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OPTIMAL CONFIGURATION OF ELECTRONIC NETWORKING TECHNOLOGIES FOR SUPPORTING D/B PROJECTS

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Abstract. Electronic Networking Technologies (ENT) have only begun to make inroads into the construction industry practice. ENT provide unparalleled opportunities for the construction industry to introduce new and innovative way of processing information. These opportunities also present a number of challenges in terms of how to plan for and implement ENT services. There is a significant potential for large benefits from the correctly developed and applied ENT solutions for construction projects activities. This paper presents an assessment model for determining utility of various ENT services and the optimal configuration of ENT services for D/B projects. Web and FTP services were included in the ENT configuration as the tools to support all activities that require information retrieval. E-mail, list server, video conferencing, and remote access services were included in the ENT configuration as communication tools. An implementation scenario of the utility assessment model and a discussion on issues that should be considered in implementing ENT services in construction are presented.

Keywords: design-build, electronic networking technologies, Internet, utility assessment.

1. Introduction

A study by the authors developed an assessment model to measure the usefulness of ENT services by focusing on their utility in supporting information processing in D/B project activities. The modeling of utility assessment of ENT services has been based on the multi-attribute value measurement [1]. The utility of ENT services for construction activities is a part of ENT's overall acceptability in the construction industry, and is defined as the measure of how the ENT services can support project activities during the project life cycle. Its utility will vary depending on project activities, the parties involved, and the environment in which the activities are taking place [2].

Analysis results from the survey on the utility of ENT services for Design-Build activities are extensively used to describe the use of ENT services by all project participants during the life cycle of the project. Furthermore, the utility of each ENT service is analyzed to decide which services should be included in the optimal configuration of ENT services for supporting Design-Build activities. A heuristic algorithm was developed to determine the optimal configuration of ENT services.

An implementation scenario was developed to perform the utility assessment of ENT services. The scenario includes providing the primary ENT services, selecting activities on which to focus, investigating other ENT services, using the assessment model to measure the utility of ENT services, configuring ENT services for the selected activities, and planning the implementation.

This paper presents the assessment model to determine utility values of various ENT services and the optimal configuration of ENT services for D/B projects. Subsequently, it also provides an implementation scenario of the utility assessment model developed and a discussion on the practical issues that should be considered in implementing ENT services in construction project activities.

2. Communication needs in construction

The construction industry suffers from fragmentation, for the many different types of businesses comprising typical construction project. In a large project, the project organization is complex and has many phases. A project team consists of many parties with different professional and technical disciplines, expertise, resources and business interests. The project life cycle is divided into separate phases, ie, feasibility study, design, procurement, construction, operation, maintenance, and eventual retrofit or demolition. This management environment

is widely believed to be a significant impediment to successful implementation of IT. Problems of implementation of IT in construction are in essence organization and technology integration problems, involving the exchange of information and knowledge among different parties.

Tatum [3] suggested integration through the application of IT as a method for linking the traditionally discrete phases of design and construction. However, the performance of the construction industry cannot be addressed by the use IT only. Nam and Tatum [4] suggested four major means to increase construction integration: contractual, organizational, information and non-contractual. Organizational integration is needed in order to implement the information integration. Therefore, a combination of organizational and technological integration is required and a structure that organizationally links the project participants, as well as allowing the efficient sharing of information, is necessary [5].

The adoption of Concurrent Engineering into the project delivery process from manufacturing industries is also believed to support the organizational integration. Concurrent Engineering is intended to improve the performance during the design process by considering all aspects of the project's downstream phases concurrently, eliminating the non-value adding activities, and encouraging a multi-disciplinary team [6, 7]. 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 [8].

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 [9]. Based on prior experience, communication technology for transferring information plays an important role in CIC implementation [10].

3. Electronic networking technologies (ENT)

There are information technologies that have potential for use in all integration aspects in construction. One such area is the electronic networking technologies (ENT), which include the Internet, intranet, and extranet technologies. ENT has attracted the industry's attention with its platform, time, and geographic independence. Since it first emerged about 30 years ago, the Internet has evolved quickly and has become a collection of networks, growing even faster as the World Wide Web (WWW) emerged. At the turn of the millennium, ENT access now is not only available to government, educational, and research education, but has opened up widely to commercial users. ENT growth in the last five years has been explosive in many areas of business and commerce. The current trends in ENT can also be regarded as opportunities to meet a variety of project communication needs in the construction industry.

Despite an explosive growth of the ENT usage in many areas of business and commerce, the construction industry has not kept pace to the same degree [11]. However, many large construction firms have entered the ENT age. The basic ENT services such as electronic mail, remote login, file transfer, network news, and the Web have become familiar tools for some construction managers, and many project web sites are utilized as a portal to facilitate collaboration between parties in a project. Current Web technologies make the Web-based project management services available for construction companies, while the ongoing research in academia constitutes new opportunities that can be used to improve construction processes [12]. It was also concluded that the ENT have been used by visionary contractors who pursue changes in technology and by pragmatic contractors who typically wait until a product is established as an industry standard [13].

However, efforts to implement ENT in construction activities should be preceded by the assessment of their utility in specific application scenarios. The scenarios are likely to be different in each project delivery system due to the different nature and extent of teamwork required from all project participants. An assessment model to measure the utility of ENT services to support activities in a particular project delivery system is needed [1].

4. Assessment model of utility of ENT services

4.1. Utility of ENT Services

In the field of Human-Computer Interface, utility is considered as one of measures of the usefulness of a system and defined as the measure of whether the basic functions of a system can do in principle what is needed [14, 15]. Using a human-machine system framework [16], this definition of utility can be broadened into how the available service provided by a system can support the user's needs in performing a particular task in a particular environment. The authors deployed this broadened definition into ENT system and construction project activities, and defined the utility of ENT services for construction project activities as the measure of how the basic functions of ENT services can support those activities performed by all project participants during the project life cycle. ENT services used as communication and information retrieval tools have basic functions to distribute, search, and retrieve information.

The utility of ENT services will vary depending on the project tasks, the project parties involved, and the work environment in which the task is taking place. In addition, it will depend on the type of project delivery system used in the project since for each project delivery system the project tasks, the characteristics of the parties involved, and the work environment of each stage are different.

