# UTILITY ASSESSMENT OF ELECTRONIC NETWORKING TECHNOLOGIES IN CONSTRUCTION

Internet applications in construction

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Durability of Building Materials and Components 8. (1999) *Edited by M.A. Lacasse and D.J. Vanier*. Institute for Research in Construction, Ottawa ON, K1A 0R6, Canada, pp. 2259-2269.
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## Abstract

Despite an explosive growth in virtually all areas of industry and commerce, Electronic Networking Technology (ENT) has only begun to make inroads into the construction industry practice. Although information exchange protocols in construction firms and on construction project sites make it difficult to take advantage of most ready-made solutions applicable in other industries, there is a significant potential of large benefits from the correctly developed and applied ENT solutions for construction firms and construction project site offices. This paper describes the ongoing research effort to determine variables related to the application of ENT protocols for the main types of construction project delivery systems and to measure the utility of ENT configurations in facilitating communication between parties involved in a construction project with respect to specific project delivery systems.

Keywords: Electronic Networking Technologies, Internet, Intranet, Multiple Attribute Value Measurement, project delivery system, utility assessment

## 1 Introduction

The key to maintaining and upgrading U.S. built infrastructure is the technological prowess of the construction industry, a $500 billion plus business and the largest contributor to the national economy. Construction industry at the end of the 20th century is facing many challenges from the market, as the forces to change and to incorporate new advanced technologies into the construction process become stronger (Fisher and Yin 1992). Construction, like branches of other industry, has already entered the information age by using information technology in a variety of ways. Yet the information technology is still used in a disintegrated fashion and there

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are many limitations with the current use of information technology in construction (Betts et al. 1991).

Meanwhile, the construction industry suffers from fragmentation, since within any sizeable construction project the project organization is complex and has many phases. A project team consists of many parties with different level of knowledge, disciplines, expertise, resources and interests. The project life cycle is divided into several separate phases, (i.e. feasibility study, design, procurement, construction, operation and maintenance, and eventual retrofit or demolition.). This management environment in the construction industry is widely believed to be a significant impediment to successful implementation of information technology in construction. Problems of implementation of information technology in construction are in essence organization and technology integration problems, involving the exchange of information and knowledge among different parties to a project. Pudicombe (1997) suggested ways to achieve organizational integration by the use of contractual and social/psychological approaches, and to achieve technological integration by the use of integrated computer technology.

## 2 The need for communication tools

One approach that has been used to incorporate the organizational integration is related to the management system which the owners choose in conducting the project. This approach is based on facts that the degree to which the construction can be integrated into the process is determined by the project delivery system (Walker 1996). The traditional method, i.e. separate design and construction, fragmented the phases and the construction team. In recent years, the owners have started to implement other delivery systems that can increase the degree of integration, such as design-build, turnkey and Build-Operate-Transfer (BOT), as well as by allowing a constructor to participate in the design process and creating more designer/contractor teamwork (Gordon 1994).

That approach is supported also by the adoption of Concurrent Engineering into the construction industry from manufacturing industries. Concurrent Engineering is intended to improve the performance during the design process by considering all aspects of the project's downstream phases concurrently, eliminating of non-value adding activities, and encouraging multi-disciplinary team (Love and Gunasekaran 1997). To implement this, there is a need for tools that can support collaborative environment. The enabling information and communication technologies are important in the establishment of effective communications protocols for collaborative work in construction management (Anumba 1996).

For accommodating technological integration, the concept of Computer Integrated Construction (CIC) is commonly used. CIC is a computer-based concept that is intended to integrate project participants into a collaborative team with the utilization of computer applications through all phases of a project (Teicholz and Fischer 1994). From some experiences, the communication technology to transfer information plays important role in CIC implementation (Miyatake et al 1992).

Regardless of the approaches used in incorporating integration in construction, communication tools is a must. The greater the level of collaboration and concurrency in a process, the greater the level of coordination required. This will lead to more communication between phases, processes and parties.

## 3 Electronic networking technologies as communication tools

There are enabling information technologies that have a potential for use in all integration aspects in construction. One such technology is the Electronic Networking Technology (ENT), which includes the Internet, Intranet and Extranet technologies. The ENT has attracted the world's attention with its distinctively advanced features, such as platform, time and geographic independence. Since it emerged about 30 years ago, Internet has been evolving very fast. It is now becoming a collection of networks, with millions of individuals and businesses connected to the Internet, and it is growing faster as the World Wide Web (WWW) emerged. ENT is widely believed to be capable of supporting collaborative work environments. The Forrester Report concluded that Internet and Intranet technologies will remove many of the obstacles to collaboration within firms and across teams, and predicted that the more useful collaboration tools will appear by the end of 1999 (Brown et al. 1996).

