AN OVERVIEW OF SYSTEMS UTILIZING INFORMATION AND COMMUNICATION TECHNOLOGIES: FIVE RESEARCH CASE STUDIES

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Systems utilizing information and communication technologies have been created and developed in the Construction Engineering and Management Group at the University of New Brunswick.The aim of this research work was to introduce and integrate software and other tools such as hypertext, spreadsheets, database software, expert systems, shell programs, and artificial intelligence into an industry which is fundamentally conservative and historically slow to change and adopt innovative tools. The research included but was not limited to the development of a hypertext system for the processing of construction claims, an integrated decision support expert system for earthmoving selection and estimating, the use of Visual Basic ® to customize certain Microsoft applications to determine the effects of change orders on construction performance, the use of a hypertext information system and a simple spreadsheet to assess significant risk factors and to evaluate project uncertainties so that their effect could be shown on the project schedule, and a software application for the information management of a quality management system in a mega highway project. The results of the research and development activities showed that the construction industry will keenly adopt innovative technologies but only under the right conditions. The development of emerging information and communication technologies can provide a means of improving or replacing traditional methods by utilizing computer software and the experience, knowledge and judgement of many experienced practitioners.

Keywords: construction performance, information and communication technologies, expert systems, hypertext.

INTRODUCTION

The construction industry, a naturally conservative industry, has taken time to accept emerging technologies. However, in a relatively short time the more technical segments of the industry went from regarding expert systems as rather too academic to readily adapting the technology in their systems.

Many analytical methods have recently been used in the development of systems, such as regression analyses, modelling, neural networks, random deviation detection, and many more. Combined analytical and computer methods have also been used in the development of decision support systems including expert systems using artificial intelligence and modelling. Computer software has been utilized in the development of systems such as shell programs, spreadsheets, hypertext, database software, and project management systems.

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An important aspect of this research and development work was to show that emerging technologies and innovative systems could be very effective in an industry, which is fundamentally conservative and historically slow to change and adopt innovative technologies. It was found that innovative systems could be introduced under the right conditions. The winning conditions were when there was a close collaboration between the practitioners and researchers, an upper management champion to manage the introduction of the innovative systems, and a fairly obvious perceived need and usefulness of the new system.

The scope of the research described is limited to some of the systems which have been developed in one group using emerging information and communication technologies in construction engineering and management. Systems in the areas of claims, risk, scheduling, change orders, equipment selection, quality systems are briefly described to show which technologies have been used. The new technologies, shown in Table 1, included hypertext, expert systems and the use of artificial intelligence, shell programs, Visual Basic®, Microsoft applications, spreadsheets, databases, browser interfaces, and handheld interfaces.

Table 1: New technology tool – functional activity.

New technology tool / method	**Functional activity**
hypertext	claims
expert system, artificial intelligence, shell program	earthmoving operations
hypertext, spreadsheet	risk – schedule
visual basic ®, Microsoft applications	change orders
databases, browser interfaces, handheld interfaces	quality

The objective of the paper is to show how the introduction and integration of innovative systems can utilize emerging technologies and thus benefit management in the construction industry.

HYPERTEXT

A system was developed which used hypertext in the processing of construction claims (Christian & Bubbers, 1992). As is well known today hypertext is a method of text retrieval. Before the advent of Windows and the many common uses of hypertext, this research helped pave the way in the early 1990's in the practical use of hypertext in construction management. It showed that a hypertext system could inform the user of the rights and obligations contained in the contract conditions. The hypertext nodes guide the user to relevant information contained in various documents. The system can inform less experienced users what constitutes reasonable costs and is capable of presenting the user with a contrary opinion thus making the user aware that claim decisions in construction are not always straightforward.