Table 1. Attributes for assessing the utility of ENT services

Major attributes (1)	Minor attributes (2)	Description (3)
Distribution *(D)*	Format *(D_1)*	The type or format of digital information being distributed.
	Size *(D_2)*	The size of digital information that can be distributed using ENT services.
	Destination *(D_3)*	The intended destination of the distributed information.
Search *(S)*	Method *(S_1)*	The search method provided by the ENT services to be used in searching for information.
	Location *(S_2)*	The awareness of resource location where the user can search information effectively and efficiently.
	Results *(S_3)*	The quality and quantity of the search results.
Retrieval *(R)*	Characteristics *(R_1)*	The awareness of characteristics of digital information to be retrieved.
	Ownership *(R_2)*	The user's right of usage of the retrieved information.

4.2. Assessment attributes

The modelling of utility assessment of ENT services has been based on the multi-attribute value measurement [17]. This measurement involves determination of attributes to be used in assessment, assessment of the weights of importance of attributes, assessment of single attribute values, and the use of an additive model to gain overall values of measurement. The assessment model has major attributes and minor attributes for utility assessment purpose.

Attributes to measure the utility of ENT services were developed by focusing on the information process supported by ENT. The major attributes were derived from the basic functions of ENT services in information processing, ie, distribution *(D)*, search *(S)*, and retrieval *(R)*, while the minor attributes were derived from those major attributes based on the ENT system model, ie, factors that affect the ability of ENT services to perform basic functions such as characteristics of providers, receivers, storage, and digital information itself. Table 1 shows the list of major and minor attributes.

4.3. Mathematical models

The assessment model was developed on a project activity basis since each project activity needs a different type of information and different parties are involved. The assessment of weights of attributes was performed by comparing the importance of each relevant attribute to each other in a particular activity. The assessment of a single attribute value is based on the minor attributes and is performed by assigning utility value directly to each ENT service under evaluation in a particular activity. Additive aggregation is performed to calculate the overall utility of each ENT service using the weights of attributes and single attribute values of particular services. This assessment model provides straightforward calculation of overall utility values and easy assessment on both weights of attributes and single attribute values of utility [2].

If the ENT service to be evaluated is denoted as i (= 1...14) and activity is denoted as j (= 1...t), the single-attribute values of each attribute, D_k, S_l, and R_m, can be denoted as $V_{ij}(D_k)$, $V_{ij}(S_l)$, and $V_{ij}(R_m)$, respectively. Here, $V_{ij}(D_k)$, $V_{ij}(S_l)$, and $V_{ij}(R_m)$ are the utility values of the i^{th} ENT service for activity j under attribute D_k, S_l, and R_m respectively.

The trade-offs among minor attributes are quantified as importance weights of minor attributes. The weights are denoted as W_{Dk}, W_{Sl}, and W_{Rm} for minor attributes D_k, S_l, and R_m, respectively. An additive value function is applied to aggregate the single-attribute values. $V_{ij}(D)$, $V_{ij}(S)$, and $V_{ij}(R)$ that represent the utilities of i^{th} ENT service in distributing, searching and retrieving information respectively for activity j, can be obtained as follows:

$$V_{ij} = \sum_k W_{Dk}.V_{ij}(D_k), \text{ where k = 1, 2, 3} \quad (1)$$

$$V_{ij} = \sum_l W_{Sl}.V_{ij}(S_l), \text{ where l = 1, 2, 3} \quad (2)$$

$$V_{ij} = \sum_k W_{Rm}.V_{ij}(R_m), \text{ where m = 1, 2} \quad (3)$$

Further aggregation will lead to obtaining the utility of i^{th} ENT service for activity j by using the weights of major attributes of distribution *(D)*, search *(S)*, and retrieval *(R)* in another additive value function (4). The weights assessment can be accomplished by comparing the relative importance of the activities with respect to each other. The weights denoted W_D, W_S, and W_R are for distributing, searching and retrieving information processes respectively.

$$V_{ij} = W_D \cdot V_{ij}(D) + W_S \cdot V_{ij}(S) + W_R \cdot V_{ij}(R). \quad (4)$$

The utility of i^{th} ENT service for a particular project delivery system is defined as:

