.

In what concerns the IS, the volume of information and the number of branches in the network can grow to an extent that it soon becomes unmanageable. High volumes of cross-linked information have to be processed, transacted and stored.

Dispersion - This variable measures the relative distance between Participants and project locations.

Naturally, along with the natural geographical dispersion of the construction sites, participants are also based in distinct locations.

Because most of the participants do not belong to the core organisation, a wide spread of projects/participants away from the contractor's area of influence will dramatically increase complexity in the Information System.

Following the trend of globalisation, Construction companies have also extended their reach across borders, which burdens the IS even further as different technologies will have to be introduced.

Differentiation - Construction projects range from highly standardised to highly customised.

It is usual to make a distinction between Public Works and Civil Construction. In the former, the projects can be bridges, roads, monuments, public buildings, universities, airports, subways, etc. Civil Construction is dedicated to building houses, residential buildings, offices, industrial plants and commercial buildings.

Surprisingly, it is frequent a Construction company to display simultaneously, many of these projects in its portfolio, as different as they can be.

This wide differentiation range is also applied to information content. In short, a standardised project requires templates to be applied repeatedly, whereas in a customised one, the information content will be of a highly variable nature, and so will be its volume.

Dynamism – This variable measures the speed of change in the network configuration. The previous ones can be regarded as representing space or shape; this one introduces another dimension – time.

Because of the high rotation of the projects in the company's portfolio, the Information network will have a variable physical and logical configuration. Even considering a single project, all across its duration, it is possible to identify different participants in different periods of time whose level of activity is itself dependent on time.

As it could be seen, Construction Industry scores high in all of the four 'Ds', meaning that is one of the most complex industries to be managed.

Moreover, there are problems particular to the construction environment that hinder the success of an ideal Information System for the Construction Industry.

These problems show up in every participant but are mostly located on the constructor side.

Some reasons have been identified through the contacts established with the CI professionals and clearly, there is a consensus among the opinions collected:

- The constructor (or the building company, to be more precise) is traditionally bound to the construction art. It is often ran by elderly people who are experts in the building business but not so keen in these new technologies, then ignoring their potential to boost competitive performance.

- The competitive stress in what concerns this issue is not felt as a reason of concern. Therefore, the stimulus to invest in IS can be considered null: the IS is not regarded as a competitive advantage.

- Another problem is the dispersion of the construction sites, already stated. It is not only the distance between them, but also its nature: the technological infrastructures are precarious as well as the on-site conditions - and it is on site where the information is needed and most of it is created.

- Moreover, computer illiteracy is considered more widespread in these companies, than in any other participant.

These were the reasons that mostly contribute to the uniqueness of the construction setting. It was not the objective to make a dissertation around the subject but to create a background to support the solutions presented further on.

2.2 The Construction Project - phases and participants

A Construction Project is carried out in successive phases, involving different participants.

In broad terms, a typical chronology of these phases is shown in Figure One.

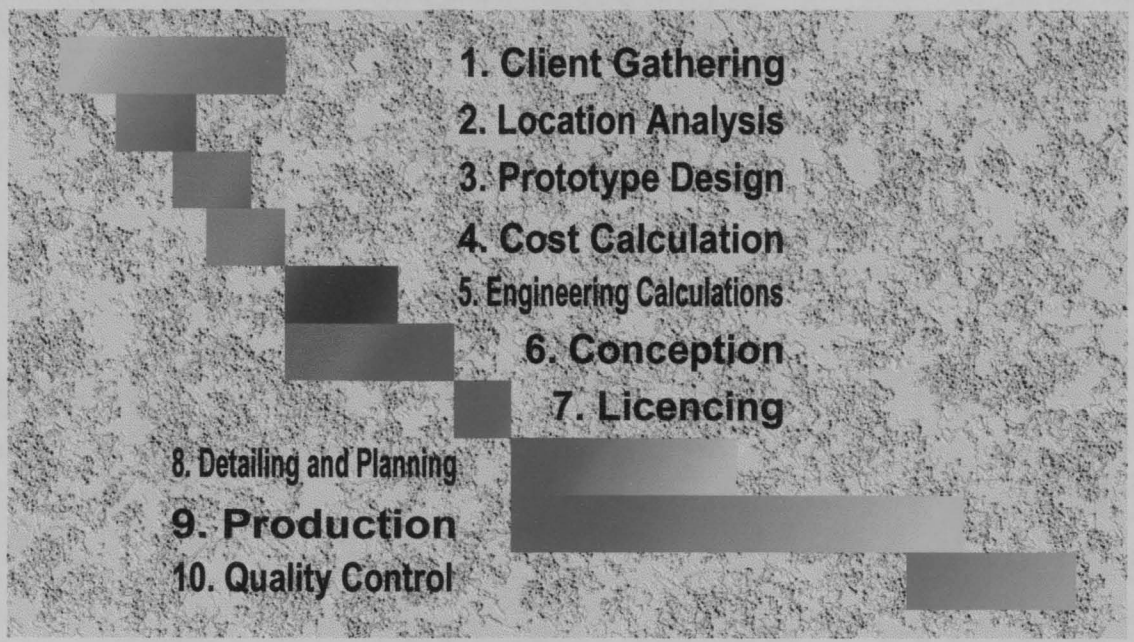
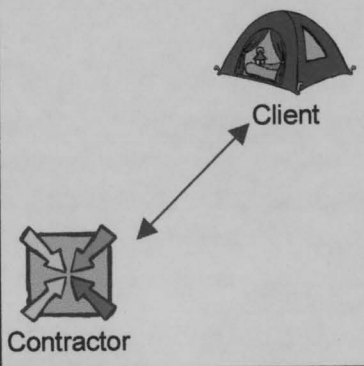
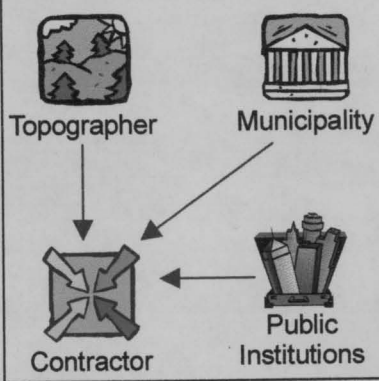
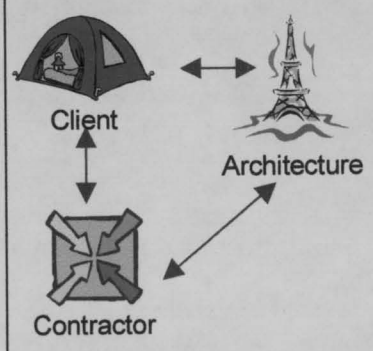
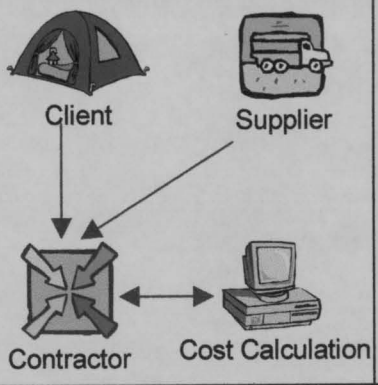
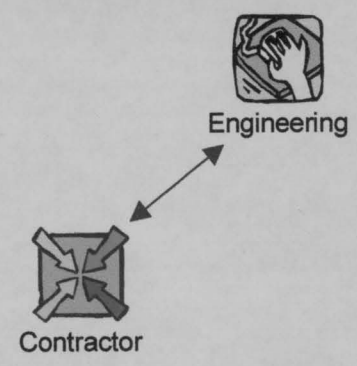
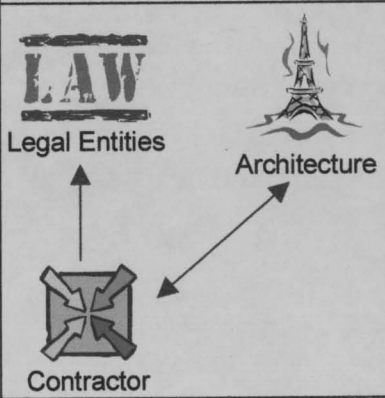


Figure One – Phases in Construction

Table One presents the participants and characterises their information exchange.