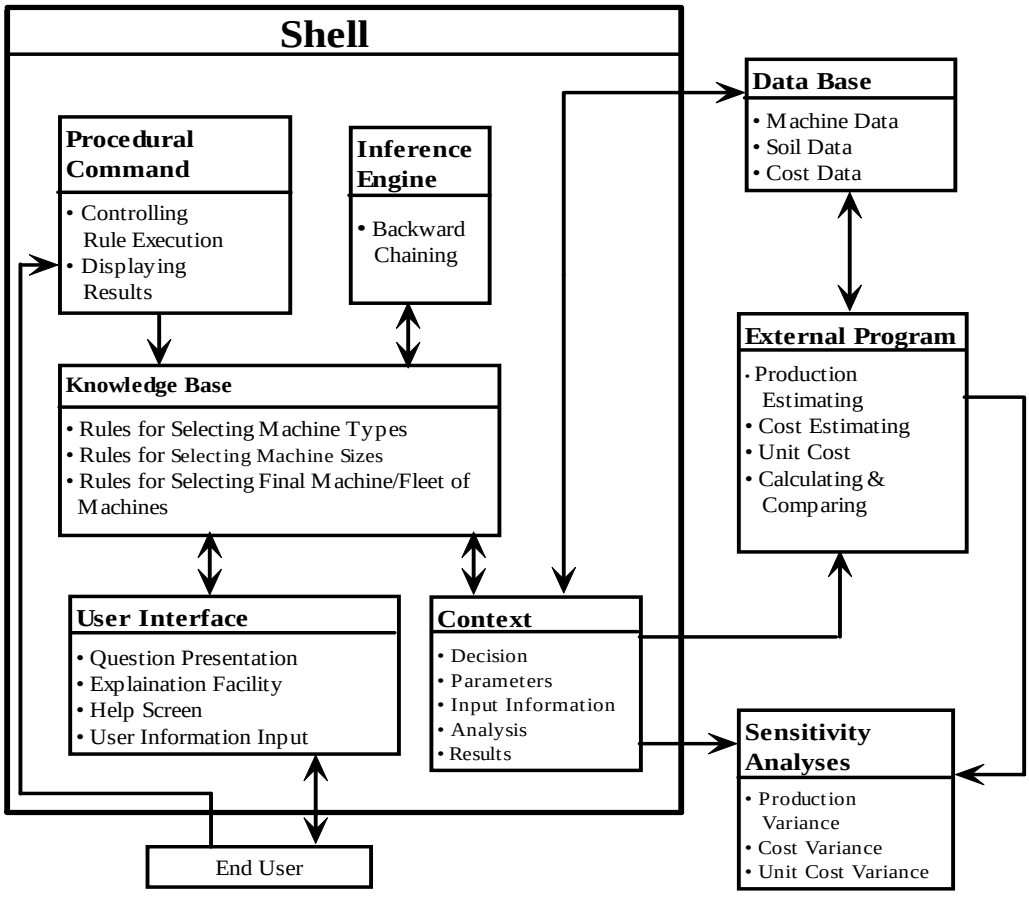
EXPERT SYSTEM – SHELL PROGRAM – DATABASES

A computer based integrated interactive decision support expert system was developed for earthmoving equipment selection and estimating using a shell program (Christian & Xie, 1998). The system contains a knowledge base, into which the knowledge obtained from experts in the industry and from other sources is stored, a user interface, with a question and answer format with explanation and help facilities, and an inference engine. The structure of the system also includes three databases,

giving data on machines, soil characteristics, and costs. Sensitivity analyses are also possible within the system.

The system has the capability of selecting appropriate fleets of machines from sixty machines considered in the system, and estimates their outputs and costs, based on the given working conditions. Through a relatively easy question-answer routine of consultation, recommendations and answers can be rapidly made and presented by the system. In the planning for equipment in an earthmoving operation, a decision should be made on what machines should be employed in the operation. In making such a decision, many interactions between engineering and economic considerations must be taken into account. By searching different sources and consulting with experts, knowledge on various common types of earthmoving operations was acquired and stored in the knowledge base of the expert system developed. To acquire knowledge regarding the type of machine versus the type of operation, and to implement the knowledge in the expert system, a rating system for selecting machines that are suitable to each operation was developed. Machines were weighted according to their appropriateness to each type of operation. Many experts contributed to this knowledge base. The expert system used human expert knowledge, in a specific domain, to reach a level of performance achievable only by a group of skilled human experts. The research showed that as a decision support tool, an expert system for earthmoving operations can assist an earthmoving planner, especially one who is less experienced. Even a skilled planner may benefit from such an expert system as it can quickly reach a solution that could be used as a reference or a datum. Refer to Figure 1 for the structure of the system.

Figure 1: Interaction between the Various Components of the Software



HYPERTEXT AND SPREADSHEETS

A systematic way to consider and quantify uncertainty in construction schedules was developed (Mulholland & Christian, 1999). The system uses knowledge and experience acquired from many experts, project-specific information, decision analysis techniques, and a mathematical model to estimate the amount of risk in a construction schedule at the initiation of a project. The model provides sensitivity analyses for different outcomes where the effect of critical and significant risk factors can be evaluated. The system includes the following two key features:

1. A hypertext information system for schedule risk identification
2. A spreadsheet to describe and evaluate project uncertainty.

Part of the development of the system utilized a Macintosh PC and commercially available application programs called HyperCard and Excel. In the system, the HyperCard application program provides an information module that can be used in identifying schedule risks. The Excel spreadsheet is the tool used for modelling the effects of the risks on the project performance time.