In order to implement the approaches for enabling electronic integration in construction using ENT, careful planing and innovative strategies are needed. Gerstein (1987) concluded that the critical element is neither the application area nor its underlying technology that makes IT strategically important. It is the specific role of a particular technology application to a given industry at a point in time that makes the difference. Regardless of how attractive the use of ENT in the construction industry may seem, the efforts of implementing such technology should be preceded by the evaluation of its utility in a specific application scenario. The evaluation will determine whether the ENT based applications in construction project management will perform as intended.

## 4 Objectives of ENT assessment

The main objective of the assessment effort is to measure the utility of ENT for various types of construction projects, and further specific objectives are derived as follows:

1. To determine attributes to be considered in measuring the utility of ENT for a given construction project with a particular project scenario.
2. To measure the utility of ENT for construction industry, with regard to the degree of integration associated with the specific project scenario.
3. To develop optimal ENT configurations for various type of construction projects based on the assessed value of utility of ENT.

## 5 Utility of electronic networking eechnologies

Utility is only one of the measures of practical system acceptability under attribute of usefulness as depicted in Fig. 1. Here, utility is defined as the ability of the functionality of the system to fulfill in principle what is needed by the user.

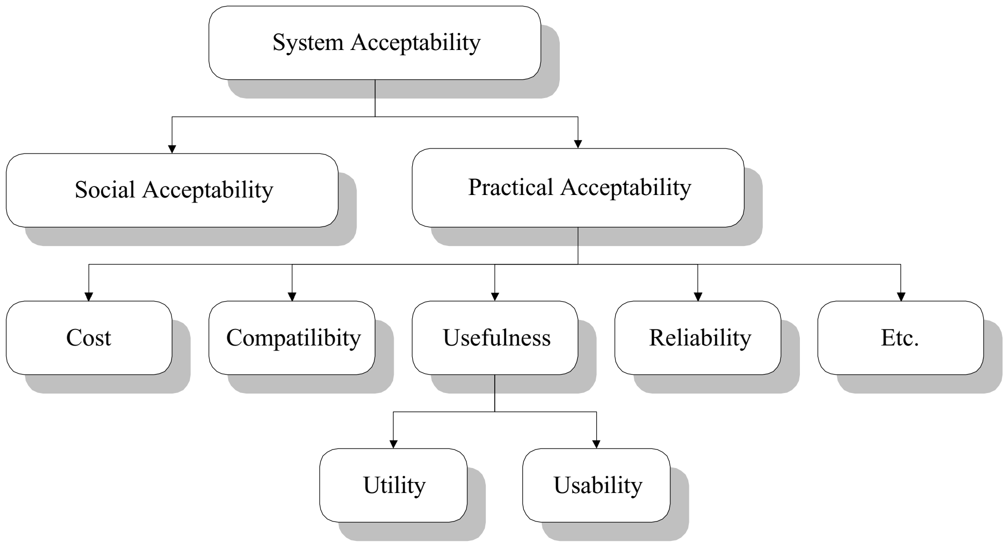


**Fig. 1: Model of the attributes of system acceptability (partially adapted from Nielsen 1993)**

Based on the above definition, the utility of a system can be measured with respect to its functions. A successful system in terms of its utility requires much attention to the characteristics and identity of the user, the user's task being supported, and the environment in which the system operates. Those aspects suggest the implementation of a human-machine system (Shackel 1991) as depicted in Fig. 2. With this framework, the definition of system utility can be broadened to include determination how the available system can support the user needs in performing a particular construction management task in a given environment.

Deploying the above framework into the electronic tools for project management will explain the definition of the utility of ENT for construction projects. Furthermore, the utility of ENT for construction projects can be defined as to how the ENT services can support project tasks during the project life cycle. The utility of ENT will vary depending on the project task, the project parties involved, and the environment in which the task is taking place. It means that the utility of ENT will vary depending on the type of project delivery system used in the project since for each project delivery system the project task, the characteristics of the parties involved and environment of each stage are different. The utility of ENT for each project delivery system is useful in determining the ENT configuration for a particular project scenario. Different configuration of ENT will be needed for different project scenario not only for facilitating different type of project tasks and users, but also for accommodating different level of collaboration and concurrency in each project delivery system.