		PARTICIPANTS	DESCRIPTION
PHASE 1	Client Gathering		Wishes and expectations of the **Client** are transferred to the project co-ordinator – the **Contractor**. This will start a cycle where prototype development and cost calculations are continuously revised until approval.
PHASE 2	Location Analysis		**Topographers**, **Municipalities** or other **Public Institutions** provide information about the site topography. Geological studies have to be made in order to analyse site conditions. Director plan information, functional and environmental restrictions have to be collected.
PHASE 3	Prototype Design		In the prototype development phase, a model of the construction work is developed. It starts with a simple volumetric study and can end in a physical small-scale model or 3D graphical animation, for example. For this, the contractor involves an **Architecture** department or company.

PHASE 4	Cost calculation		After this, a more complete definition of the project is developed in order to make the cost calculations, involving a **Cost Calculation** department. This phase uses information stored in the contractor's knowledge base and **Suppliers** are contacted to set up specific prices.
PHASE 5	Engineering Calculations		Being approved by the Client, the project has to be further detailed to include structural analysis, electricity, gas, telephone, ventilation, water supply and drainage infrastructures. Specific **Engineering** skills are needed.
PHASE 6	Conception		Simultaneously, the architectural details are concluded. Plan views and other drawings complete the portfolio of documents necessary to the project approval by the **Legal Entities**.
PHASE 7	Licensing		This set of documents has to undergo the approval of the **Municipality** and other **Public Entities**.

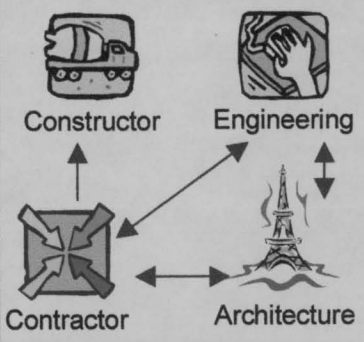
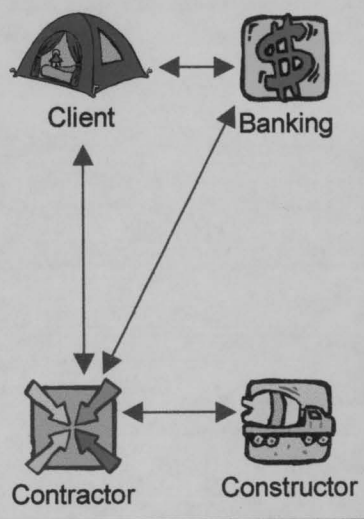
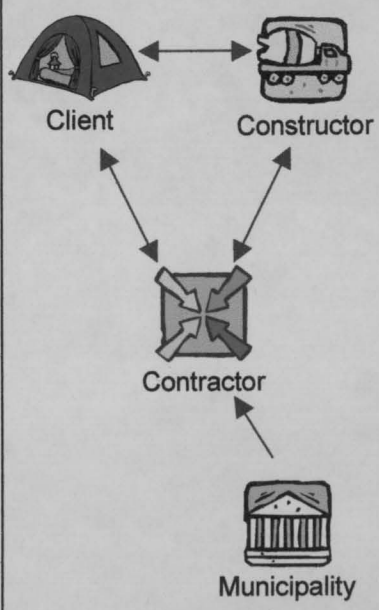
PHASE 8	Detailing and Planning		Then, the drawings have to be exhaustively detailed to prepare on-site production, as they are crucial to its efficiency. The planning of the building activities is set taking in consideration not only that specific project, but all the company's projects.
PHASE 9	Production		Entering production phase, the drawings and specifications are duplicated and sent to the construction site. On the opposite direction flow the material requests, progress reports, filled-out cost control forms and many other documents that compose the upper quartile of the information volume transacted during project duration. Included here are the contracts with **Suppliers**, **Constructors**, **Subcontracted companies**, etc. **Contractor/Client** relationship is extended with financial transactions, while **Banking Institutions** take their place in the network.
PHASE 10	Quality Control		This activity is carried out by the **Constructor**, the **Contractor** and the **Client**. Non-conformities lead to corrective measures and with them, a complete update of several databases has to be performed. **Municipalities** have another intervention, as legal inspections have to be carried out. When the actual building activity ceases, there is still an important component without which, the project database will not be concluded – Post-sale support. Legally, it lasts for five years but in practice, it can last up to a decade. From the very first phase, the system has to learn the organisation, as information is fed back and cross-related with results. The knowledge base that has been formed is to be used in the following projects. This concept is known in literature as the *Learning Organisation*.

Table One – Participants in Construction

2.2.1 The C.I as an Extended Enterprise

The dimension and complexity of modern construction projects have led the traditional constructor to outsource most of its activities, concentrating its efforts in the core business of management, becoming a contractor.

Although this couple-of-decades-old evolution or trend may seem to be profitable for the Companies in general and to the Sector, a serious draw-back holds better results: the contractor has not left behind a constructor's mentality. It would not be a problem if he had reached out to embrace the philosophies associated with the new field of business; but it is not so. This handicap of company owners has been pointed out frequently as the most common reason hindering an efficient management of the business.

Despite some companies have kept a production component in their activity, namely the concrete work, they seem to have more affinities with a Service Company than with an Industrial one. The contractor's main activities are to co-ordinate participants and manage the information network. A huge planning activity is, in most cases, the central concern of such companies.

From this configuration emerges the Virtual Corporation nature of a construction project. It is a set of otherwise non-related companies that are bound together to carry over a specific project; the binding element is the Contractor.

Many definitions of Extended Enterprise or Virtual Corporations - it is not relevant to make the distinction here - are available throughout literature but the one presented by the University of Bern represents best this concept:

> *'A virtual corporation is a kind of horizontal and/or vertical enterprise co-operation of independent firms with the possible participation of institutions and/or persons to achieve a service or product on the basis of a common understanding of the business. Each company will contribute primarily to what it regards as its core competencies. There is a time limit on the existence of the virtual corporation caused by the fulfilment of its business purpose. From the viewpoint of an external observer, the virtual corporation appears as a unitary enterprise.'*

As it was seen before, a construction project is close to be the perfect example of what has been defined.

Although there are companies that integrate some of the activities, in most cases they are performed by legally independent entities sharing a *common understanding of business.*

Another keyword to retain from the definition is *Time Limit.* The Extended Enterprise is bounded by one project at the time, even when any of the entities is chosen to participate in different projects, at the same time or not. The period of intervention is well defined for each participant: in some cases, it is present during the whole project duration, in other cases it is only hired to perform a single task.

Nevertheless, from the outside - and hopefully from the inside - the Extended Enterprise can be seen as a unitary organisation.

2.3 Information System specification

The previous chapters described the Construction Industry setting and defined the Information trade between the participants throughout project duration. As it was seen, the IS will have to formalise, implement, and manage the Information flows between the participants.

Making use of specific **technologies**, it will be able to provide intelligible **information** to improve **organisational** performance. Ultimately, it will become a valuable **strategy** tool. (Figure Two)

The diagram is meant to go beyond the simple grouping of those concepts; it can be seen as a spiral of increasing abstraction, starting with a tangible matter – Technology – moving on to a form of intellectual Input/output – Information – addressing corporate structure – Organisation - and finally, corporate Strategy.