$$V_i = \text{S } W_{ij} \cdot V_{ij}. \quad (5)$$

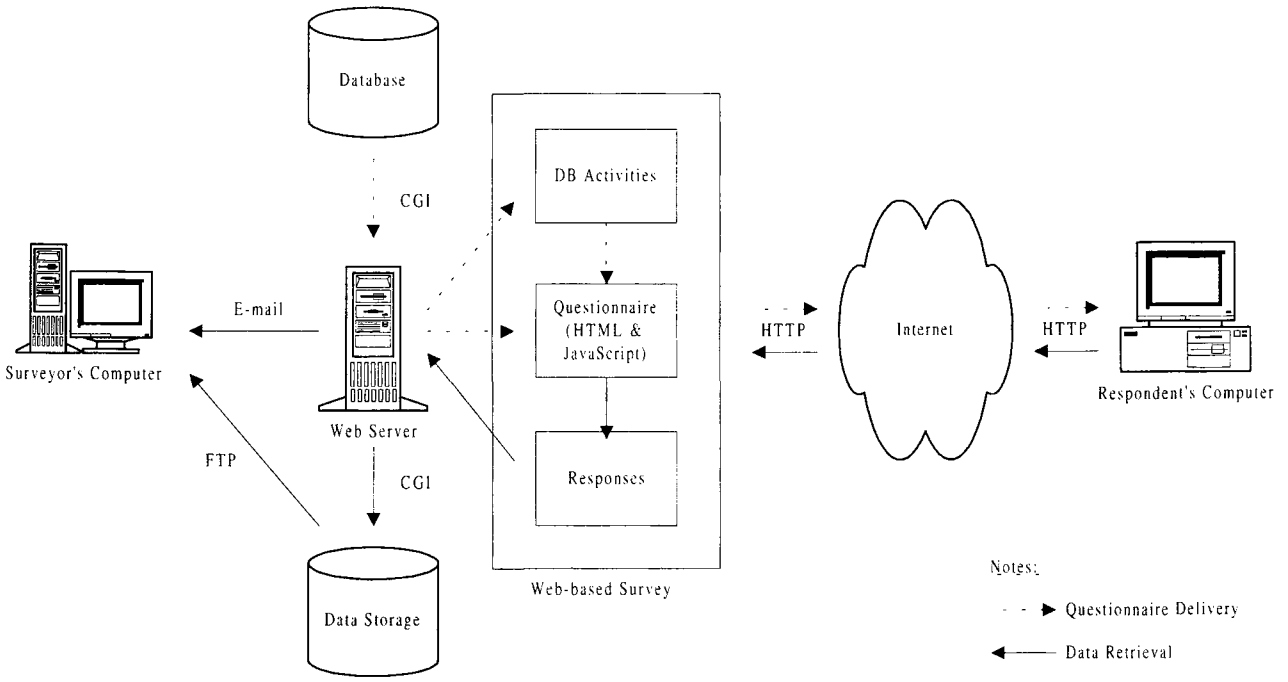

Fig 1. Architecture and processes of the Web-based survey

Where W_{ij} is the weight of i^{th} ENT service for activity j, which can be assessed by comparing the activities with respect to their overall value adding contribution to the project.

5. Survey design

The implementation of the assessment system will be accomplished in a survey by D/B professionals' reviews focusing on their attitudes, experiences and opinions of the utilization of ENT services on their projects. The developed assessment model was translated to a self-administered questionnaire for the survey purposes. The survey on utility of ENT services for D/B projects was designed to obtain practitioners' opinions on the utility of ENT services in supporting D/B activities. A self-administered questionnaire was chosen because it has many advantages compared to telephone or face-to-face interviews, ie, lower cost, large-geographic coverage, larger samples, and ease of implementation [18].

The target population for the survey was D/B project professionals, which was further narrowed down by the following criteria:

1. Experience in D/B projects or working knowledge of D/B activities.
2. Experience in using ENT services for daily activities, preferably related to work in D/B projects.
3. Knowledge of the potential use of ENT services in D/B activities.

6. Survey instruments

Electronic mail and Web technologies were utilized as survey instruments. This combination has become widely used in thousands of construction-related and other types of surveys and polls being conducted over the ENT. Since the topic of the self-administered survey relates to the use of ENT services, the use of e-mail and Web technologies in this survey is appropriate [2]. Fig 1 depicts the instruments of the Web-based questionnaire.

E-mail has three main functions in this survey. First, E-mail was used to invite people to respond to the questionnaire. With an e-mail as the cover letter or invitation, the URL of the survey site was transmitted. The second function of e-mail is to notify the surveyor if the questionnaire has been transmitted. Finally, e-mail provided most of the communication between the respondents and the surveyor regarding the survey.

The questionnaire itself utilizes Web-based technologies such as HTML, JavaScript, and CGI. HTML has been used extensively to generate, format, present, and administer the questionnaire. Most of the survey's Web pages are generated by a CGI program created using *Perl* version 5.0. The CGI program then generates 'on-the-fly' every sections of the questionnaire in HTML format. JavaScript was used to control the interactivity between.

7. The Web-based questionnaire

The Web-based questionnaire is divided into eight separate pages by design in order to control the flow of the answering process by respondents. The logic of the questionnaire follows the developed assessment model as depicted in Fig 2. Following are the descriptions of the questionnaire.

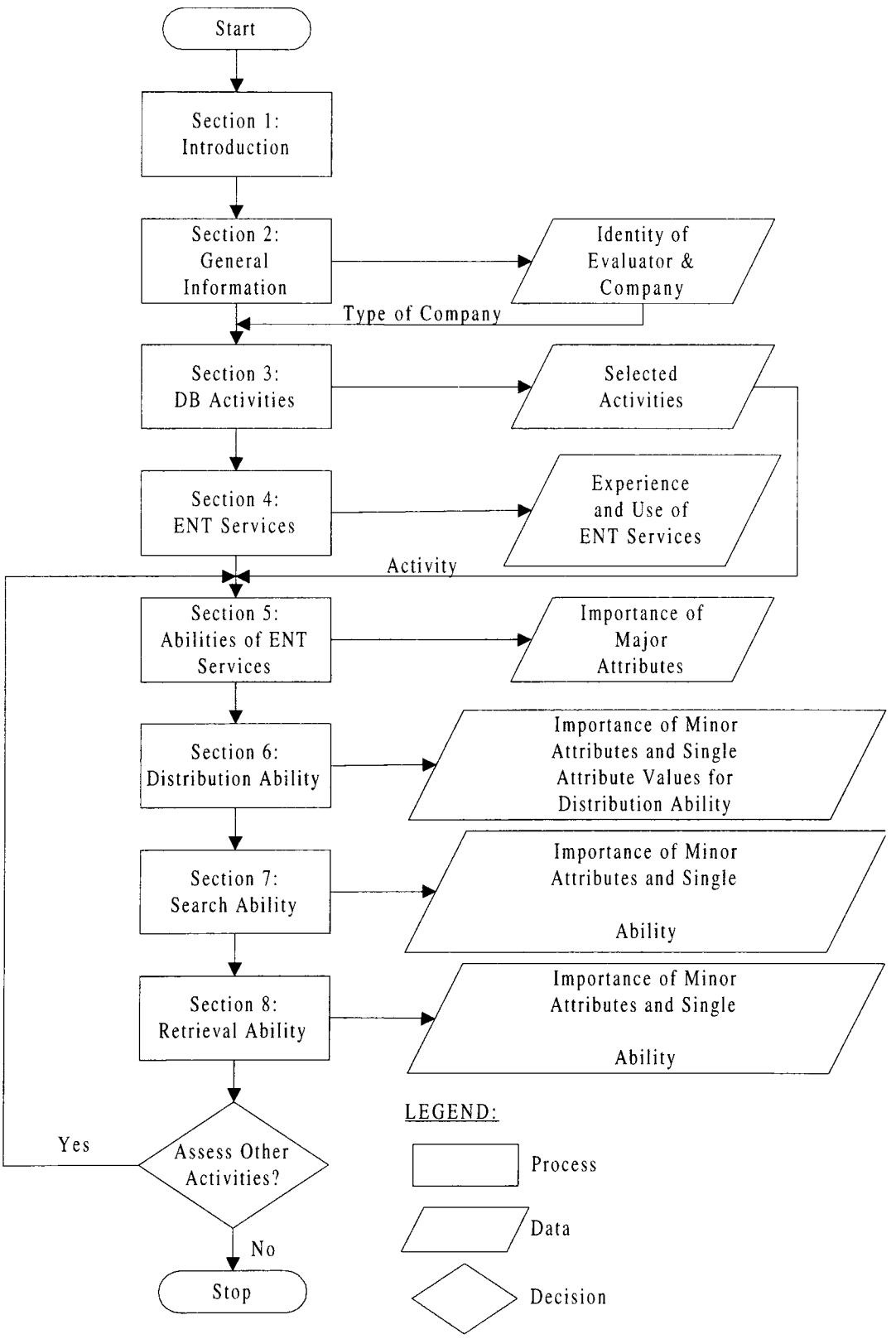

Fig 2. Logic of questionnaire

Section 1: Introduction. This section introduces respondents to the survey by giving explanations regarding the objective of survey, instructions, and explanation of navigational help, ie, index of subjects and search engine to assist the respondents while answering the questions.