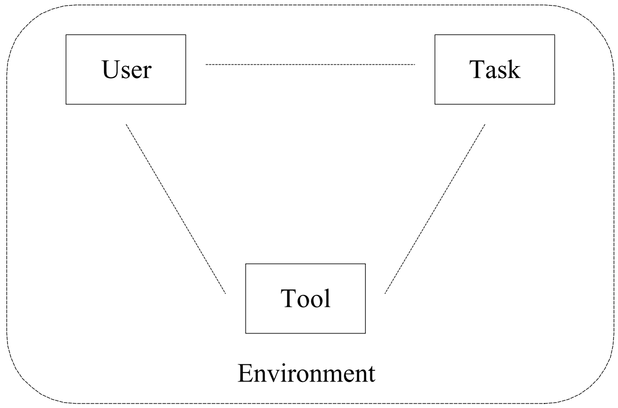


**Fig. 2: Human-machine system (partially adapted from Shackel 1991)**

## 6 The tool for measuring the utility of ENT

To evaluate ENT utility, measurement criteria based on ENT performance and users' attitude can be used. Evaluating the utility of a system such as ENT is not only a matter of evaluating the performance in supporting the user's tasks, but also evaluating the user's experience in performing a given task with the use of the given ENT system. The typical intended users of the suggested evaluation technique are construction management professionals that use ENT in some of their most challenging projects.

A feasible tool for use to measure the utility of ENT is the Multi Attribute Value Measurement (MAVM). MAVM is an appropriate tool for measuring user preferences. Direct Rating method can be used to assess the single attribute value of each attribute, Ratio Estimation can be used to assess the weights, and the additive function model will be used for aggregation model (Winterfeldt and Edwards 1986).

Measuring the utility of ENT for every type of project delivery system can be useful as a feedback for decision making process in a variety of decision tasks such as:

1. Whether to use ENT in a given construction project using a specific project delivery system; by comparing overall utility of ENT for all types of projects within this category.
2. To what extent a project will use ENT; by choosing a particular ENT which hold some criteria in term of utility.
3. How to increase the functionality of ENT to support construction processes; by analyzing ENT that have low utility with respect to a particular attribute.

## 7 Assessment methodology

In order to achieve the stated objectives, the assessment methodology is organized into three parts. The first part deals with the project delivery system, the second deals with ENT, and the third with assessing the utility of ENT for the given project type. The assessment scenario is depicted in Fig. 3.