The shape of the diagram translates the interaction and inter-dependence between the sectors. This is, when the IS overcomes the problems regarding one of the sectors, it is also contributing to answering other sector's questions. Higher-level items inherit most of its problems from lower-level items as well as the solutions found.

Finally, when the IS is able to address all those problems, the Organisation is set free to put a better focus on its Strategy, having in the IS an indispensable tool.

Those definitions derive from problems found in the Extended Enterprise and, therefore, contribute to the specification of the IS for the C.I.

Figure Two – I.S. Challenges

Communication - There must be a means (physical or not) for the participants to exchange information. It becomes an IS problem when the parties are not able to share the same space or moment in time. This channel can be a telephone line, internal mail, an e-mail system or whatever suits best the needs of the organisation.

Synchronisation - The relevant information must be available, when and where it is needed. If this is not achieved, the problems will spread across all the other sectors.

For example, detailed drawings must be available on site when it comes to start the production phase. Reports about past performance of a supplier must be present when considering the acquisition of an important product.

Compatibility - As outputs from one participant are inputs for another, there must be the highest degree of compatibility of the transacted information in order to reduce processing time, error proneness, ambiguity and, ultimately, cost. This compatibility must also be ensured at the physical communications level.

This means that format compatibility is crucial. For example, productivity is well reduced if the electronic drawings come in such a format that is simpler to ask for a printed version and draw it all over again.

Availability and accessibility - Information must exist and be reachable in real time.

The appropriate level of security must be installed so that information is made available only for authorised users.

Standard and frequently used reports must be created and stored so that it is possible to have access to them in real time without having to process them in the moment they are needed.

Up-to-date - It is critical to ensure that everybody is working with the most up-to-date information. Updating procedures must be kept to the simplest so that updated information overrides previous versions as soon as possible.

It is really a problem when it comes to drawings, considering that can exist hundreds or thousands of them in each project.

By working with electronic documents, it becomes much easier to share information and to upgrade it in a fast and secure way.

Consistency and congruency - The linkage between cross-related information must be constantly monitored and conveniently supported.

For example, it must be possible to identify which department requested the materials of order X, which has been sent to the supplier. After that, the invoice must be checked with the order and the materials actually delivered.

It is the IS's task to ease the human intervention from these time-consuming activities.

Relevance - Not all the information is relevant for every participant. Excessive information is de-informative. A pre-filtering of information is required.

Usually, a prototype designer is not interested in building detail drawings, for example.

Usefulness - Even if it is relevant, information can still be of no use because it is not detailed enough or it is too late, for example. The appropriate level of conciseness must be attained so that further processing is not required.

The higher you climb in the company's hierarchy, the less data you must have.

As an example, information is considered useful when a supplier calls and it is possible to know, in a minute time, what orders have not yet been satisfied.

Tracking and Threading - It is essential to know what information is available in the network, who owns it, who is working on it, its status, from who it came and where should it go next.

It is just as simple as knowing who to send the customer's complaint form; or to know how complete is the detail of the new type of wooden frame that has left the hands of the architect and has gone for prototype manufacturing.

This is the primary role of the IS - to define and implement the information flows within the company.

Complexity - The interaction between the information carriers increases the complexity and reduces overall manageability of the process. The correct balance between information volume per document and link usage must be carefully pondered. Fast and intuitive linkage between elements is of absolute importance as it improves readability.

Preferably, the documents should be short, providing the user with concise information, but allowing him to go deeper in detail if necessary. However, the trade-off must be kept in mind: the more links there are the more complex the system will be and the time to retrieve all the information will increase.

Distribution, maintenance and duplication - This cost is easily assessable in physical information carriers and it is likely to be concentrated on the project co-ordinator. A cost dispersion, advantageous for the contractor, can jeopardise the controllability of the network.

Working with electronic documents, this cost is substantially reduced, because few are the cases where it is required the paper-form original to be replicated. It can be accessed indistinctly by whoever is entitled to it. It is the IS's administrator's responsibility to assure the maintenance (manage permissions, index, organise, back-up, restore, replicate, etc.) of stored information.

Record keeping - It is of vital importance the consolidation of a project record but, as previously stated, information relevance must be kept in mind. Not every piece of data is eligible to take part in the record.

As it was said before, during project execution, a close control on document version is needed and a standardised versioning procedure must be designed and universally accepted within the extended organisation.

Bureaucracy - As the network grows, combining different organisations and with it, different cultures, expertise and ways of work, bureaucracy is prone to appear in the form of excessive paper work, duplicated information, multiple approval procedures, never-ending forms and so on. Moreover, if a Quality Management System is implemented, the amount of documented information, that once ran verbally, grows exponentially.

Conflict of interests between participants - Theoretically, the relations between participants should be of a co-operative nature, working together as one organisation. However, personal, isolated goals arise and the resulting friction can become a burden to the co-ordinating entity.

It is the case of the conflicts between architects and engineers or the commercial department and the treasury department.

The contractor, as the core organisation, is expected to plan, implement, manage and monitor all the information flows, keeping an overall insight of each project while creating its internal information base.

Moreover, a personal involvement in developing the System is essential to the desired results. It is not enough that it is accepted; it has to be created by every single user.

Again, although this description may have seemed related to computer-automated procedures, it is not necessarily so. As it was previously stated, it is of extreme importance that the Information System is finely tuned while in the 'on paper' phase and only then the automation component can be applied. If some procedure is not perfectly working before the automation phase, it will only amplify its effect. This risk can seriously compromise the success of the implementation.

Needless to say, the System has to be cost-effective. Here, ROI means Return On Investment but also Return On Information.

3. Information Systems for the C.I.

3.1 Evolution

The following Maslow-like diagram (Figure Three) was designed during the project in order to show the IS needs of a multi-participant industry, such as Construction.

The original Maslow pyramid hierarchically represents the needs of the human being, from physiological to personal realisation. This diagram is the transcription of analogous needs in IS. It is complemented with their evolution - historical and implementation phases - the technologies that compose it and the effects suffered by its management.