The hypertext system is used to store and give access to information concerning previously experienced schedule risks. The main system is composed of schedule risk information (facts, data, and heuristics) linked together using hypertext tools. Refer to Figure 2. The information can be in the form of text, graphics, or pictures.

The hypertext links in the system provide the means to access the documents within the database. A spreadsheet database was created to model uncertainty in the engineering design phase. The spreadsheet is also used to model the total project schedule risk. Refer to Figure 3. The information can then be displayed pictorially on the computer screen using the graphical functions of the spreadsheet program.

VISUAL BASIC® AND MICROSOFT APPLICATIONS

Forty different projects were examined in detail to determine the effects of change orders on performance for various types of contract (Christian & Cariappa, 1999). The number and the cost of changes were identified and changes were tracked to show the effect on performance and quality. The tracking of changes was made easier with the use of computers. One of the aims of the research was to create an interface between suitable software, with the objective of facilitating the monitoring of the performance of projects. A decision was made that a spreadsheet and a scheduling package would be preferable for recording and analyzing the data. A search and analysis of the available software packages that could be customized to meet the required objectives was made. The software was required to keep track of the changes occurring during the project and show the effect the changes had on the schedule and the cost of the project. As a result of the search, it was decided that Visual Basic® from Microsoft would be used to customize certain Microsoft applications. Visual Basic® programming language for Windows is the modern dialect for BASIC (Beginners All-purpose Symbolic Instruction Code) programming language. The two packages that were selected to interface with Visual Basic®, in this case, were Microsoft Project® and Excel® as they could be modified using the macros and the Visual Basic® editor. A Visual Basic® interface was created for this purpose. Refer to Figure 4. An advantage of the customized software is that it enables the user to input data for an individual activity simultaneously in both packages.

Figure 2: Hypercard Risk Identification – System Strategy

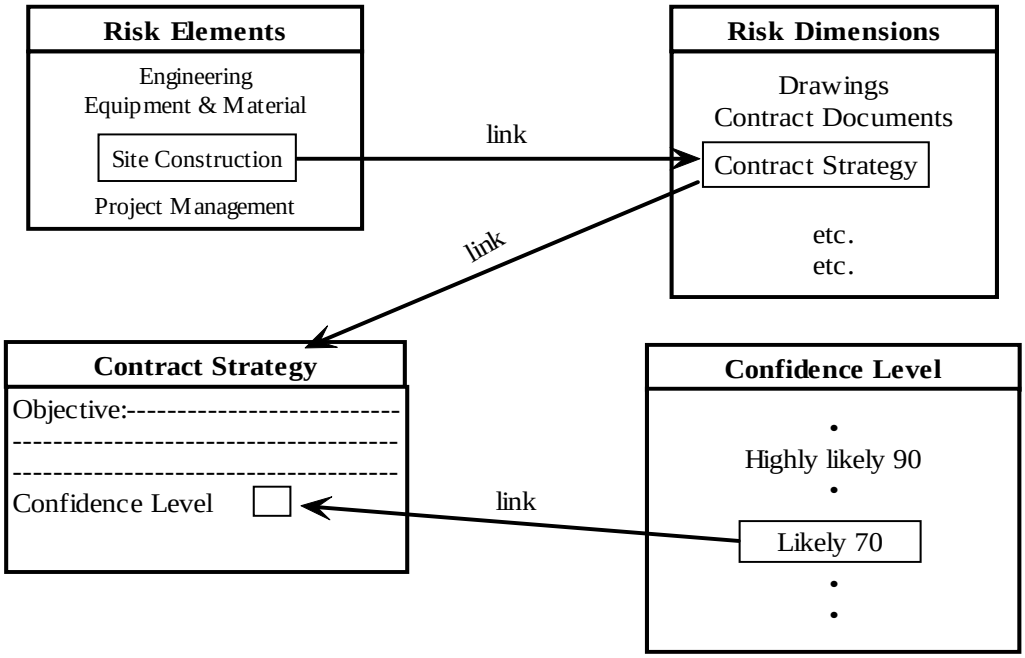
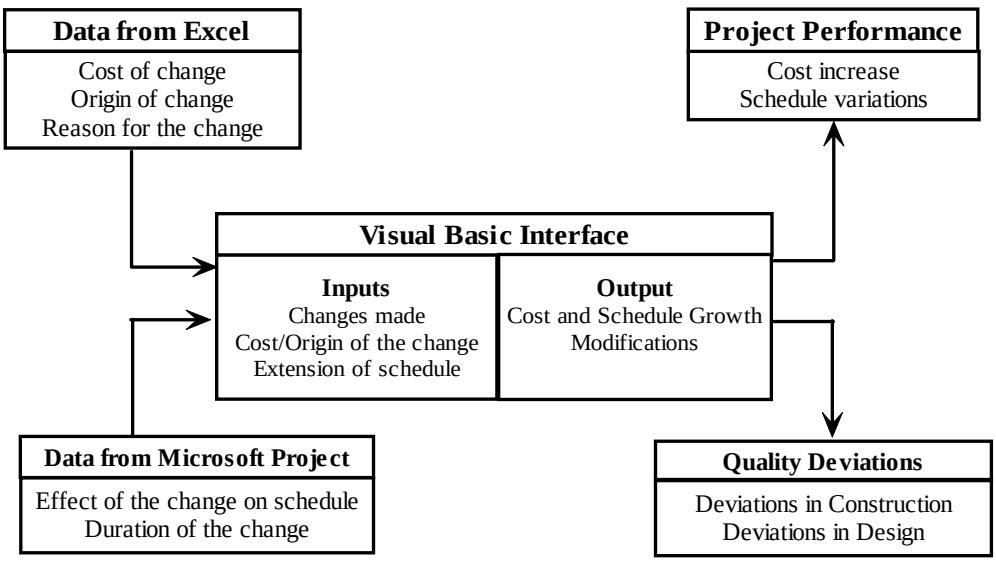