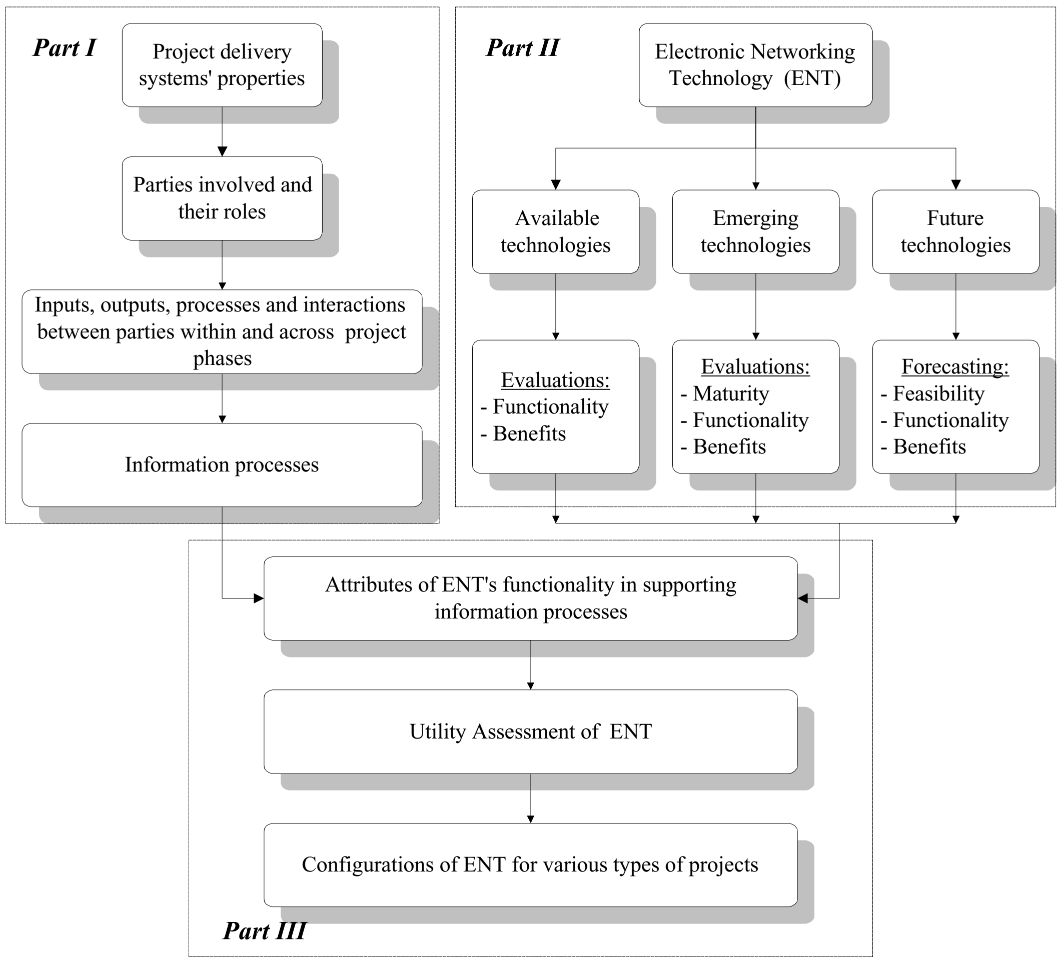


**Fig. 3: ENT Assessment Scenario**

The first part of the assessment scenario is intended to investigate characteristics and the role of the potential users of ENT in a construction project, the users' tasks that can be supported by the use of ENT, and the environment where the user's tasks are performed in every phase of the project life cycle. All possible processes that can be supported by ENT will be developed and analyzed by focusing on information processes.

The second part of the scenario is intended to investigate the type of functionality provided by ENT (i.e. Electronic mail, File Transfer Protocol, World Wide Web, Archie, Video conferencing, etc.), not only the ones that are already available but also the ones that are emerging and might be available in the future.

The third part develops the assessment system of the utility of ENT for various construction projects and for implementing ENT in specific application scenarios. Attributes to measure the utility of ENT can be developed by focusing on the information process supported by ENT. MAVM can be used further to measure single attribute utility and overall utility of ENT by assigning weights to each attribute.

The implementation of the assessment system can be accomplished by using expert reviews by industry practitioners. For this purpose, a questionnaire can be developed to enable the assessment of the utility of ENT. The questionnaire can be distributed to the respondents over the World Wide Web. The content of the questionnaire can be based on the developed assessment system and the selected procedure of MAVM. The results of the implementations of the assessment system can be useful to draw conclusions and to determine the configuration of ENT for various construction projects.

## 8 Implementation example

This implementation example describes a hypothetical utility assessment of ENT for a hypothetical project scenario. Some assumptions made for this example are:

1. The selected project delivery system for this example is a general contractor (GC).
2. The parties involved in this project are: owner, architect/engineer, contractor, suppliers and subcontractors.
3. All parties have been using ENT for supporting their operations and projects.
4. The objects of evaluation are the functionality of Internet and Extranet, such as electronic mail, FTP, telnet, list server, newsgroup etc., in supporting construction processes. Assume there are three functionalities to be evaluated, which are E-mail ($i = 1$), FTP ($i = 2$), and WWW ($i = 3$).
5. Attributes for measuring the objects of evaluation are the ability of ENT to distribute the information ($D$), to search the information ($S$), and to distribute the information ($R$). All attributes are assumed independent of each other.
6. The evaluation is focusing on five processes in the construction phase, which are: schedule monitoring ($j = 1$), submittals and document control ($j = 2$), change management ($j = 3$), process invoices ($j = 4$), and cost monitoring ($j = 5$).

The single attribute values of the objects of evaluation have values between 0 and 10, and are assessed using the Direct Rating method. The weights of the importance of attributes and processes have values between 0 and 1, and are assessed using the Ratio Estimation method. The aggregation of the single attribute values are performed using an additive model as follows:

$$V_{ij} = W_D \,.\, V_{ij}(D) + W_S \,.\, V_{ij}(S) + W_R \,.\, V_{ij}(R) \quad \textbf{(1)}$$

$$V_i = \sum W_j \,.\, V_{ij} \quad \textbf{(2)}$$

Where *i* is the number of ENT functionality to be evaluated and *j* is the number of construction processes. The single attribute value of $V_{ij}(D)$, $V_{ij}(S)$, and $V_{ij}(R)$ are the utility of *i* ENT functionality in distributing, searching and retrieving information respectively for construction process *j*. $W_D$, $W_S$, and $W_R$ are the weights of attributes of the ability of ENT functionality in distributing, searching and retrieving information respectively. These weights are assessed by comparing the importance of the attributes to each other in a particular construction process. The utility of *i* ENT functionality for construction process *j* ($V_{ij}$) can be derived using equation **(1)**. The utility of *i* ENT functionality for a particular project delivery system ($V_i$) can be derived using equation **(2)**, where $W_j$ is the weight of process *j* that can be assessed by comparing each construction process with respect to their importance in the project.