Section 2: General information. This section contains questions regarding the identity of the respondent, ie, name, e-mail address, company's name, position of respondent in the company, type of company, and year of birth. Some data in this section are used in the succeeding sections, such as e-mail address for the purpose of data recording, and type of company for the purpose of categorizing the respondents and selecting the list of Design-Build activities. The type of company field consists of six categories, namely 'Construction Contractor,' 'Civil Engineering/Designer,' 'Project Owner/Client/Investor,' 'Education Institution,' 'Internet Service Provider to Construction Industry,' and 'Construction Software Developer.'

Section 3: Design-Build activities. This section provides a list of D/B activities that are determined based on respondents' answers in Section 2, ie, type of company. The list of activities covers all common activities that are necessary in a D/B project delivery system and information exchange between project participants. The respondent should select at least one activity for the purpose of evaluation. The list of activities contains hyperlinks to descriptions of all activities to make sure the respondents understand the selected activities.

Section 4: ENT services. This section contains five questions related to the use of ENT services. The first question is intended to get information regarding respondents' experience with ENT services. The second question asks the usage of ENT services by respondents, whether they are for work-related or personal activities. The remaining questions relate to specific use of ENT services. The respondents are asked to select which ENT services they have used, frequently use, and are not aware of. All 14 ENT services are listed and provided with hyperlinks to the descriptions of each ENT service. Those services are:

- E-mail
- List server
- Newsgroup
- File transfer
- File system
- Remote access
- Gopher
- WWW
- Chatting
- MUD
- Virtual reality
- Audio streaming
- Video conferencing
- Internet phone

Section 5: Abilities of ENT services in processing information. Before entering Section 5, the respondents are reminded with an alert that they have to focus on a particular activity in answering the questions in this section. Section 5 is intended to get respondents' opinions on the importance of major attributes, ie, distribution, search, and retrieval. In this section the term "major attribute" is understood as the ability of ENT services to process information, in order not to confuse the respondents with many terms. To assess the importance of major attributes, a scale from 1 to 5 is provided; '1' represents 'unimportant' and '5' represents 'extremely important.'

Section 6: Distribution ability. In this section, respondents assess the importance of the minor attributes of distribution ability; ie, format, size and destination, and a single attribute value of utility of each ENT service with respect to each minor attribute. The assessment of importance of minor attributes is comparable to the assessment of importance of major attributes in Section 5. The term "minor attribute" is translated into the factor that affects the ability of ENT services. For the assessment of the single attribute value of utility of ENT services, a scale 1 to 5 is used; '1' represents 'useless' ENT service and '5' represents 'extremely useful.' A response option of 'don't know' is also offered to accommodate the lack of knowledge and experience in a particular question and/or ENT service. All 14 ENT services are listed as the objects of assessment.

Section 7: Search ability. This section has the same format as Section 6. In Section 7, respondents assess the importance of minor attributes of search ability, ie, method, location, and results, and a single attribute value of utility of each ENT service with respect to each minor attribute. Both assessments are performed similarly as the assessments in Section 6.

Section 8: Retrieval ability. This section has the same format as Sections 6 and 7. In this section, respondents assess the importance of minor attributes of retrieval ability, ie, characteristics and ownership, and a single attribute value of utility of each ENT service with respect to each minor attribute and are performed similarly as the assessments in Sections 6, 7.

The assessments process in Sections 5, 6, 7, and 8 are performed based on activity selected in Section 3 as the assessment context. Depending on the number of activities the respondent selected in Section 3, the respondent may have to perform Sections 5, 6, 7, and 8 several times. Where the respondent has selected more than one activity, there is always a reminder about which activity the respondent should base the evaluation every time the respondent finishes with one activity and enters the next selected activity.

8. Survey results

The survey was conducted between March 1 and April 30, 2000. A total of 378 qualified professionals from the D/B industry and academia responded to the survey, constituting a response rate of 36%. More than 70% of the respondents occupy positions in middle to top management and have more than 15 years of experience. More than 80% of respondents have been utilizing ENT services for work-related activities for more than two years. The majority of ENT services used in the

survey are acknowledged by more than 50% of respondents, but 28.7% of respondents actually have never used the services. The subsequent analysis confirmed adequately validity and reliability of the survey [2].

The survey produced the utility values of 14 ENT services in supporting D/B activities. Table 2 presents the value of the utility of each ENT service in distributing, searching for, and retrieving information in a D/B project, ie, column 2, 3, and 4 respectively. Moreover, the values of overall utility of each ENT service in a D/B project (column 5) can be obtained based on the developed assessment model.

Table 2. Utility values of ENT services in D/B projects

ENT services (1)	Utility values			
	Distribution (2)	Search (3)	Retrieval (4)	Overall (5)
E-mail	4,482	3,821	4,169	4,179
List server	3,159	3,039	3,238	3,11
Newsgroup	2,552	2,7	2,759	2,6
FTP	4,175	3,544	3,923	3,903
NFS	3,563	3,272	3,425	3,31
Telnet	3,53	3,253	3,305	3,305
Gopher	2,379	2,627	2,544	2,422
WWW	4,148	4,119	4,012	4,104
IRC	2,313	2,202	2,274	2,224
MUD	2,091	2,047	2,099	2,003
VR	2,386	2,147	2,281	2,232
Audio	2,403	2,205	2,385	2,219
Video	2,864	2,501	2,637	2,611
Phone	2,644	2,442	2,465	2,435

The categorization criteria based on the utility values of each ENT service have been developed and depicted in Table 3. According to these criteria, e-mail, Web, and FTP services are considered as the primary services needed for supporting D/B activities. The primary services have superiority in distributing, searching, and retrieving information compared to other services. Table 4 shows the classification of ENT services for supporting D/B activities.