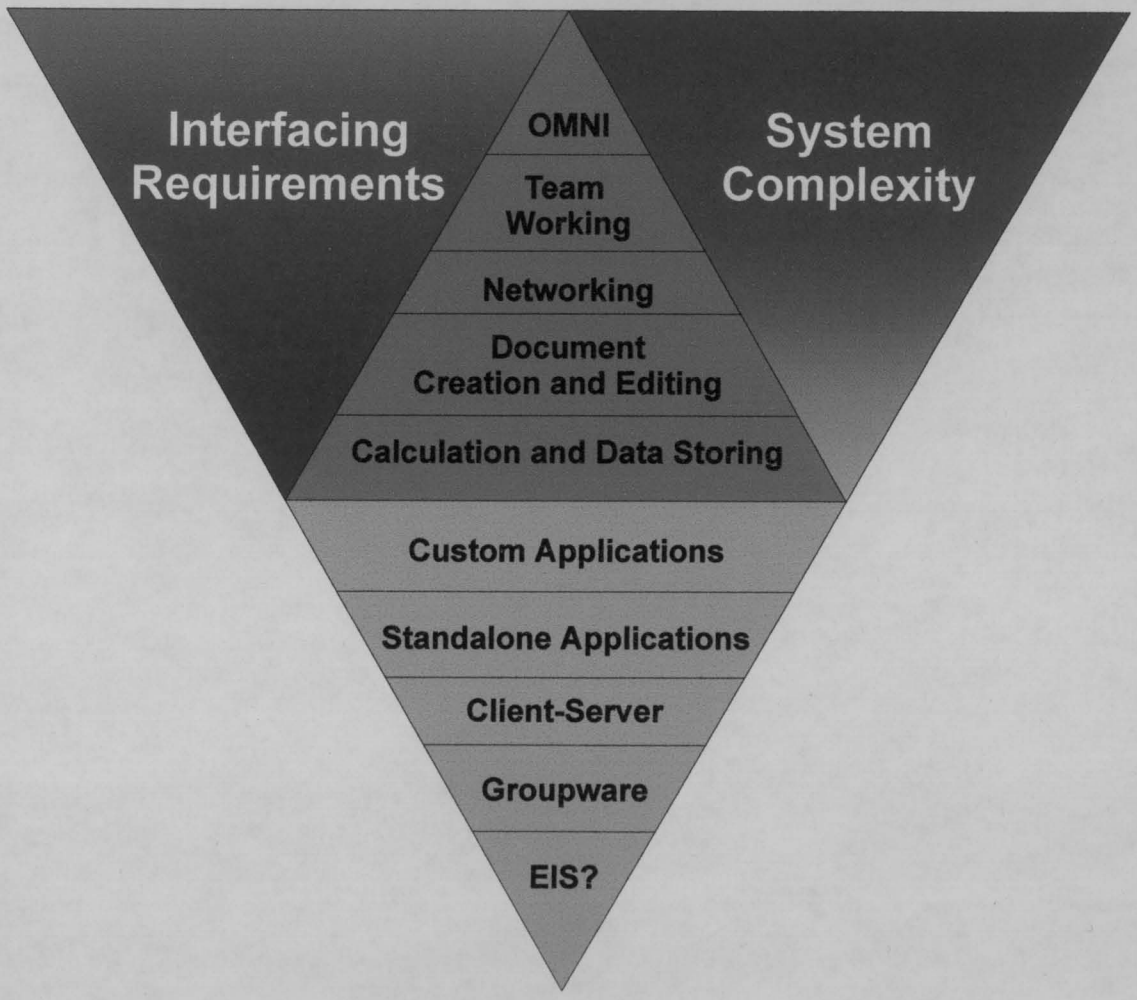


Figure Three – I.S. needs and evolution

The central triangle is the stepping stone for the diagram. It represents the abstract needs, which are materialised in the lower triangle. On the sides, the technical implications of climbing the pyramid are shown.

The first task an IS is expected to do is to calculate. That is the reason for which computers were invented - to free human intervention from repetitive and time consuming activities. Custom-made applications were developed to overcome this problem. They have few interface requirements as they addressed very particular, non-related fields and fitted company-specific needs.

Data storing and retrieval is also a basic requirement to handle the high volumes of information that are produced.

Bookkeeping applications, legacy systems, engineering calculation applications, customised spreadsheets and database management systems, are in the base of such systems. Dedicated and isolated hardware is used to implement them.

The next step was to assist in document creation and editing. It was meant to reproduce the paper document in an electronic way, with all the advantages that came with it – the ability to be edited, reusability and neat looking of the documents.

However, the ultimate objective was always to produce a paper document. Standalone applications are used to perform this task. Examples are word processors, spreadsheets, CAD software, simple planning software and more. These applications were initially used to replace typewriters and drawing boards, but are now becoming powerful productivity tools.

Interfacing between applications is turning critical while common, isolated PCs do the job.

When the number of users becomes significant, the distance between them increases, the volume of electronic information is substantial and communication needs arise, a step upwards is required. A bridge between machines is built. Commonly used applications and data are stored centrally and accessed remotely. This is the essence of the client-server architecture.

With networking, another variable has been introduced: the ability to share information electronically.

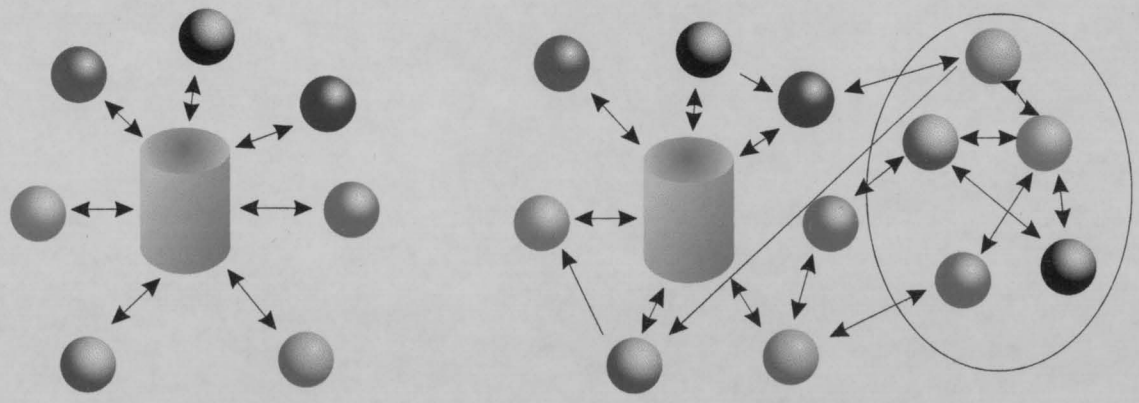
The physical connection between units must be accomplished and networking operating systems are required. Management of the IS is needed as overall complexity increases. Compatibility must be assured also at the physical level.

Team working is the ability to combine individual expertise into corporate knowledge. GroupWare is a category of software that enables companies to create, share and leverage this corporate knowledge. Figure Four distinguishes Networking from Team Working.

Until now, *information* was the chosen keyword. This was so because it is a more tangible concept, but it is in fact *knowledge* that is really in stake; information is only its carrier.

Networking enables people to share information but is not adequate to share knowledge in a transparent way. With this step, companies will be able to profit from enhanced, live co-operation between the participants.

A more technical description of GroupWare will be presented in the next section, but similar technical considerations can be made at this stage: Interfacing between applications is now indispensable.



Traditional Networking **Team Working**

Figure Four – Networking vs. Team Working

System complexity is increased because participants are actively communicating among each other. Changes at the physical level are despicable.

The paradigm of any Information System is omniscience. The focus has evolved from data handling to information management, then to knowledge leveraging and now to wisdom. This is the ultimate objective: to feed wisdom to the decision-maker, setting him free to define corporate strategy.

Such Information System must blanket the whole organisation, every detail, every action and every implication.

3.2 Present state - Islands of Automation

The Islands of Automation shown in Figure Five are a metaphor that translates the evolution, present state and future of Information Systems in the Construction Industry.