Figure 3: Excel database – modelling uncertainty and risk

Database – Engineering

Risk #	Risk Source	Level of Importance	Confidence Level	Description
89	----------	L	L	----------
90	----------	L	L	----------
91	----------	M	H	----------
92	Site Investigation	H	M	Changes – Insufficient Site
93	----------	H	M	Investigation
94	----------	M	M	----------

Figure 4: Interaction between the Various Components of the Software



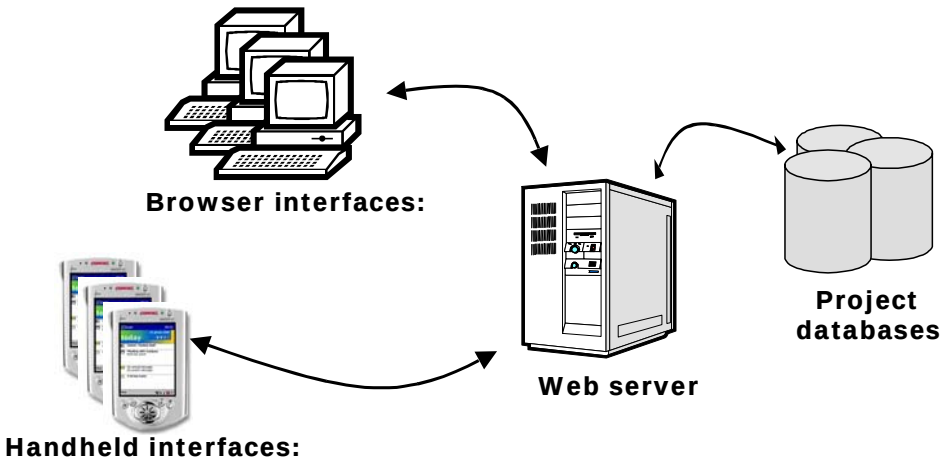
SOFTWARE APPLICATIONS – MS ACCESS® – ALLAIRES COLD FUSION® PUBLIC-PRIVATE PARTNERSHIP

A Quality Management Tool (QMT) was developed and implemented for the design-build-operate company in a public-private partnership mega highway project. The resulting software application (QMT) was designed and developed with the following functional characteristics: it should support the information management needs of the project and deliver an effective quality management system, it should cover various levels of detail in storage, viewing, and reporting information, it should be flexible and extensible in its set-up and use, it should employ an integrated approach to construction management information with an open data structure, and finally it should support analysis in conjunction with the ability to report on elicited information.

The QMT is a web-based system created from the concepts of previously developed systems and focuses primarily on quality, safety and environmental construction information. Figure 5 shows the overall architecture for the system.

Two software applications, Allaire's Cold Fusion® and Microsoft's Access®, were used for development and the system is hosted on a server running Microsoft's Internet Information Server®.

Figure 5: QMT system architecture



The interface for the QMT was based on previous work completed for other modules of collaborative web based tools for the construction industry by the Construction Technology Centre Atlantic. Collaborative Project Environment (CPE) is a system that supports data sharing and collaboration during the construction process through a centralized point where information is housed and access is controlled through a web browser interface. The scope of information supported by CPE is wider than that of the QMT. An extension to QMT was developed to explore the application of handheld computers. This permitted portability and field entry of deficiency related information for inclusion in the project database.