Table 3. Categorization of ENT services based on utility values

Category (1)	Utility Values (V) (2)
Primary	3,67 <= V <= 5,00
Secondary	2,33 <= V < 3,67
Tertiary	1,00 <= V < 2,33

9. Optimization model FOR configuring ENT services

As the results of the survey, not all 14 ENT services have the same utility for supporting D/B activities and there is no single service that can fulfill all communication and information retrieval needs at the same time. Too many activities are taking place during the life cycle

Table 4. ENT Services in D/B projects

Category (1)	ENT services (2)
Primary services	Email
	WWW
	FTP
Secondary services	NFS
	Telnet
	List server
	Video
	Newsgroup
	ENT phone
	Gopher
Tertiary services	VR
	IRC
	Audio
	MUD

of a project requiring different types of information, and it appears that each ENT service has a specific utility to support these activities. In order to optimally use the available ENT services, custom-configuration of these services is practical.

In order to determine the optimal configuration of ENT services in supporting D/B activities, an optimization model should maximize the utility of ENT services configuration and at the same time fulfill the need for both communication and information retrieval tools. The ENT services that are included in the configuration should also have adequate utility values. The optimization model is formulated using a *pseudomodel* [19] as follows:

- Objective: Maximize utility values of the ENT services configuration.
- Subject to:
  - o Each ENT service should have adequate overall utility value.
  - o The ENT services configuration should meet the needs for communication and information retrieval.

The objective in this *pseudomodel* is defined as the total of the overall utility values of ENT services. These values can be obtained from column (5) of Table 2. The first constraint is that each service should have an adequate overall utility value. Subjectively, the adequate overall utility value is defined as 2.33, which is the lower bound of the secondary ENT services. The second constraint is defined as that the specific function of each ENT service should meet the need for communication and information retrieval. This *pseudomodel* can be translated into a mathematical model as follows:

$$\text{Maximize: } Z = \sum_{i=1}^{14} v_i . x_i \,. \tag{6}$$

$$\text{Subject to: } v_i \geq 2.33 \,. \tag{7}$$

$$x_i \in C \,, \tag{8}$$

where: x_i = 0 or 1, inclusion or exclusion of the i-th

ENT service; $i = 1...14$, index of ENT services; V_i – the overall utility value of the i-th ENT service; C – A population of ENT services that have specific functions to fulfill the need for communication and information retrieval tools.

While the objective and the first constraint can be calculated using this mathematical model, the second constraint cannot. This situation leads to the use of a *heuristic* approach as an approximation method to find the 'optimal' solution [19].

The algorithm of the heuristic approach is described as follows:

1. Select ENT services that have overall utility values greater than or equal to 2.33.
2. Map each selected ENT services based on its function to the following categories:
    1. Communication
        a. Asynchronous
        b. Synchronous
    2. Information retrieval
        a. Distribution systems
        b. Retrieval systems
    3. If two or more services have a similar function, the one with the higher overall utility is retained. Each category should not contain ENT services that have a similar function.
    4. Even though there are four categories, the number of ENT services included in the configuration could be more than four because each ENT services could have a specific function that can be a compliment to other services, and thus can be considered to be included in the same category.

Following the application of the algorithm given above and the information obtained from Table 2, the optimum configuration of ENT services with respect to the maximization of the overall utility can be described as follows:

1. ENT Services for asynchronous communication:
- E-mail service. This service can be used to communicate between project participants, distribute information in any type of format and file size, directly to the receivers, and to retrieve any information that can be distributed using this service. The information that is transferred using this service should not be information that needs immediate action from the receivers.
- List server services. A list server service can be used to provide a discussion forum by providing a single address to distribute information to a group of receivers and deliver it directly to each one on the list. This service is a compliment to e-mail service.

2. ENT services for synchronous communication:
- Video conferencing service. This service provides a computer-to-computer synchronous communication that delivers pictures and voices in a conference session. This service can be used to provide an alternative to face-to-face meeting.
- Remote access service. This service can be used to enable users to communicate with remote computers. This service is a must when it comes to maintaining the operation of ENT services and will be used mainly by the person who is responsible to administer the ENT services.

3. ENT services for distribution system:
- File transfer service. This service can be used to distribute any format of file with any size of file to a designated storage that is accessible to project participants. This service can be used to search the archives of project files and to retrieve the needed files from the storage.

4. ENT services for retrieval system:
- Web Service. This service can be used to distribute rich multimedia information and as the interface for searching and retrieving information. Since this service can provide a user-friendly interface, it can be used as the centralized interface of other ENT services.

In configuring ENT services, it appears that the primary services are the first services to be addressed since they have high utility values. Since not all activities can be fully supported by the primary services, the secondary services will then be addressed. The tertiary services, which are not considered to have enough utility to support D/B activities, are excluded from the configuration. However, if the technologies behind the tertiary services become more advanced and mature, and their applications are not limited to specific activities, the tertiary services should be considered in the configuration.

10. Implementation scenario

The following is a discussion of implementation scenario of the assessment model and ENT configuration in a project. The implementation scenario is intended to be a guideline to perform utility assessment of any ENT service and to determine optimum configuration of ENT services that will be used in a project. A representation of the implementation scenario is depicted in Fig 3.

The implementation scenario follows the following steps:

1. Establish the primary ENT services as the essential services that should be available in every project.
2. Select several activities in which the ENT services will function and use those activities as the assessment context and analyze the selected activities by identifying the type of information involved.
3. Investigate the characteristics of additional ENT services that need to be assessed.
4. Apply the assessment model to measure the utility of additional ENT services.
5. Develop the optimal ENT services configuration for supporting selected activities.
6. Plan the implementation of ENT services in a project.