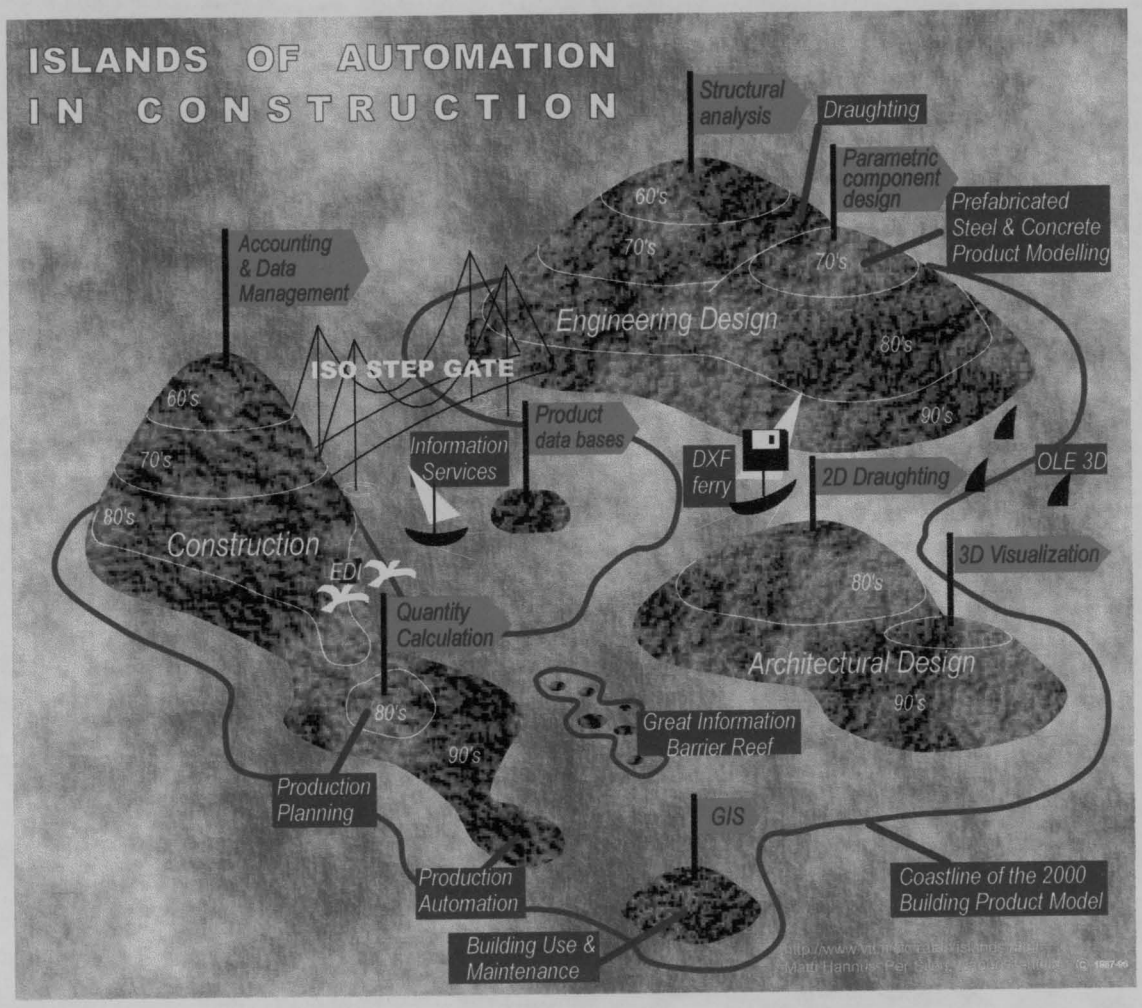


Figure Five – Islands of automation

The initial IS was formed by the standalone development of key-intervention areas where automation was most needed and where it could be easily introduced – Engineering Design Architecture Design and Construction.

In the early phase, they have automated calculations and stored data electronically.

Afterwards, they were used to produce and manage documents.

As these isolated subsystems were created without any concern of compatibility between them, only the natural evolution of the subsystems will be responsible for the creation of common interfaces. However, while this is not a reality, artificial interface agents carry the information from one subsystem to the other. It can be identified as the networking phase, while a rudimentary form of teamwork is taking shape.

When water level between the islands drops, team working will become increasingly used and the IS will aim to an integrated approach to all the activities in Construction.

This figure summarises three key-points already described in the report - the isolation in computer systems that support the CI; the tools used in each project activity; and the evolution of the IS in the CI.

3.3 Traditional Technologies

In order to accomplish the project's objective – to identify a Project Information Management Tool – an initial set of applications and technologies have been researched.

Solutions encountered in other industries were analysed, since information was easily available. They have also matured for enough time in order to draw sustained conclusions.

Although not technically comparable between each other, three initial approaches have been made:

Electronic Data Interchange/Management (EDI/EDM)- For its presence in the retail sector's transactions, much similar in terms of the number of participants.

SAP R/3 - For the results achieved in both industrial and service sectors. A true 'must' in the IT world.

Workflow Management Tools (WFMT) - Firstly as a suggestion from the Dutch project supervisor, and corroborated by the usage of WFMT in the financial meanderings where the volume of transacted information carriers is substantial.

3.3.1 EDI/EDM

EDI is a way of exchanging information between computer systems that work with different, incompatible data formats.

To put it in a simple way, data from one application (a legacy system, for example) in one company is translated into a standardised exchange format. Then it is sent to an exchange network (VAN - Value Added Network) to be transported, and finally converted back into the format recognised by the end computer system (Figure Six).

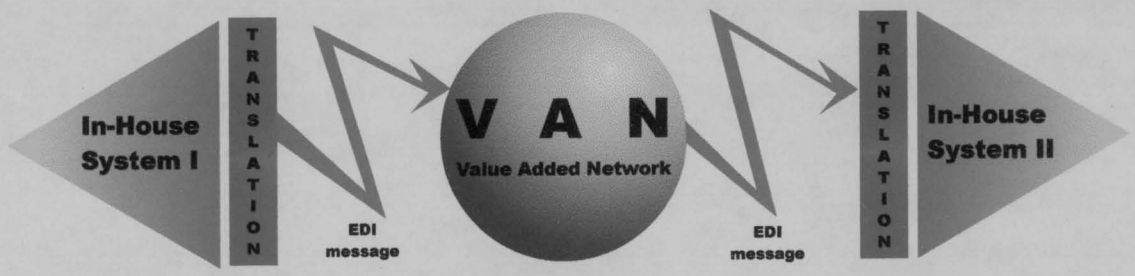


Figure Six – The EDI process

Figure Seven shows how different participants' computer systems can be interfaced through EDI to exchange vital business documents.

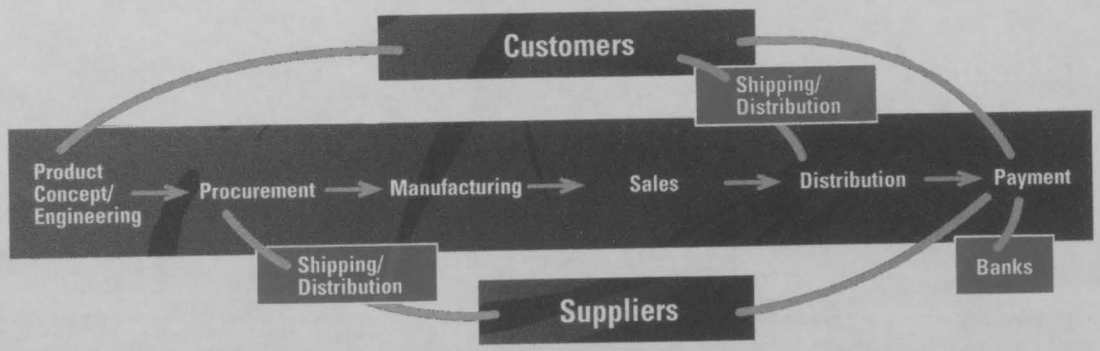


Figure Seven – EDI partners (Source – General Electric)

However appealing it may look and how suitable it may seem, EDI is not fulfilling all the CI needs, as it only addresses the communication and compatibility requirements.

Since its communication structure is very rudimentary and added that the nature of information which is transacted cannot be translated by the EDI engine, it is not eligible to be the ideal solution.

For example, if an architecture design application is not able to transfer data with an engineering calculation program, EDI will not bridge this gap. EDI would be the solution to make compatible the two calculation programs used by two contractors in a consortium, for example. (This is made evident in the 'Islands of Automation' figure, where EDI is represented only in a small part of the construction island)

3.3.2 SAP R/3

SAP R/3 is an integrated management tool that covers areas from marketing and sales to human resources, accounting to planning and a never ending list of third party plug-ins that make the whole system a bulky, generalist, highly flexible but costly adaptable environment.

Here is a list of the modules that compose the R/3 application.

Human Resources (HR) The HR module contains comprehensive solutions for planning and administering personnel. Its applications cover functions such as personnel planning and development, seminar and convention management, room reservations planning, cost planning, recruitment, administration of wages and salaries, time management, performance related wages, travel expenses, and payroll accounting. The functions integrated in the HR module fulfil all human resources management requirements while simplifying and speeding related HR processes.