DISCUSSION AND CONCLUSIONS

The process of implementation of the five systems described tended to be automatic. Most of the researchers were attached to companies or government/corporation

departments and were conducting the research on an intermittent full-time or part-time basis. To a large extent therefore the systems were introduced in-house and have been utilized and modified since the research was conducted. The degree of implementation varied. At one extreme, when the Quality Management Tool was developed, the system was immediately implemented in the construction of the mega highway project where one of the research team members was basically full-time on the 200 km project site. The project is now complete but there are plans to modify the system for future projects from the lessons learned. At the other extreme, where the hypertext system was developed for processing construction claims, the system was developed more as a proof of concept, so that the researcher, who was a senior engineer within the company, was able to utilize the knowledge gained from the process for future projects in his large consulting engineering company. In between these extremes, the systems were implemented and integrated into other less technical systems within government departments, companies and corporations. Some of the systems were also extensively used very effectively in undergraduate student assignments and projects and were modified from the experience gained.

The methods used to develop the system and body of knowledge for the five case studies included the elicitation of knowledge from colleagues and the many experienced practitioners within the organization of one of the research team members. Other methods used to acquire knowledge and capture and elicit the experience of practitioners were through extensive questionnaires, extensive studies of the organization's data, and studies of the organization's procedures. Advice on the latest computer systems and innovations was gained from experts within the Faculty of Engineering, the Faculty of Computer Science, the Department of Integrated Technology Services, and the Information and Communication Technology Centre all within the university, and also in-house experts within the company organizations. Sometimes the latest innovative technologies were not used because the researcher from a particular company needed to use the company's own computer systems so that the newly developed system could be easily integrated.

Findings from the research ranged from proving the concept could work to the successful, complete and immediate adoption of the systems as it was developed. There was a distinct downside in the development of two of the systems described in the case studies. Projects come to an end, and it has been found that as time elapses before the next major project commences, it is difficult to redevelop the momentum of the research, and to reassemble a research team.

Systems utilising emerging information and communication technologies can be extremely useful to management in the construction industry providing that the right conditions exist for their introduction. These innovative technologies can provide a means of complementing or replacing traditional methods by utilising computer software and the combined experience and knowledge of many experienced practitioners.

The rapid development of information and communication technologies contributes to effective ways in reaching solutions which are sometimes difficult to obtain manually using conventional mathematical and analytical methods. Traditional methods employed in construction management decisions involve qualitative information. Experience, judgement and intuition are often needed to make a decision from many diverse factors. Because of this, traditional approaches are often inadequate. The development of emerging information technologies provides a way to overcome the

limitation of traditional methods, to a certain degree, by incorporating the experience, rules of thumb, and judgement of many knowledgeable experts.

The right conditions which make the research and development of emerging and maturing technologies successful are when there is a close collaboration between industry practitioners and researchers, an upper management champion, to effectively manage the implementation of the innovative system, a fairly obvious perceived need and usefulness, and proof that the new system will ultimately be cost effective.

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REFERENCES

Christian, J. & Cariappa, A. 1999. "Using Software to Monitor Performance of Construction Projects", p.229-234, *Civil-Comp. Press*, Oxford.

Christian, J. & Mullholland, B. 1999. "Risk Assessment in Construction Schedules", *Journal of Construction Engineering and Management*, Vol. 125, No. 1, pp.8-15, American Society of Civil Engineers, New York, January/February.

Christian, J. & Xie, T.X. 1998. "A Computer-Based Integrated System for Earthmoving Equipment Selection and Estimates" (Invited paper). Vol. 5, No. 2, pp.1-18, *International Journal of Construction Information Technology*, England, Winter, 1998.

Christian, J. & Bubbers, G. 1992. "Hypertext and Claim Analysis", *Journal of Construction Engineering and Management*, Vol. 118, No. 4, pp.716-730, American Society of Civil Engineers, December.

Mrawira, D., Rankin, J. and Christian, J. 2001. "Challenges of Quality Information Management in A Public-Private Partnership Highway Project Environment: Lessons from the Fredericton to Moncton Highway Project", *2001 Annual Conference of the Transportation Association of Canada*, CD-Rom, Halifax, Nova Scotia, 2001.

Lundrigan, B., Mrawira, D., Rankin, J. and Christian, J. 2001. "A Quality Management Tool for a Public-Private Partnership Highway Project", *4th Construction Specialty Conference of the Canadian Society for Civil Engineering*, C46-CD Rom, Victoria, British Columbia, May 30-June 2, 2001.