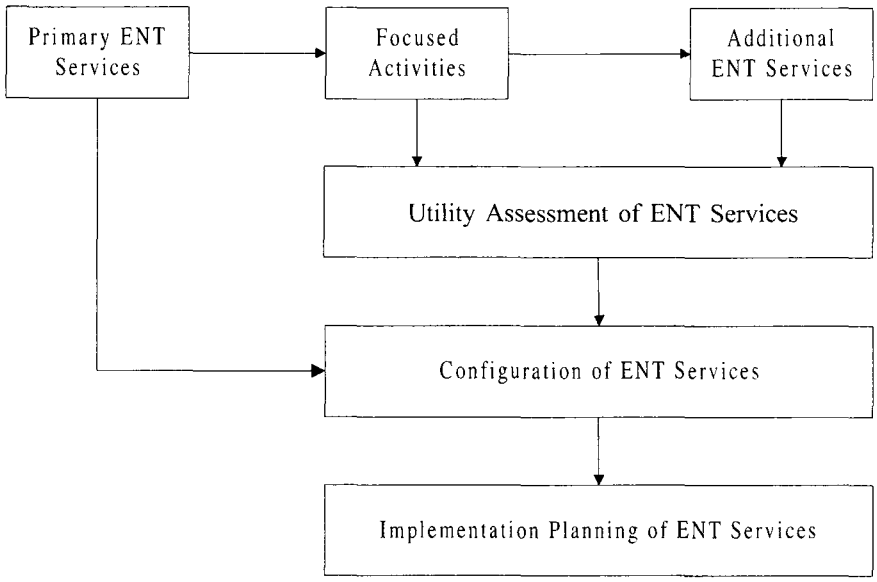

Fig 3. Implementation scenario of utility assessment of ENT services

10.1. Primary ENT services

As acknowledged earlier in the analysis of results and the configuration of ENT services, the primary services, ie, e-mail, Web, and FTP services, are considered to have high utility and to be the basic ENT services that should be used in each project. These primary services already cover the needs for asynchronous communication and information retrieval tools in relevant D/B activities. Evidence of the high utility and popularity of these primary services as results of the survey considered these services as essential services. Therefore, there is no need to assess the utility of these services.

10.2. Selection of activities to focus on

The primary ENT services may fulfill asynchronous communication and information retrieval needs in the project.

However, the primary ENT services may lack the ability to support synchronous communications and therefore cannot fully support particular activities. Consequently, there may be a need to find other ENT services to support specific activities and activities that need synchronous communication. On the other hand, ENT services are generally still regarded as new technologies to be implemented in a construction project. The implementation of new technologies could cause a temporary loss in productivity, as the users go through a learning curve in applying the services [20].

In order to implement the additional ENT services without sacrificing productivity, activities that need to be supported by the services should be selected carefully [21]. In this scenario, the activities were selected based on the need of synchronous communication tool and specific needs that are not addressed by the primary ENT services. Further analysis is required to determine the type of information involved and which parties will provide and use the information in each selected activity. The result of this analysis will explain the nature of each activity, the characteristics of information needed, and parties involved in providing and using the information. An example of the result of the process of activities selection is provided in Table 5.

Table 5. An example list of the selected activities

No. (1)	Activity (2)	Type of Information (3)	Provider (4)	User (5)
1.	Advertise RFP	Instructions and descriptions	Owner	Designers & contractors
		Standard contract forms	Owner	Designers & contractors
		Specifications	Owner	Designers & contractors
		Design guidance	Owner	Designers & contractors
		Evaluation criteria	Owner	Designers & contractors
		Schedules	Owner	Designers & contractors
2.	Complete Constructability Review	Drawings	Designer	Contractor
		Schedules	Designer	Contractor
		Specifications	Owner, Designer	Designer, contractor
		Methods	Contractor	Designer
		Cost estimate	Designer	Contractor
		Lessons learned	Designer, Contractor	Designer, contractor
		Documentation	Designer, Contractor	Owner

Table 6. An example of characteristics of the additional ENT services

ENT Services (1)	ATTRIBUTES							
	Ability to distribute information			Ability to search for information			Ability to retrieve information	
	Forma (2)	Size (3)	Destination (4)	Method (5)	Location (5)	Results (6)	Charecteristics (7)	Ownerships (8)
List server service	Multi format (text + attach.)	Medium	Direct community	Properties (date + subject)	High	Medium	Low	Medium
Newsgroup service	Multi format (text + attach.)	Medium	Direct community	Properties (date + subject)	High	Medium	Low	Medium
Chatting service	One format (text)	Small	Direct community	Properties (addresses)	Medium	High	High	Medium
Virtual reality service	Multi format (text + graphics)	High	Indirect community	Properties (objects)	Low	Medium	Low	Low
Audio streaming service	One format (audio)	High	Indirect community	Properties (subjects)	Medium	Medium	Low	Medium
Video conferencing service	One format (video)	High	Direct community	Properties (addresses)	Medium	High	Medium	Medium
Internet phone service	One format (audio)	High	Direct individual	Properties (addresses)	Medium	High	Medium	Medium

10.3. Additional ENT services

A list of additional ENT services with potential use in supporting the selected activities is needed. The primary ENT services are removed from the list since those services are already included in the configuration as the essential services. An example of a list of additional ENT services is depicted in Table 6.

The next step is to conduct a search for more information regarding additional ENT services. This investigation can reduce the number of additional ENT services to be considered by focusing on services that can fulfill the need of the selected activities, eg, a need for a synchronous communication tool. The investigation should also include an analysis of the characteristics of each service that can be used in the utility assessment process. The characteristics of each additional ENT services should be based on the minor attributes of the assessment model as described in Table 6.

11. Utility assessment of ENT services

The assessment model described earlier is used for determining the utility value of each ENT services based on the selected activities. Issues related to the practical application of the assessment model are as follows:

1. Time to assess. The assessment model is designed to accommodate all activities during the life cycle of the project. To gain all benefits from the assessment model and to implement ENT services efficiently as early as possible in the project, the ENT assessment should be conducted before the start of the project. The results of the assessment can be implemented in any other project that has similar activities and project delivery method. On the other hand, the assessment should be revisited when:

- There is a need to change the focused activities. Various activities may have different information to be used that may lead to different communication and information retrieval needs. For example, the 'Negotiation' activity needs face-to-face meetings that involve live images and voices of the negotiators. In this case, the activity needs a synchronous communication tool. If the focused activity is 'Processing As-Built Drawings,' an information retrieval tool is necessary to distribute and retrieve electronic CAD files.
- There are new ENT services to be considered. New or emerging ENT services may have different functions that could complement older ENT services. For example, video streaming and Internet fax services are emerging onto the market and can be a complement to the traditional video conferencing and e-mail services.