Financial Accounting (FI) All relevant financial accounting data is collected here for international accounting and reporting purposes. At the same time, complete documentation and comprehensive information capabilities permit up to the minute information for enterprise-wide monitoring and planning tasks.

Controlling (CO) This module's harmonised planning, control and monitoring tools for enterprise-wide controlling systems permit a uniform reporting system for co-ordinating the content and routing of corporate processes.

Sales and Distribution (SD) The SD module actively supports all sales activities. The integrated functions support pricing, speed-order processing, and ensure timely delivery. The functions also enable interactive, multi-stage

configuration of variants and have direct links to profitability analysis and production.

Materials Management (MM) Workflow driven functions streamline all purchasing processes and enable automatic evaluation of vendors. Precise inventory management and warehouse management reduce procurement and warehousing tasks. Another benefit is integrated invoice verification.

Production Planning (PP) Equipped with integrated processes for all common types of production, PP permits planning and controlling of standard manufacturing, made-to-order production, and manufacturing of products with variants, as well as process manufacturing, made-to-stock production, and even project-oriented manufacturing. Extended MRP II functions and electronic kanban are included, as well as open interfaces to factory data acquisition, process control systems, Computer Aided Design (CAD), and Product Data Management (PDM).

Project System (PS) In conjunction with Purchasing and Controlling, the Project System coordinates and controls all project phases from bidding through design and approval, to resource management and cost settlement.

Plant Maintenance and Service Management (PM) This module integrates planning, control, and processing of preventive maintenance and inspection tasks, as well as service management functions. These functions increase machinery and technical equipment availability both internally and within a third party customer's facility.

Quality Management (QM) QM monitors, captures and administers quality control efforts along the entire supply chain. It coordinates inspection processing, initiates corrective measures, and integrates laboratory information systems.

Investment Management (IM) IM administers capital expenditure activities and projects, handling all aspects from planning to settlement This module also performs profitability calculations and simulates depreciation options.

Treasury (TR) A complete solution for efficient financial management, Treasury ensures companies' global liquidity and comprehensively organises financial investment while limiting associated risk.

Enterprise Controlling (EC) This module comprehensively monitors all factors of relevance to a company's business success, adds relevant performance indicators, and conforms the data into customised management reports.

Workflow (WF) SAP Business Workflow is another resource available to increase the efficiency and productivity of business processes. Workflow streamlines and automates the flow of corporate information, sharpening the visibility of task assignments and organisation

Although the IS specification did not thoroughly include a reference to its cost, SAP R/3 is immediately thrown out of the race by its exorbitant price. SAP Consultants at Price Waterhouse state that the initial investment in this product can surpass $1.000.000.

Quoting the same source and SAP itself, the great number of success cases on the basis of the popularity of SAP, do not include the Constriction Industry. Yet, the reason is not known. Along with some unfavourable opinions from IT professionals contacted for this purpose, this was the main reason for which SAP R/3 was left behind in the research.

3.3.3 WFMT

Before presenting the Workflow Management Tools, it is convenient to better define Workflow, as it will be used further on as being an important part of GroupWare tools.

A workflow is a collection of steps that, when followed, accomplish a certain objective. These steps, called activities, are performed by either people or programs on an Information Processing System. A workflow management system drives and monitors workflow by feeding the person responsible for an activity with the relevant work items and data at the right time. Typically, workflow management capabilities include a computer-based tool that graphically depicts the work in the organisation. They also include details of responsibility; location; status; process cycle time; process costs; and the relationships of workflows in the overall system.

This presentation seems to fit quite well the CI needs defined previously. However, basic questions arise: How easily can these steps be defined? Is the structure of the workflow stable in time? Does it not randomly vary from project to project?

It is also well known that such systems are highly expensive and experience shows that they are only paid back when used to process large volumes of structured documents, which is the case of insurance companies or banking institutions.

It is definitely the solution to automate the information exchange, but lacks the insight needed to build the knowledge base of the organisation. It is a system that is designed by the IS department, not collaboratively carved by the organisation.

3.4 GroupWare

GroupWare is not a traditional technology. It is a quite recent concept of Information management. However, the experience of the people who collaborated in this research, led to the investigation of such an approach.

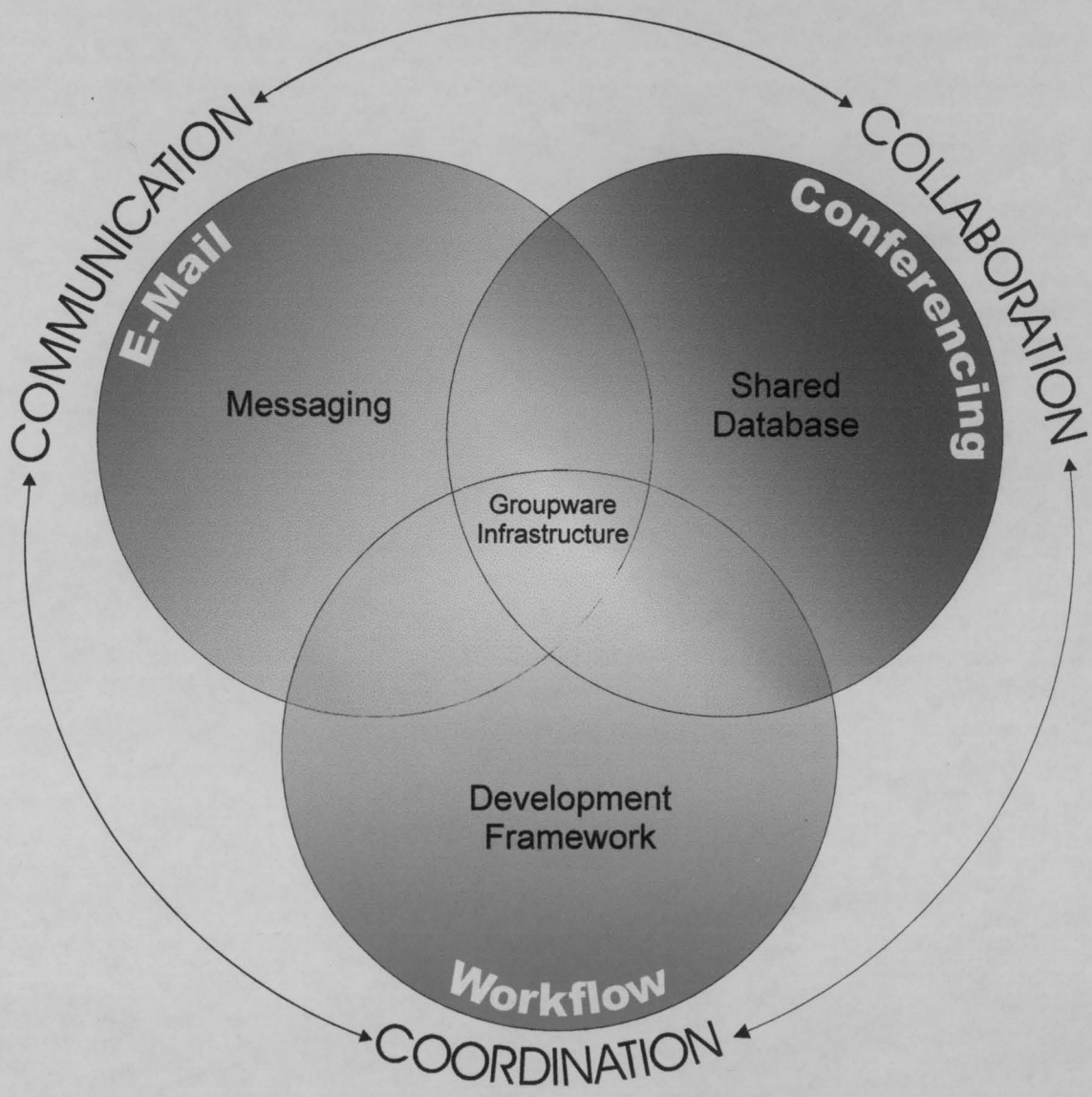


Figure Eight – Modes of Group Work

(Source – Lotus Corp.)