For this implementation example, the result of the assessments by the respondents of the questionnaire and the aggregation of single attribute values are depicted in Table 1 to 4. Table 1 depicts the assessed weights of processes and the weights of attributes *D*, *S* and *R* for each process.

**Table 1: Assessed Weights**

| Construction Process (*j*) | Process Weight ($W_j$) | Weight of Attribute | | |
|---|---|---|---|---|
| | | $W_D$ | $W_S$ | $W_R$ |
| 1 | 0.2 | 0.40 | 0.40 | 0.20 |
| 2 | 0.2 | 0.50 | 0.14 | 0.36 |
| 3 | 0.2 | 0.38 | 0.38 | 0.25 |
| 4 | 0.2 | 0.40 | 0.20 | 0.40 |
| 5 | 0.2 | 0.40 | 0.40 | 0.20 |

The assessed single attribute value of each object evaluation for each process is depicted in Table 2 to 4 under column 'Attribute'. Using the assessed weights from Table 1 and the additive models (1) and (2), the aggregation of single attribute values are calculated and depicted under '$V_{ij}$' column.

**Table 2: Assessed single attribute value of utility of E-mail (*i* = 1)**

| Project Phase | Construction Process (*j*) | Attribute | | | $V_{1j}$ |
|---|---|---|---|---|---|
| | | Distribute | Search | Retrieve | |
| Construction | 1 | 4 | 2 | 6 | 3.60 |
| | 2 | 9 | 8 | 8 | 8.50 |
| | 3 | 8 | 6 | 8 | 7.25 |
| | 4 | 7 | 8 | 8 | 7.60 |
| | 5 | 4 | 2 | 6 | 3.60 |
| | | | | $V_1$ | 6.11 |

**Table 3: Assessed single attribute value of utility of FTP ($i = 2$)**

| Project Phase | Construction Process ($j$) | Attribute | | | $V_{2j}$ |
|---|---|---|---|---|---|
| | | Distribute | Search | Retrieve | |
| Construction | 1 | 6 | 5 | 8 | 6.00 |
| | 2 | 7 | 5 | 6 | 6.36 |
| | 3 | 4 | 5 | 6 | 4.88 |
| | 4 | 2 | 2 | 3 | 2.40 |
| | 5 | 6 | 5 | 8 | 6.00 |
| | | | | $V_2$ | 5.13 |

**Table 4: Assessed Single Attribute Value of Utility of WWW ($i = 3$)**

| Project Phase | Construction Process ($j$) | Attribute | | | $V_{3j}$ |
|---|---|---|---|---|---|
| | | Distribute | Search | Retrieve | |
| Construction | 1 | 7 | 8 | 6 | 7.20 |
| | 2 | 5 | 8 | 5 | 5.43 |
| | 3 | 8 | 8 | 4 | 7.00 |
| | 4 | 5 | 3 | 3 | 3.80 |
| | 5 | 7 | 8 | 6 | 7.20 |
| | | | | $V_3$ | 6.13 |

Some conclusions can be drawn from Table 2 to 4 which are associated with the construction process $j = 1$, which is schedule monitoring:

- The ability to distribute and to search information of WWW are assessed to have the biggest value ($V_{31}(D) = 7$ and $V_{31}(S) = 8$). While FTP is assessed to have the biggest value in retrieving information ($V_{21}(R) = 8$).
- Using an assumption that the feasible functionality should have value of utility of ENT more than 5.0, FTP and WWW are assessed to be feasible for monitoring of project schedule ($V_{21} = 6.00$ and $V_{31} = 7.20$).

For other processes, the same approach can be used to have the acceptable utility of ENT functionality for particular process. Furthermore, using an assumption that the feasible functionality for supporting a construction project should have value of utility of ENT more than 5.0, all evaluated functionality in the example (i.e. E-mail, FTP and WWW) can be used for supporting a GC project delivery system since $V_1 = 6.11$, $V_2 = 5.13$ and $V_3 = 6.13$. Further analysis from the conclusions above will arrive at the configuration of ENT for a GC project delivery system.

## 9 Conclusion

ENT as enabling communication technologies in distributing, searching and retrieving information for construction processes are expected to solve the organizational and technological integration problems in construction. Implementation of ENT should be proceeded by the evaluation of utility of ENT which can be assessed by Multi Attribute Value Measurement technique. The result of the assessment can be used to develop the optimal configuration of ENT for a particular project delivery system and its processes.

This paper describes the ongoing research effort to determine variables related to the application of ENT protocols for the main types of construction project delivery systems and to measure the utility of ENT configurations with respect to specific project delivery systems.

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