2. Potential users of the assessment model. All participants involved in the project, ie, the owner, contractor, and designers, can benefit from the assessment model. The assessment model does not focus on a particular party involved in the project, rather on activities performed by the particular parties. Project owners can use the assessment model before project commencement and use it to determine the ENT services to be used for supporting internal business and project activities. The contractors and designers can use this assessment model to determine optimal configuration of ENT services for

their internal business and their involvement in a project with the owner, subcontractors, and suppliers.

3. Assessment procedures. The assessment process itself can be performed in a group discussion meeting. Furthermore, the procedure of ENT assessment can be followed as described in earlier sections. The questions on the questionnaire can be asked of any individual who is invited to the meeting. The assessed values and weights can be calculated as described in the assessment model. This is possible since the method of calculating the ENT utility values and weights of importance involve average measurement and normalization based on total ratings given by each individual.

4. Applications to other project delivery systems. The assessment model can also be implemented to project delivery systems other than D/B, such as Build-Operate-Transfer, Construction Management, and traditional Design-Bid-Build. In this case, the same procedure can be followed, but the list of activities should be adjusted to reflect the particular type of project delivery system. Each project delivery system will have a different list of activities, parties involved, and relationships between them.

11.1. Optimal ENT configuration

The results of the utility assessment are then analyzed by a heuristic algorithm to determine the optimal configuration of ENT services. According to this algorithm, the additional ENT services that have a higher value of overall utility will have a better chance to be included in the configuration. A decision must be made to determine the acceptable minimum value of overall utility for inclusion in a service.

As suggested in the algorithm, the final decision in configuring ENT services can be reached by comparing those services that have adequate overall utility values with the primary ENT service, whether those services compliment the primary ENT services or not. For example, list server service can be a compliment to the E-mail service. Another way to decide whether additional services can be included in the configuration is by analyzing the function of these services, ie, whether the services can support specific needs that cannot be addressed by the primary ENT services. For example, Internet phone and video conferencing service can support activities that need synchronous communications.

11.2. Implementation planning of ENT services

After performing the assessment of utility of ENT services and determining a configuration of ENT services, a planning process to implement this configuration of ENT services is still required. This implementation-planning process is intended to optimally use those services by defining the scope of operation, specific functions, and operation policies. Other things are very well addressed in this process too, such as the cost of ENT services and implementation considerations.

Following is an example of definition of operations scope, functions, and policies to implement the primary ENT services.

1. E-mail service. The basic function of this service is asynchronous communication replacing paper-based communication tools. Specifically, this service is used to distribute any information to any individual or groups of people in the project. E-mail could be widely used in any types of correspondence between project participants not requiring immediate response from the receivers. Some policies regarding the use of this service could be defined, such as the requirement that all people at a certain level must have e-mail address, how often project participants should check e-mail messages, limitation of the size of file attachment in an E-mail message, documentation of every e-mail messages, whether the correspondences using e-mail service could be used as legal evidence, etc.
2. Web service. The Web service is used to provide information regarding the project through a "project Web site". This web site is a place to distribute information regarding the project that needs to be acknowledged by all participants, and also an interface to search and retrieve any information needed by all participants. Some policies could be defined regarding the content and use of the project Web site. For example, the project web site can be divided into secure and non-secure sections. The secure section provides project information, such as drawings, contracts, and project status that are intended to be available for project participants with permission to access. On the other hand, the non-secure section is designed to be open to the public as part of the public relation campaign of the project.
3. FTP service. The FTP service is used as an informational retrieval tool in the form of files. This service can be used to distribute any type of file with any size of file to a designated storage. The storage acts as an archive of project files, which can only be accessed by authorized users. FTP is a convenient method to distribute and retrieve a large number of files at the same time. Some policies regarding the use of this service could be defined, such as the structure of directories, type of files, and access control. This service can work well together with the Web service as it supports transferring a large number of files needed for the project Web site, while the Web site environment provides a user-friendly interface for transferring files.

12. Issues related to implementation of ENT services

12.1. Cost considerations

Having configured the optimal ENT services, a major issue to be considered is the cost of ENT implementation in a project [6, 22]. The implementation costs can

be categorized into cost of ENT planning, cost of ENT infrastructure, and cost of information creation and information use. In this section, the discussion of cost items related to the implementation is not intended to be extensive, rather it is only intended to provide a framework for estimating the cost of implementation of ENT services in a project.

1. Cost of ENT planning. The cost of ENT planning is considered as the amount of resources spent for configuring the optimal ENT services for the project, as explained in the previous section. Following are the cost components of the ENT planning:

- Man-hours. Time spent by project team members during in-house discussions and decision-making processes constitute the major cost. Other costs are incurred by hiring experts to participate in the planning process. When the planning process is given to a consulting firm, the total cost of outsourcing becomes the major component of this cost category.
- Information. The in-house discussion meetings should be provided by adequate information that is prepared before the meeting. Costs are incurred for creation of or providing medium for the information and the process of gathering information from various sources.
- Supporting facilities. Various facilities are needed to make the in-house discussion possible. Those supporting facilities include a meeting room, accommodations, equipments, supplies and meals.

2. Cost of ENT infrastructure. The cost of ENT infrastructure consists of the cost to provide external and internal ENT infrastructure. The external infrastructure consists of communication technologies that are needed to be connected to the Internet backbone channels. The internal ENT infrastructure consists of communication technologies to enable people within the project or organization to access the ENT services, and information technologies to support the creation and use of information. The cost of internal infrastructure is normally much higher than the cost of external infrastructure [23]. Furthermore, since this internal infrastructure relates to the ENT configuration, the level of its cost determines the level of services available [24].

Following are the cost components of the ENT infrastructure:

A. External infrastructure

- Internet Connection. In order to access the Internet, a project or organization minimally requires an Internet Service Provider (ISP) who can provide Internet connection and a communication link to that provider. There are various options available to connect to Internet, such as using dial-up connection or a leased line connection. A dial-up connection provides limited speed and services. On the other hand, a leased line connection provides more speed. In order to customize the ENT services and gain full control of the services, the leased line connection is suggested.
- IP address and domain name. This cost component may be optional. A domain name is a way to locate an organization on the Internet. Claiming a domain name for an organization makes locating the organization on the Internet easier; a unique domain name of an organization is better than having a long and confusing name from ISP or numeric IP address. The cost includes name registration and optional redirect services.
- Router. A router is a device that can connect two networks that have different IP addresses. This router will connect the ISP network and the project or organization network. The router can be a hardware device or simply a software program. The latter type is the most economical solution since it only requires a computer with two network interface cards and a software router.