3.4.1 Definition

As defined by LOTUS - market leader with its LOTUS NOTES integrated solution - GroupWare is a category of software that enables companies to create, share and leverage corporate knowledge.

In short, it relies on a set of tools which enable people to work together through **communication**, **collaboration** and **co-ordination**. (Figure Eight)

Associated with these three modes of group work, there are technologies such as electronic messaging, information management and workflow/process automation. They are usually materialised in the shape of e-mail, electronic conferencing and bulletin boards, and forms routing and tracking, respectively.

The synergy emerges from the combined use of those three modes makes GroupWare such a powerful tool in corporate productivity.

- **Communication**

Communication in this context is the transmission of knowledge. In an electronic environment, knowledge takes the form of messages whose sender can be a person or an application, and so can be the recipient.

Just like ordinary mail, it relies on a store-and-forward technique, meaning that the information is moved from place to place until it reaches the recipient. The great advantage of this technique is that it does not require that the parties be synchronised in time, so a message sent in any moment in time will be laying in the recipient's mailbox until it is read.

The keyword in this technology is *push*. The message is pushed all the way from sender to recipient, therefore relying on the former to actually initiate the process but leaving him with no further control of the rest of the process. This is, if the message is to be replied, little has he to do to influence the action of the recipient. Combining the other modes of GroupWare, in particular the co-ordination one, this problem can be overcome by, for instance, displaying alert messages at the recipient's desktop until it replies back to the sender. Some systems will provide the sender with a delivery receipt when the message reaches the final mailbox; and a read receipt when the recipient actually reads the message. This is more than simple messaging; it is already a form of flow automation.

It can be stated that this technology solves the problem of information distribution: from the sender's point of view, it is faster to deliver it, and from the recipient's point of view, it is faster to get it. However, this versatility and ease-of-use can have a significant draw-back: it is very likely that the recipient's mailbox gets filled with irrelevant messages to a point that he will not be able to distinguish which is relevant or not - it is called information overflow.

Electronic messaging is intended to handle one-to-one, one-to-many and many-to-one communications. However, because of its ease of use, it is frequently used to carry many-to-many communications. The volume of transacted information will grow in a combinatorial way and the participants will not be able to manage and absorb it. The pushing model is suitable to perform such kind of operations, specially if they occur in an unstructured way.

This is where the collaboration mode has its application.

- **Collaboration**

Collaboration relies on a shared space to combine the individual participants' expertise into a whole that is greater than its parts.

As in communication, collaboration has an asynchronous nature, which enables the participants to overcome the barriers of time and space, but it is designed to handle many-to-many communication in a more coherent way.

Its most common application field is in shared databases, which can host discussion groups, electronic conferencing or reference publishing systems. In many aspects, the World Wide Web itself can be considered as a GroupWare tool. One can make information publicly available through HTML pages; discussion forums are a form of teamwork; and e-mail is the perfect service for exchanging messages and documents. A software development platform is also present.

When confined to the company's boundaries, Internet technologies become Intranets where that concept is adapted to meet the corporate needs. By merging participants' Intranets, an Extranet is created.

The main difference between communication and collaboration is that the latter uses a *pull* technique instead of the *push*. This means that it is the recipient's responsibility to fetch the information from the shared space. He is able to decide in which discussion group he will participate, which information to read and what messages he wishes to see posted. In such databases, the thread of the messages is kept and displayed so that every participant is able to identify which message replies to which, and can easily post follow-ups on any of these. The discussion group can also be moderated. A sorting and browsing tool is usually incorporated so that the information retrieval is made in a faster and intuitive way.

The same information overload problems can arise in collaboration tools: the number of different discussion groups and electronic conferencing systems can increase to a point where it is almost impossible to retrieve all the relevant information, causing a productivity loss.

It is obvious that a combination of pull and push techniques is desired so that the passiveness of shared databases is minimised. For example, the system must be able to notify the author when the remark he has posted in a discussion group has been replied.

- **Co-ordination**

The previous modes of group work highly rely on each participant to have an active role in the process, whether in the form of pushing or pulling information. This leaves room for delays, data loss, and utterly a decrease in productivity and installed confusion, specially when the system follows an unstructured or ad-hoc configuration.

However, some systems or subsystems are highly structured in nature. Many procedures follow a very structured logical path, exhibiting a pre-defined, conditional workflow based on status and conditions. Expense reports, supplier appraisal forms and weekly progress reports are examples of such processes.

In such cases it is not advisable (nor desirable) to have the participants simply co-operating at their free-will. A co-ordination entity is required to assure the complete and accurate flow of the information. To accomplish this, it is necessary an applications development environment and the adequate tools.

Workflow applications define forms, specify operations on these forms, specify routing logic for the forms, specify how external data is to be accessed or modified, specify triggering actions to be taken when specific conditions are met, etc.

But when the processes are not so structured, being defined dynamically as the work is being done, the inclusion of the previous technologies is essential. Support for informal conversation, joining communication with co-operation, must be added to a simple, flexible co-ordination tool.

Most real work involves dynamic movement between structured, unstructured, ad-hoc and pre-defined work. The first two can be managed by routing - based on messaging technology - and tracking - based on shared database technology. The last, require an integrated application development framework which exploits services of both messaging and shared database.

What makes a GroupWare tool powerful and versatile is its ability to integrate the three modes of group work in a way that fully exploits the synergy of their combination.

3.4.2 Implementation

GroupWare as presented is just a concept, not a specific tool or application. It should always be understood as so.

LOTUS NOTES is the industry leader in GroupWare-based products. There are no doubts that NOTES is able to implement the features described in a fully integrated way, despite the high cost, closeness and proprietary formats.

The other alternative for implementing a GroupWare solution is the creation of an Intranet. Developing an Intranet consists in implementing Internet technologies *within* the organisation.

The main components of the Internet – and therefore of the Intranet - are:

Communications Protocol - The ability to connect and communicate between networks and individual desktop devices.

File Transfer - The ability to transfer files between point-to-point locations.

Mail - The ability to provide direct point-to-point communication between individuals or groups.

Web browsing - The ability to provide access to information on a one-to-many basis on demand. This is what is called the World Wide Web.

Terminal emulation - The ability to access existing infrastructure applications.

User interfaces - The increasing technical complexity is available in a transparent, seamless and intuitive way.

Typically, within the early adopters of Intranet solutions, the application of this technology is being used as follows:

Publishing corporate documents - Human resource guides, newsletters, annual reports, maps, company facilities, price lists and product information literature are just a few examples of documents which can be published for a more efficient, cost-effective distribution across the entire organisation.

Access into searchable databases - Interface between existing databases and the browser - the application that makes the navigation possible - is simple to develop and transparent to the user. The result is a more widely available information, using standard access mechanisms.

Corporate/department/individual pages - Combined with powerful search engines it is possible to leverage the knowledge referred in the GroupWare description.

Simple GroupWare descriptions - With the forms support, it is already possible to implement some of the GroupWare capabilities. Further developments in this area are expected in the near future.

Software distribution - Internal administrators can use the Intranet to distribute software and perform updates 'on-demand' to users across the network. With the introduction of Java - a programming language specially designed for the Inter/Intranet - the creation and transparent distribution of objects (including small-scale or even fully featured applications) 'on-demand' rather than just data, will be possible. The co-ordination mode can thus be implemented in the Intranet using this feature.

Mail - With the introduction of Internet mail, this technology has received a significant boost in what regards versatility, connectivity and content richness.

User interface - The evolution from the Graphical User Interface (GUI) to an End User Comfortable Interface sees in the Intranet a challenging opportunity. The point-and-click simplicity of hypertext can dramatically change the way users interface with the computer. Hitting a hypertext link does not necessarily have to take the user to another page - it can ring an alarm somewhere else, run a procedure or anything else.

As it could be seen, the basis for a fully collaborative teamwork is already set-up. Although this technology still lacks maturity and is waiting for substantial developments in the area of the application development environment, it reveals itself quite promising in dethroning proprietary GroupWare solutions.

As a first approach to the problem, the comparison between Intranet solutions and LOTUS NOTES leads to the following considerations:

Cost - In many ways, cost can be the most compelling argument for adopting an Intranet based solution.

NOTES client software is situated above $69 per user, while commercial Web browsers start from $20 although it is also possible to use other browsers free of charge.

Server software can cost $10.000 and $1.000 for NOTES and Intranet solutions, respectively.

On the long run, to maintain an Intranet solution can cost only $10.000, while the similar Notes solution can go up to $250.000.

Content management - Less expertise is required from the common user to publish its own documents, setting free the expensive IS resources from the mundane document management tasks that are associated with Notes.

Proprietary vs. Open Systems - Although LOTUS Notes is not a totally proprietary system, it requires a skilled, intensively trained and expensive IT department to set-up, maintain and develop the Notes infrastructure. In addition, the tools required to carry over this development are quite expensive.

Intranet solutions are based on true open technologies derived from the WWW. The explosion in the Internet over the last years has increased the number of tools freely available for both client and server side development. In addition, compared to LOTUS Notes, it is clearly easier to implement new technology from the WWW, such as Multimedia or Java into an Intranet solution, thereby considerably reducing development costs.

Converging technologies - In many ways, Intranet solutions and LOTUS Notes are converging to provide similar functionality. From the Notes side this can be testified by the inclusion of Web capabilities in its latest release; from Intranet side, it is possible to recognise the continuous attempts to come closer to proprietary GroupWare solutions. Netscape - the industry leader in Intranet solutions - affirmed that in six to twelve months its Intranet products will outperform or at least be at the same level as the proprietary GroupWare solutions.

Performance - In terms of performance, Intranet solutions can be faster. Lotus Notes relies on 'synchronised replication' to ensure that data across multiple Notes servers is consistent. For remote users in particular, LOTUS Notes can fail to deliver fast access to databases.

The Common Gateway Interface (CGI) available only in Intranet solutions provides a fast and easy way to integrate legacy applications and databases.

GUI development - Standard Web browsers provide a single point-and-click environment from which users can access information and applications. Using specific products, the front-end is truly Web-enabled and can be easily customised and developed to suit individual or corporate needs. As these tools use the same standardised code as the common Internet applications, it requires less development effort than the GUI provided by LOTUS Notes. The same can be extrapolated to user adaptation.

3.4.3 The path to follow

A step-by-step implementation of GroupWare is the path that will lead to the most satisfactory results.

The main contractor is the participant that is expected to lead the process, as it is the central entity, responsible for gluing the organisation together.

The first step is to publish information and to make it available corporate wide. It can be simply corporate PR information or it can be the Quality Manual, for example. This will make users familiar with an environment where information is not laying in the desktop, nor it is stored in the local hard disk. It will not take long before they fell the need of having crucial information at their fingertips, not in a shelve somewhere in the building.

Then, informal communication should be encouraged. A simple e-mail mechanism has to be implemented so that users can send messages and share documents directly. The purpose of this step is to make users aware that they are not alone in the network. They can take advantage of being able to make contact and to be contacted by everyone. Some external communication can be enabled at this stage: company to company electronic communication can start.

Next, it is time to increase the interaction with the system. Filling in forms for data input is important and very useful. Shared databases and organised forums can be introduced. Users must be always fed-back with the information they have produced.

The next step is to enable users to create their own content. Reports, letters, memorandums, profiles and so on, must be carefully monitored by the IS in the initial phase. It is crucial that people feel that their work is appreciated and is kept well organised in the system. This is the phase where most attention must

be paid so that the system does not turn into a chaos of lost, irrelevant, misplaced and useless information.

Then, automation of certain procedures can be attained. After the processes are made stable and users are well acquainted with the system, it is time to free both the users and IS managers from repetitive tasks by integrating content creation with messaging or form filling with any other component of GroupWare tools.

Opening the firewalls to the other participants is the next step. This should also be made according to the previous stages, so that a smooth integration is reached. Safe access to the outside world can be granted and the productivity will increase dramatically.

These steps were taken in order to provide the users with an increasing degree of abstraction: from a centralised physical location to an environment where it is not relevant where the information or the people are, as long as they are there.

This is the ultimate objective of GroupWare: fostering collaborative work without the need of being together.

4. Conclusions

Despite its millenary history - and maybe this is the reason - the CI is still in the dawn of the information performance. In the last decades, it has been busy improving the technical performance, focusing on the methods and production resources, but somewhat neglecting the information processes in the background. Not that these processes have not been rethought, restructured and thoroughly tested through practice - many companies have even undergone Business Process Re-engineering (BPR) actions - but it is the way they are managed that is rudimentary. Compared to other industries, Construction is still trying to keep up with the Industrial Revolution but it can hardly be said that it has awaken to the Information Revolution.

Nevertheless, the Construction Industry has become aware that an efficient management of corporate information has implications that go beyond the simple competitive advantage: it has become crucial to grant its survival.

To accomplish this, all efforts should be directed towards the optimisation of the information processes, namely the standardisation and automation of certain clusters, where possible and advisable.

Therefore, their Information Systems must be finely tuned so that they enhance the core management activity.

Moreover, it is peacefully accepted that no attempt to organise or to rationalise a certain process should be dissociated from a computer system to support it.

GroupWare - whatever the form it takes - plays an important role in creating a robust solution for the Construction Industry's Information Systems.

In fact, the GroupWare concept is already being used in companies without being called so: network resources have been used to cope with the problems that GroupWare is willing to overcome. For example, shared directories on the network servers are used to exchange files asked for during a phone call. Application programming languages are used to customise and automate certain activities inside and outside the program environment.

It is then obvious that a solution that is able to integrate all the features GroupWare invokes, in such a seamless and transparent way, is indispensable. Although it could not be tested in real corporate environment during the research phase, this concept fits perfectly in the primary needs which have been identified.

However, one must be not tempted to force this solution into practice; it must come as a consequence of the process. The decision must be problem oriented, not solution driven.

5. Bibliography

Due to the actuality of the issues taken care in this research, most of it has been made through on-line investigation, using the Internet as a means of obtaining the information. This is the reason for which the references are predominantly electronically-based and why paper-form literature was deterred.

Because Web pages are highly volatile, as they often change addresses or are simply eliminated from its location, it is more useful to provide the address of the organisation that has produced it rather than the complete URL, which would most certainly lead to a dead end.

http:\\www.lotus.com
http:\\home.netscape.com
http:\\www.microsoft.com
http:\\www.ge.com
http:\\www.sap.com
http:\\www.sybase.com
http:\\www.collabra.com
http:\\www.forrester.com
http:\\www.anderson.com
http:\\www.pseybold.com
http:\\www.tbg.com
http:\\www.brill.com/intranet
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Some literature in paper-form was also analysed:

Production control in construction [Melles and Wamelink – 1993]
Construction Management and Economics journal

Although found only on the WWW, the work of the following authors was considered:

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Betts, M.

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