B. Internal infrastructure

- Server. A computer that performs as a server is needed in order to implement ENT services. A number of servers are preferable to provide various ENT services. This cost component will depend on the number of ENT services that will be provided and the amount of information that will be handled by the servers.
- Modem. A modem is needed to provide remote access to all project participants. Providing a number of modems is preferable to increase the availability of remote access service to all project participants. This cost component will depend on the number of concurrent and allowed users to access the server remotely.
- Software. To implement ENT services enabling software is needed at the server side. In order to implement the optimum configuration, some application server software is needed, such as e-mail server, FTP server, Web server, mailing list server, newsgroups server, remote access server, etc. Generally, this cost component will depend on how broadly the server can provide the service. For instance, e-mail server software will depend on the number of e-mail accounts that it can provide, and a Web server will depend on the number of concurrent users accessing the server.
- O&M. Another important cost component is cost related to operation and maintenance of the internal infrastructure, such as the cost of hiring an administrator to maintain the servers and infrastructure, as well as the cost for repairing and upgrading hardware and software.

3. Cost of information creation and information use

- Hardware. In order to create information that can be distributed using ENT services and to use the information provided by ENT services, computers are needed. These computers should have the abil-

ity to connect to ENT services such as modems or network interface cards. This cost component will depend on the number of staff members that are assigned to work on information creation and information use on the project.

- Software. Some software is needed to create information that can be distributed using ENT services and to use the information. For instance, to create an HTML document to be published using Web service, a text editor or HTML editor software is needed. To use ENT services on the client side, some software is also needed, but, generally, the client software is available free or already bundled with the operating system software.
- Human resources. This cost component is related to the number of people that are assigned to perform information creation and information use. Training cost is one of the important portions of this component. Salaries given and resources to maintain hardware and software for supporting information creation and information use are other portions.

12.2. ENT security

ENT security should provide protection from intentional and unintentional acts that could prove harmful to the information provided by ENT services and other resources (Dasan and Ordorica 1997). The security of ENT includes physical access and service access. In physical access security, the servers should be secured by providing a 'server room' through which only authorized personnel with proper skills can access the servers directly, and other infrastructures should be located securely from physical access that can be harmful to them. Service access security includes controlling access to all ENT services and monitoring those accesses. Security should be in place to provide access only for valid users, to provide permissions to access the server further for specific users, and to monitor users' activities to make sure the security system is effective [25].

12.3. Organizational issues

The implementation of ENT services, like other information technologies, is likely to result in additional staff needs or redesign of organizational functions [7], both inside the project participants' firms and in the project itself. Keen [26] suggested creating an organizational boundary spanning and the arrangements to manage the ENT services. The arrangements may include who control the services, who has permission to access, and who should maintain the services. Each project participant can assign their employees dedicated time to the operation of ENT services, while other employees could still utilize the specific services designated for their activities.

Furthermore, the security system employed in each ENT services also makes the boundary spanning in the project. On the other hand, the existence of boundary spanning in the project limits the way people communicate in the project [21]. It is hard to find a group of individuals in a project who communicate primarily with one another and with no one else. If the available ENT services are only limited to a few people who have access to the services, and there is need to communicate with others, then the ENT services limit the way people communicate. Therefore, there is a need to determine the optimum boundary of the ENT services.

12.4. Risks management of ENT services

Despite the advantages of ENT services to support project activities, the implementation of these services may generate liability concerns that relate to the transmission errors of information [27]. Winick [28] believed that errors might occur due to defects in the hardware responsible for its transmission and receipt, and due to the transmission process itself. In order to manage the risk associated with the use of ENT services and electronic documents, Ericksen [29] suggested that each participant should adopt and enforce a detailed, but realistic, policy regarding the use of services in the project, such as:

- Criteria for what information may be received;
- Procedures for verification and authentication of information received;
- Recognition that any information used in ENT services can become a part of project records;
- Directions to treat ENT services as the formal communication tools in the project.

Moreover, Stein and Winick [27] identified other exposures to liability associated with ENT implementation in a project, such as the definition of deliverables of electronic documents, control of ownership and reuse, and risk shifting. It is suggested that an adoption of appropriate contract provisions and the management of personnel through well-described procedures are the chief tools of risk management [28].

12.5. Adoption of ENT services and resistance to change

Since ENT services are relatively new in project activities, there are several issues to be considered in order to achieve their successful implementation. Those issues relate to the fact that people can be categorized as visionary or pragmatic when adapting a new technology such as ENT [30], and this argument applies to the construction industry [13]. O'Brien [21] suggested that in order to successfully implement ENT services, planning should carefully consider the resistance that exists among the practitioners, who tend to avoid change and take a longer time to adopt a new technology into their environment. Several solutions are suggested to overcome this problem such as providing new job descriptions related to operation of ENT services, establishing rules and

enforcing them, and involving upper management members in socializing ENT services and evaluating their performances throughout the life cycle of project [21]. The implementation of ENT services in Design-Build activities will follow a learning curve until the project participants realize the utility of ENT services as communication and information retrieval tools.

13. Conclusions

This paper described an assessment model to measure the utility of ENT services for D/B activities. A survey to implement the assessment model has demonstrated the potential use of the model in determining the optimal configuration of ENT services for supporting D/B activities. Web and FTP services were included in the ENT configuration as the tools to support all activities that require information retrieval. E-mail, list servers, video conferencing, and remote access services were included in the ENT configuration as communication tools.

The implementation scenario presented in this paper can be used as a guideline to perform the utility assessment of ENT services. The scenario includes providing the primary ENT services, selecting activities on which to focus, investigating other ENT services, using the assessment model to measure the utility of ENT services, configuring ENT services for the selected activities, and planning the implementation. Issues related to costs, security, organization, risk management, and the attitude to resist changes are to be considered in the implementation of ENT services in construction project activities.

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